Is the UK's flagship 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

David Connell
Senior Research Associate, Centre for Business Research
Cambridge Judge Business School

Foreword by **Greg Clark MP**

May 2021

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BIOGRAPHIES

Greg Clark MP

Greg Clark is Member of Parliament for Tunbridge Wells and Chair of the Science and Technology Committee. Joining the Cabinet in 2015, having held positions in HM Treasury and the then Department for Business, Innovation and Skills, he served in the last Parliament as Secretary of State for Business, Energy and Industrial Strategy.

Prior to his election in 2005, Greg was a business consultant with Boston Consulting Group before becoming Special Advisor to the Secretary of State for Trade and Industry. He later joined the BBC as it's Controller of Commercial Policy and was subsequently Director of Policy for the Conservative Party.

Born in Middlesbrough, Greg was educated at Cambridge University and awarded his PhD at the London School of Economics.

David Connell

After a period with the UK's National Economic Office, David Connell joined Deloitte Haskins and Sells where he led its High Technology Group. Between 1988 and 2006 he was a member of the, recently founded, Technology Partnership's senior management team. As TTP Group plc, this became one of Cambridge's most successful STEM based companies, with several spin off businesses. David led TTP's strategy consulting arm, advising international corporations on R&D strategy, corporate venturing and innovation. He was also Chief Executive of TTP Ventures, which invested in third party, early stage STEM businesses.

David has had a long term interest in industrial and innovation policy and has co-authored reports commissioned by Margaret Thatcher, George Osborne and Ed Miliband. In 2017 he led an independent review of the UK SBRI programme and procurement based innovation funding commissioned by 10 Downing Street. At CBR his research has focused on STEM based company start-up, growth and funding strategies, the commercialisation of academic research, intermediate research organisations, and the innovation policies of role model economies, including the US, Germany and Taiwan.

He has degrees in physics, operational research and economics from Bristol, Lancaster and London (Birkbeck College) universities respectively.

ABOUT THE CENTRE FOR BUSINESS RESARCH

The CBR, established in 1994, conducts interdisciplinary, evidence-based research on the determinants of sustainable economic development, innovation and growth. CBR research has pioneered new methods of data collection and analysis of enterprise and innovation, novel approaches to macroeconomic modelling, and original datasets tracking legal and regulatory changes and their economic impact over time. Current projects are examining inequality in cities, the effects of IMF structural adjustment policies, macroeconomic projections for the UK economy, social rights and poverty alleviation, law and finance in the BRICS, the role of universities in knowledge exchange, business development in the Cambridge region, and the relationship between contract forms and innovation in construction and infrastructure projects.

The Centre's areas of specialisation include the construction and analysis of large and complex datasets on SMEs and innovation, longitudinal analysis of regulatory change affecting business firms, and fieldwork-based studies of corporate governance and organisational practice. The Centre has made a significant contribution to the development of research methods and theory in the analysis of law and finance. The Centre's research is disseminated to and used by managers, policy-makers and regulators in numerous countries.

Its research draws on expertise in University of Cambridge departments ranging from the Faculties of Economics, Law, and Human, Social & Political Science, the Departments of Geography, Land Economy, Politics & International Studies and Engineering, to Cambridge Judge Business School.

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Any errors, omissions or misunderstandings are my own responsibility.

FOREWORD

Greg Clark MP

The next five years promise to be one of the most propitious for UK science, engineering and technology businesses and research institutions in living memory.

The Covid pandemic – and the extraordinary success of developing, testing and delivering multiple highly-effective vaccines in months – has underlined the impact of research and innovation on the lives of everyone.

The Government has chosen as the prime pillar of its Integrated Review of security, defence, development and foreign policy strategic advantage through science and technology.

And the current administration has not only recommitted to the target of 2.4% of national income to be invested in research and development by 2027 – from 1.7% in 2017 – that was established in the 2017 Industrial Strategy, but to doubling the government's science and innovation spending to £22 billion by 2024/5.

Faced with such a favourable climate, it is essential to get policies right so that not only are these targets met, but they have the intended outcomes: a more prosperous, secure and advancing nation.

That is where David Connell's forensic and expert perspective comes in. Achieving the Government's ambitions – in terms of money and impact – can't be done by the public sector alone. To achieve the 2.4 percent target even with £22bn in the public science budget requires the private sector, according to the National Centre for Universities & Business, to spend £17.4bn a year more on R&D in 2027 than firms did in 2017.

Yet David Connell points out that the drivers of private sector investment in R&D are too little understood by government, and so policies are not well set.

The paper makes a powerful case for looking again at R&D tax credits and the Patent Box – subsidies paid for through the tax system which cost over £8 billion a year: 16 times more than the match-funded grants available to businesses through Innovate UK.

Alarmingly, David Connell argues that the impact of the tax credits on business investment in R&D has been nugatory – with the increase in companies' own investment representing less than half the cost to the taxpayer of the subsidy scheme. And, around half a billion pounds a year of that cost is thought to be subsidising research conducted outside the UK.

The government has adopted a striking ambition, and now it is the moment to consider if we have the policies to achieve it. If more taxpayers' money is going to be spent on what has been established as a national imperative, we need to know it can be expected to work – or else use it more productively to accomplish the desired ends.

David Connell's authoritative paper could not be better timed as we embark on a drive towards an innovation-intensive economy to be created as the prime objective of national policy.

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EXECUTIVE SUMMARY

David Connell, Centre for Business Research, University of Cambridge

The UK R&D tax credit scheme was introduced in 2000 in order to provide better government funding for R&D in small and medium sized businesses, which were not well served by the existing system of grants. After pressure from industry, a large company scheme was added in 2002, and both schemes have since been steadily increased in generosity and scope. Roughly 60% is now paid in the form of "expenditure credits", unrelated to a company's tax position.

R&D tax credits now cost the Treasury an estimated £7.3 billion a year, fourteen times more than the value of R&D grants to businesses by Innovate UK, the executive arm of the Department for Business Energy and Industrial Strategy.

It is, de facto, the UK's flagship industrial policy.

Around 60,000 companies a year receive tax credits and expenditure payments from the schemes, and it is extremely popular across industry. Administration is quick and efficient, recipients have no requirement to change behaviour, or increase R&D spending and, unlike Innovate UK grants, benefitting from R&D tax credits does not involve preparing time consuming competitive bids with a limited probability of success and an ongoing reporting overhead. A recent econometric analysis by the Treasury concludes that each £1 of tax credit generates between £2.40 and £2.70 of business R&D spending, i.e. £1.40 to £1.70 on top of the £1 subsidy.

However, an analysis using Office of National Statistics data for aggregate business expenditure on R&D in the UK (BERD), the measure against which government policies to increase UK business R&D is judged, gives a completely different picture. The cost of R&D tax credits is now equivalent to around a quarter of all UK business R&D. But, as a percentage of national income, self-funded BERD (i.e. R&D spending net of the government subsidy) is estimated to be between 10 and 15% **lower** than before R&D tax credits were introduced, whilst an estimated further £1-2 billion of R&D tax credit payments now subsidises R&D undertaken outside the UK and other non-BERD compliant company expenditures.

At this rate, the level of business R&D needed to enable the Government to meet its target of 2.4% of national income being spent on R&D can never be achieved.

There are several reasons for this disappointing and contradictory picture. The expenditure used in claims is 38% higher than BERD, including £4-7 billion for R&D performed overseas. And the theory behind R&D tax credits, namely that a reduction in the cost of R&D will lead to an increase in a company's R&D expenditure, is flawed. This report offers more realistic models of company behaviour for four categories of company: large corporations; venture capital backed start-ups; "soft start-ups" and SMEs without venture capital or cash reserves; and companies with internationally mobile R&D. The expected additionality ratio for R&D tax credits is 1.0 or less in each case.

In 2013 a second innovation related tax subsidy was introduced, the Patent Box. Its aim is to encourage the commercialisation of intellectual property in the UK by charging a lower, 10% rate of corporation tax on eligible profits. The Patent Box now costs the Treasury around £1.1 billion a year, with 92% going to large companies, and over a third to companies in the finance and insurance sectors.

The rather vague nature of its objectives makes it difficult to assess the impact of the scheme, though the evidence suggests that multinational companies can benefit significantly without a commensurate investment in the UK, with the UK subsidiaries of some foreign multinationals receiving subsidies of up to £50k a year per employee.

The international balance of trade in business R&D funding has deteriorated since the Patent Box was established, with UK business spending on R&D carried out overseas roughly doubling.

Industry lobbyists have argued that to attract and retain investment it is essential that the UK tax regime for R&D is competitive with other countries. However, most of the best role models for UK policy, including Germany, Sweden, Switzerland, Finland and Israel, make little or no use of R&D tax credits. And the US scheme, based mainly on increases in company R&D spending, rather than its absolute value, costs only a third as much in relation to GDP. In fact, by 2017/18 only the French government spent more on R&D tax incentives as a percentage of GDP than the UK, and with changes since then, the UK is probably now ahead.

Influential US and EU studies have concluded that tax breaks have little or no influence on the location of R&D investments. The US study found that access to quality R&D staff was the most important factor, with tax breaks ninth and costs eleventh.

This report argues that the low level of UK business R&D, and the failure of policy to make a significant impact on it, is largely a symptom of a more fundamental problem, namely the failure to grow and retain new STEM based UK companies to replace industries in decline. This is evidenced by the UK's relatively weak position in global league tables of companies in the pharmaceuticals and biotech, medical devices and scientific instruments industries, all sectors in which large, state supported, UK domestic markets might be expected to provide a competitive advantage. And the argument is reinforced by the small number of large STEM companies to have emerged from businesses started within the Cambridge cluster over the last 30 years.

Two economic factors help to explain this.

First the relatively small size of the UK market means that new UK companies tend to grow early revenues more slowly that contemporary, peer group companies based in larger homogenous markets, like the US, and increasingly China. So, as the key source of competitive advantage shifts from *innovation* to the level of investment in R&D and global marketing and distribution, UK companies tend to lack the economies of scale needed to remain competitive, often ultimately resulting in their acquisition. The differing economics of company growth in the UK and the US has in turn influenced investor strategies.

In fact, the economics of the venture capital model, particularly in the UK where average investor returns are relatively low, means that VC’s can only deliver the returns their own investors require if they aim to exit portfolio companies through early trade sales based on their strategic value to acquirers.

Second, the UK is arguably the most attractive country in the world in which to make acquisitions, so trade sales will usually be to a US or other foreign multinational. And in most cases, this leads to the truncation of further growth in the UK.

The result is that venture capital plays a different economic role in the UK compared with the US, where downstream growth, following acquisition, is more likely to be retained within the national economy.

The conundrum for policy makers is how to balance the advantages of operating a very open economy, which attracts inward investment, with policies that encourage the retention and continuing growth of entrepreneurial UK start-ups.

An important part of the answer must be to implement policies that support the start-up, growth and funding models adopted by entrepreneurs who **have** been able to avoid selling up early and gone on to build substantial, independent UK based businesses.

The founders of companies in this category, like Arm and Dyson, have been able to achieve this by avoiding, delaying or minimising venture capital. And this has invariably been by adopting a “soft start up” model with limited founder investments and sweat equity supplemented with early revenues from consulting or development contracts for other companies, and with later product developments at least partly funded by lead customers from the public or private sectors. The early development of the Cambridge cluster is largely based on this business model, and it remains important across the UK. R&D tax credits, and conventional R&D grants, requiring match funding can generally have little or no impact on such companies during their formative stages of development.

In many cases an early trade sale to a larger company may be in the best interests of all involved, but it is important that government finds ways of supporting the minority of entrepreneurs with the desire and opportunity to grow a significant, globally competitive business over the long term and the soft start up model that can enable it.

Achieving the Government’s target of 2.4% of GDP being invested in R&D will require radical new thinking, with a joined up, evidence based approach to innovation policy across the Treasury, BEIS and spending departments. This report makes a series of costed proposals to increase the effectiveness of UK innovation policy and support the growth and retention of new UK based companies, whilst reducing overall Treasury expenditure. They include the abolition of elements of R&D tax credits and the Patent Box, new policies to support SMEs and soft start-ups by encouraging public and private sector organisations to place innovation contracts with potential suppliers, and a new class of investment funds aligned with the national imperative of growing and retaining more UK based companies.

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1. INTRODUCTION

When Prime Minister Theresa May launched the UK's Industrial Strategy in 2016 ownership was placed squarely with the renamed Department for Business, Energy and Industrial Strategy (BEIS). Increased investment in research and innovation was a key objective, with a new "Industrial Strategy Challenge Fund", managed by Innovate UK, as the primary new policy instrument.

However, the annual value of all of Innovate UK's R&D grants to business, including the ISCF, are worth less than a tenth of the R&D subsidies UK businesses receive through HMRC R&D tax credits. First introduced in 2000, R&D tax credits have grown steadily in coverage and generosity, and by 2020 cost the tax payer an estimated £7.3 billion a year.[1]

This is the UK's, de facto, flagship industrial policy.

Yet, despite the cost of R&D tax credits being equivalent to roughly a quarter of all UK business R&D (BERD), the aggregate numbers indicate that, as a percentage of GDP, the amount of R&D funded from companies' own earnings has continued to fall. By 2019 it was 10 to 15% lower than before R&D tax credits were introduced.[2] At this rate, the level of business R&D needed for the Government to meet its target of 2.4% of GDP being spent on R&D can never be achieved.

The picture presented by the HMRC's internal evaluation is rather different, however. Based on a sophisticated econometric analysis, beyond the understanding of the non-specialist, the latest reports suggest that, for companies with more than 500 employees, each £1 of R&D tax credits generates between £2.40 and £2.70 of R&D spending, figures quoted as evidence of success by ministers and the Confederation of British Industry. For smaller companies the additionality ratio is about 1.0, meaning the subsidy is all spent on R&D, but with no additional spending generated as a result of a reduction in the effective cost of doing so.

This report looks at the economic theory on which R&D tax credits are based and examines the extent to which the policy has met its stated objectives.

It also examines the impact of the closely related Patent Box tax break. Case studies suggest that this has generated inadequate economic benefits, despite paying subsidies to the profitable UK subsidiaries of international corporations worth up to £50k per annum for each of their employees.

The report considers the reasons for the disparity between HMRC's econometric analyses of R&D tax credits and the aggregate picture; and it discusses the policy implications of more realistic assumptions regarding the R&D spending behaviour of different kinds of businesses.

It then examines why policies to grow and retain new STEM based business to replace industries in decline are particularly challenging in the UK, including as a result of its attractiveness as a location for foreign acquisitions and their impact on downstream business growth. And it considers the business and financing models adopted by the UK's most successful UK STEM companies which might point towards more effective policies. Based on these success models it proposes a mix of modifications to the R&D tax credit regime together with some new policies involving zero extra cost to the Treasury.

But first we must look at the historical background to understand why R&D tax credits became so popular with industry and successive governments.

2. SOME HISTORY; WHY UK INDUSTRIAL POLICY HAS BECOME SO DEPENDENT ON TAX BREAKS

The decline in the UK's relative industrial performance has been of concern to governments since at least the early 1960s. The National Economic Development Council, whose proposed role was first outlined by Conservative Chancellor, Selwyn Lloyd, in 1961, and set up by Harold Wilson the following year, was the main policy instrument to address this for the next three decades, though its influence declined after Margaret Thatcher became Prime Minister in 1979.

After the Labour Government's White Paper, "An Approach to Industrial Strategy" was published in 1975, it was the NEDC's high level committee of industrialists and trade unionists, chaired by the Chancellor of the Exchequer, that was tasked with identifying the underlying economic problems and designing policy solutions. It was helped by a series of tripartite sector working parties, or 'Little Neddies' for individual industries and the National Economic Development Office's secretariat and research team.

Declining "non-price competitiveness", a catch all for R&D effort, innovation, design, quality, reliability and marketing effectiveness, was identified as a major cause of the UK's steady loss in global market share across many industries.[3, 4] However, the main policy response, through the National Enterprise Board, also set up in 1975, turned out to take the form mainly of company rescues. Two attempts to back the industries of the future turned out to be costly failures. Inmos a revolutionary semiconductor technology company was sold six years later after receiving £211m of government money and failing to make a profit. And the Advanced Gas Cooled Reactor (ACGR), selected as the UK's future nuclear power generation technology in 1964, was described 13 years later by its prospective UK government customer, the Central Electricity Generating Board, as "one of the major blunders of British Industrial Policy".

The failure of the interventionist industrial policies of the 60s and 70s led to a backlash that lasted long after the anti-statism stance of the Thatcher government. Politicians of all colours had become wary of making any policy proposal that might lead to them being accused of wanting to "pick winners". To do so invited derision from the press and became career limiting.

But UK industry continued its decline. During the 80s this was partly because of the inability of traditional sectors to compete with Japan and the newly industrialising countries. This was a result of their lower wage costs, access to modern technology and equipment through joint ventures or licensing, and a degree of domestic market protection that allowed indigenous suppliers to become established domestically until they were ready to expand into more competitive global markets.

The wave of UK privatisations also led to the closure, or downsizing, of government R&D laboratories. Indeed, the decline in government funded R&D outside the academic sector continued well into the 20th century.[5] The public sector had previously funded a great deal of R&D in business as a customer for innovation, with the MOD a major spender. But between 1986/7 and 2012/13 UK Government expenditure on R&D, expressed as a percentage of GDP (GERD) almost halved, with the share of what was left being spent with industry falling by nearly 60% to just 0.1 per cent of GDP, a double whammy, whose impact was unrecognised at the time.[6]

In the late 80s and early 90s, the invention by the major strategy consultancies of highly profitable consulting "products" to help corporations increase "shareholder value" led to a new turn of the screw. Even leading industrial companies like ICI, whose success depended on continued innovation, were now treated as conglomerates – a collection of assets to be bought and sold, with the managers of each business unit tasked with delivering against a set of demanding short-term financial targets over a 12 to 18 month cycle.[7] At ICI, this became known as "business tubism".

The process was often accompanied by the closure of central laboratories, which were often, probably rightly, seen as having become too academic and distant from the business units they were supposed to serve.

For many of the UK's largest, and best regarded, science and engineering companies the result of these measures was that innovation was steadily squeezed out of the system. The resulting inability of these companies to compete internationally and lack of capability for renewal, inevitably led to their dismemberment and disposal.

Between 1981 and 1997 total UK R&D spending fell from 2.0 to 1.5% of GDP and business R&D from 1.3% to 1.0%.

By the second half of the 90's UK policy makers were increasingly turning their attention to the science base as a source of innovation and industrial regeneration, through university spin-offs and technology transfer. This was partly driven by false assumptions about the origins of what had become known as the Cambridge Phenomenon and the role of academic research IP in the creation of new companies.

The lack of venture capital for STEM based start-ups was perceived as the major barrier.

In reality the expertise of company founders in identifying unmet customer needs and new opportunities was a much more important driver.[8]

The Boston and Silicon Valley STEM based industry clusters have been the subject of similar misconceptions.[9, 10]

The need for better exploitation of academic research breakthroughs has been a consistent theme of politicians for at least the last 50 years, with the claim that "the UK is good at research and inventing things, but bad at commercialisation" repeated ad nauseum in policy statement and reports. Policies have usually expected far too much from the simplistic "linear model" of technology transfer that this implicitly assumed.[11] This continues to dominate BEIS thinking today and may even have been exacerbated by the merging of Innovate UK into UK Research and Innovation, alongside the research councils.[*]

In contrast, the role of lead customers, from the public and private sectors, in driving innovation at the pre-commercial and commercialisation stages has been neglected. As has been the extent to which the innovations behind successful new STEM companies have been created by borrowing and integrating state of the art technologies and components from established and emerging suppliers to address a new market need.

Government spending on grants for business R&D was low throughout the Thatcher Government years and well beyond. And funding was strongly focused on collaborative R&D, where academic and industry partners work together on a project. This a funding model with many disadvantages for near-to-market innovation projects.[12] Small businesses, most without the ability to engage in lengthy applied research projects or match fund a grant's share of project costs, were particularly disadvantaged and grant budgets remained small.[13]

*. Innovate UK no longer publishes an annual report or any meaningful statistics on grants awarded. "The projects it funds are typically collaborations between private businesses and academia and 2 to 5 years long". UKRI Annual Report 2019–20.

The R&D tax credits programme was introduced in 2000 to address weaknesses in the UK's R&D grant programmes for SMEs. After pressure from industry a large company scheme was added in 2002, and the scope and generosity of both schemes has since been steadily increased in response to industry lobbying.

Tax credits were essentially a politically acceptable response to the low levels of businesses R&D based on neoclassical economics. They offer many advantages over other forms of government support for R&D. All UK companies are eligible. There is no possibility of politicians or officials being accused of trying to pick winners. Applications are straightforward and administration, by and large, is quick and very efficient. For officials, there is minimal danger of decisions being criticised by the National Audit Office or Public Accounts Committee.

Meanwhile, both Business Expenditure on R&D (BERD) and Gross Expenditure on R&D (GERD) continued to decline as a percentage of GDP, and in 2004, after a major science and innovation policy review, the Government set a target for GERD to grow by roughly a third to 2.5% of GDP by 2014, with BERD targeted to grow to 1.7%.[14]

Interestingly, the review concluded that the UK's low level of R&D by UK manufacturing could not be explained by differences in its industry structure compared with Germany, France and the US.[15] It also noted that "*UK business R&D is heavily dependent on foreign affiliates, attracted to the strength of the UK science base and the relative cheapness of UK researchers*". At the time foreign owned firms accounted for around 32% of manufacturing R&D, roughly twice that of Germany, France, the US, Sweden and Finland. The importance of foreign owned firms in UK business R&D has increased significantly since then, an issue discussed in Section 7.

After a downward revision by the Office of National Statistics, between 2004 and 2018, GERD grew from 1.5% to 1.7% of GDP and BERD from 1.0% to 1.2%, still far below our major industrial competitors. The 2017 Industrial Strategy White Paper set a new GERD target of 2.4% of GDP by 2027 and 3% in the longer term.

By 2020, R&D tax credits were expected to cost the Treasury £7.3 billion per annum, dwarfing by a factor of 14 the value of grants to industry through the UK's Industrial Strategy Challenge Fund and other Innovate UK grants to companies.

It is, de facto, the UK's flagship industrial strategy policy, but one that has never been subject to proper independent review, and which appears to have completely failed to deliver against its objectives. Since the scheme was introduced, the small increase in BERD achieved has been worth less than half the annual cost of the scheme to the Treasury, which is now equivalent to around 25% of all UK business R&D spending.

It is difficult to find reasons for calling R&D tax credits a successful UK policy.

3. UK R&D TAX CREDIT AND PATENT BOX POLICIES: THEORY AND STRUCTURE

Theory

R&D tax credits were introduced for UK SME's in 2000 and, after pressure from the CBI, a Large Company Scheme was introduced in 2002. The scheme has been steadily expanded in generosity and scope since then.

The economic theory behind R&D tax credits is fairly simple, namely that:

(i) because of "spillovers" the commercial return to a business of undertaking R&D projects is lower than the social return to the local, national and international economies. This is because even failed projects create new knowledge and expertise that may be profitably applied elsewhere.

(ii) companies choose which projects to undertake based on their assessment of the risk adjusted return on investment given their "user cost of capital"

(iii) R&D tax credits reduce companies' user cost of capital so they will increase R&D spending to include additional projects which would not otherwise offer an adequate return.[16]

The label "tax credit" is really now a misnomer. Over two thirds of total payments by value are in the form of expenditure credits, unrelated to a company's corporation tax position. Though many SMEs continue to take payments through the original, slightly more generous, tax credit formula.

Structure of UK R&D Tax Credit Policy

Altogether 57,000 UK companies benefited from R&D tax credits in 2017/18, the last complete year of statistics. The average subsidy rate for SMEs was 27% of reported R&D expenditure. For large companies and SME subcontractors it was 10%. Some 18,000 claims (30% of the total and 1.4% by value) were worth less than £10,000 each, while 575 (1% of the total and 41% by value) were worth more than £1m.

The cost to the Treasury across all three categories was £5.1 billion and the figure has continued to grow. HMRC has estimated that the cost will be £6.3 billion in 2018/19 and £7.3 billion in 2019/20.[17]

The scheme is very popular across industry. It is easy to access and the professional accounting firms are skilled at maximising claims. These must be made in relation to defined projects, but detailed technical narratives, required for HMRC to judge compliance with its definition of allowable R&D spending, are only required for a percentage of projects.

In most cases the scheme offers almost complete certainty, without the time consuming, box ticking process involved in configuring an Innovate UK R&D grant application to meet the detailed terms of reference of a particular call, and the low probability of success. There are several specialist R&D tax credit advisory firms, some publishing detailed guides on how to make claims and charging fees by results.[18]

HMRC aims to process 95% of claims within 28 days, with a further 20 days until payment is made. At least one advisory firm offers an advance funding service.

Unlike Innovate UK grants, the value of R&D tax credits a company is entitled to is calculated after the expenditure has been made. Companies have no obligation to change behaviour, increase R&D spending, employ new people, stick to a pre-agreed project plan or budget, or to provide frequent accounting and project monitoring reports as a project progresses.

There are currently three main schemes:

Small and Medium Sized Enterprises (SME) R&D Relief

SME's currently receive a tax deduction of an extra 130% of their qualifying costs from their yearly profit, as well as the normal 100% deduction, to make a total 230% deduction against corporation tax. Loss making companies can claim a cash credit worth up to 14.5% of the surrenderable loss.

SMEs can include 65% of subcontractor costs in their claim, provided they are unconnected businesses. This includes subcontractors based outside the UK.

In some cases, SMEs can benefit from both Innovate UK grants and R&D tax credits related to different components of the same project.

SME's are defined as businesses having less than 500 staff for the purpose of R&D tax credits, rather than the standard definition of less than 250.

Large Company Research and Development Expenditure Credit

For the first 11 years of its life the Large Company Scheme only gave credits that could be offset against corporation tax, but since 2016/17 it has taken the form of a taxable credit that loss making companies can also receive as a cash payment, and been renamed the Research and Development Expenditure Credit (RDEC) Scheme. The credit was equal to 11% of qualifying R&D expenditure in 2017, increasing to 12% in 2018 and 13% in 2020.

SME Subcontractors

Companies cannot claim for subcontracted R&D under the RDEC scheme. However, SMEs carrying out R&D on behalf of large companies as paid subcontractors can claim a cash credit for the costs incurred at the same rate as the RDEC scheme.

Patent Box

Introduced in 2013, the Patent Box is a closely related policy measure. The intention of the Patent Box is "to encourage companies to invest in the UK by retaining and commercialising their intellectual property and locating skilled employment in the country". It aims to do this by:

- *incentivising companies whose IP is already in the UK to invest in commercialisation and undertake exploitation of that IP in the UK*

- *providing an incentive for companies whose IP is outside of the UK to develop it in the UK and then invest in commercialisation and undertake exploitation activities in the UK*

- *reducing the risk of companies whose IP is in the UK shifting it outside of the UK and thus investing in commercialisation and undertaking exploitation activities in a foreign jurisdiction.*[19]

Although these statements focus on commercialisation and UK job creation, companies must have carried out "qualifying development" (i.e. R&D) on the IP, so this, and the emphasis on "skilled employment", implies that there would be a positive effect on UK R&D spending if the scheme was successful.

Under the Patent Box rules, companies are charged a lower, 10% rate of corporation tax on eligible profits derived from the IP. The Patent Box was phased in gradually, with full relief available from 2017. There were some minor changes in 2016 to comply with OECD rules.

The rules for calculating eligible Patent Box profits are much more complicated than those for R&D tax credits, making it difficult to investigate its impact in detail. Nevertheless, there is an important overlap in terms of both objectives and impact measures between R&D tax credits and the Patent Box. The evidence on impact is discussed in Section 4.

In 2017/18 some 1300 companies took advantage of the scheme, at a cost to the Treasury of around £1130 million, an average of £870k per annum for each. “Large companies” accounted for 92% of the total, and ten companies in the financial and insurance sectors for over a third.[20]

4. ECONOMIC IMPACT OF UK R&D TAX CREDITS

The original objective of the UK R&D tax credit policy was: *To improve the overall competitiveness of the UK tax system for R&D companies by increasing the incentive for them to carry out R&D, increasing R&D and innovation in the UK. The aim is to make the UK a preferred location for companies to carry out R&D and boost productivity and growth*.

Accordingly, the economic impact of the policy is examined under five different headings:

- The extent to which companies have increased R&D and innovation in the UK
- The extent to which the UK tax system for R&D companies has been made more competitive
- The extent to which the UK has become a more preferred location for companies to carry out R&D
- Whether the Patent Box has had a complementary impact
- The extent to which UK business productivity and growth has been increased

In each case we consider the available evidence and discuss whether the objectives set are appropriate.

Have Companies Increased R&D and Innovation in the UK?

The impact of R&D tax credits on business R&D spending can be objectively examined in two main ways; through aggregate ONS statistics on BERD and by econometric analyses of HMRC R&D tax credit data.

Businesses also benefit from BEIS and Innovate UK R&D grants, but as the value of these is dwarfed by R&D tax credits, this complication is ignored.

Government evaluations of the impact of UK R&D tax credits on business R&D spending have been almost entirely limited to qualitative consultations with beneficiaries and complex econometric studies. The most recent econometric analysis of the RDEC scheme in 2020 concluded that it had an additionality ratio of between 2.4 and 2.7.[21] A 2019 analysis estimated that the SME scheme had an additionality ratio of around 1.0.[22]

However, these findings are inconsistent with an aggregate analysis using Office of National Statistics BERD data. This provides the most appropriate metric against which to judge the success of the policy.

This report argues that the discrepancy is explained by a number of weaknesses in the assumptions and data underlying the HMRC's econometric analyses. The details are discussed in Section 5.

Exhibit 1 (see page 12) gives UK business spending on R&D (BERD) as a percentage of GDP in each year since R&D tax credits were introduced. This is the business component of the official measure against which the UK Government's 2.4% of GDP R&D target is measured.

The chart also shows the total cost of R&D tax credits as a percentage of total BERD. The difference, shown by the blue bars, is approximately equal to total UK business R&D funded from companies' own operations.*

*. The approximation is because R&D tax credits fund some company expenditures which are outside the definition of BERD, including a good deal of overseas R&D. This anomaly has only recently been reported by HMRC and is discussed in Section 5.

Exhibit 1 indicates that UK BERD remained stubbornly stuck at about 1.0% of GDP until 2012, growing to nearly 1.2% over the next six years, as the scheme was made more generous. The cost of the R&D tax credit schemes quadrupled over this period, and by 2019 was equal to roughly a quarter of business R&D spending.

However, as a percentage of GDP, the amount of R&D funded from companies' own earnings has continued to fall. By 2019 it was between 10 and 15% less than before R&D tax credits were introduced. And this is despite reductions in the rate of UK corporation tax from 26% in 2010 to 19% in 2017, in theory increasing self-generated funds available for investment in R&D.

This implies **EITHER** that Treasury funding has simply acted to substitute for self-funded company spending with an additionality ratio of much less than 1.0, **OR** that a continuing long-term decline in the propensity of UK businesses to invest in R&D, possibly due to structural changes, has been offset by increases in the R&D tax credit subsidy.

Both explanations are disappointing, and demand a radical rethink of the challenges that the UK's industrial strategy needs to address and the policy mix required.

If the Patent Box is also regarded as subsidising R&D spending, net business R&D funding as a percentage of BERD declined by between 15 and 20% between 2011 and 2019. This is illustrated in Exhibit 2 (opposite).

Exhibit 1 Impact of R&D Tax Credits on UK Business R&D as a Percentage of GDP

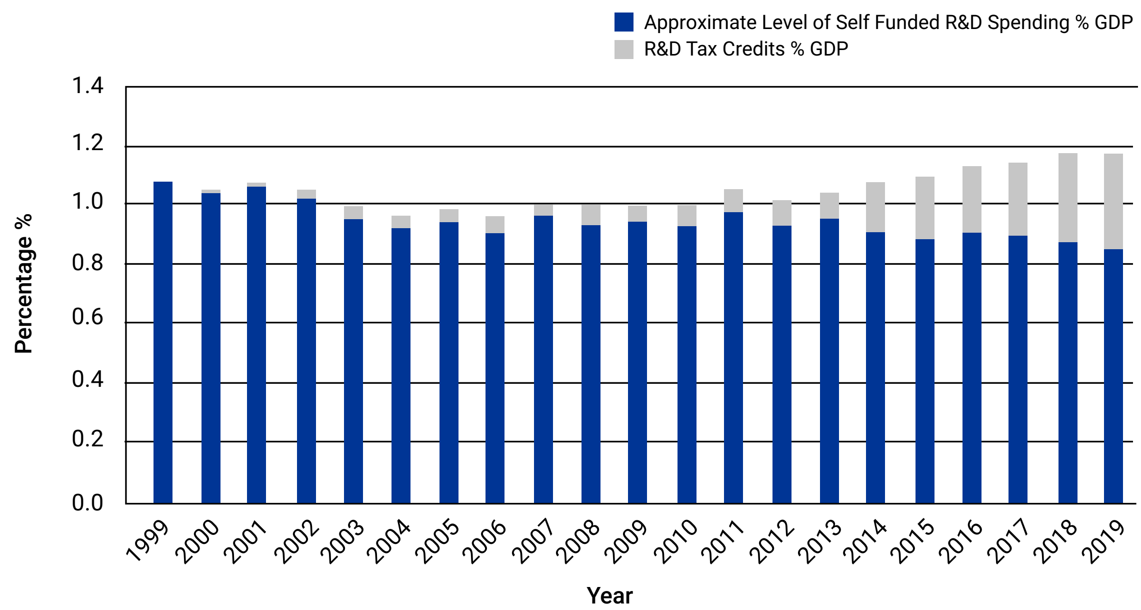
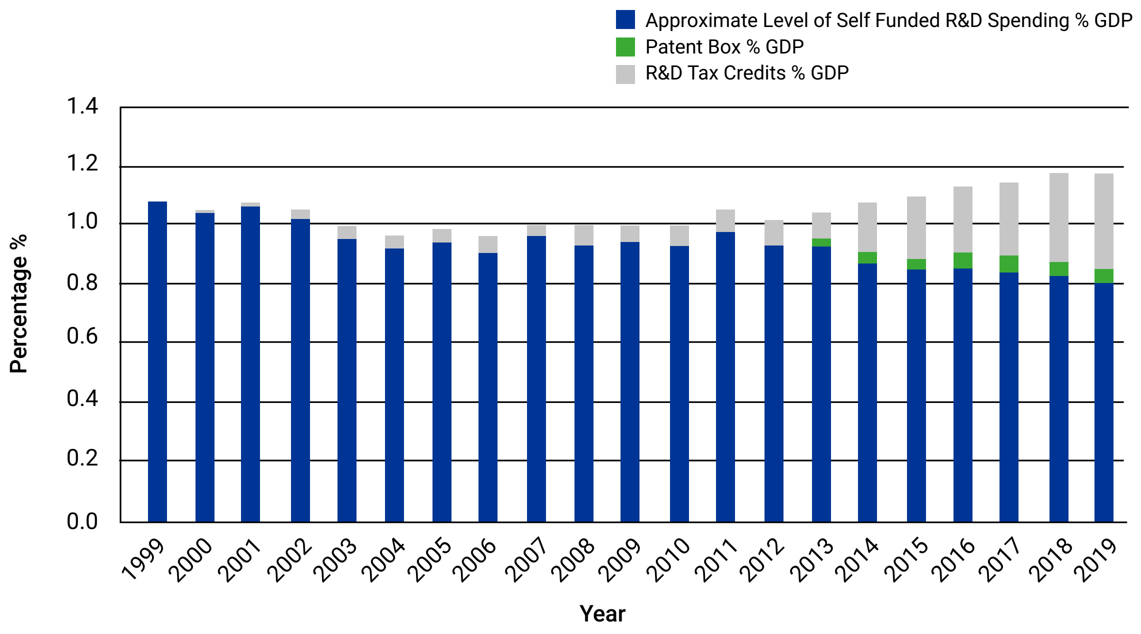


Exhibit 2 Impact of R&D Tax Credits and Patent Box on UK Business R&D as a Percentage of GDP



Have R&D Tax Credits Made the UK Tax System for R&D Companies More Competitive?

Ever since UK R&D tax credits were introduced there have been calls from industry for the subsidy to be made more generous to enable the UK to compete with similar schemes in other countries.

However, as Exhibit 3 (overleaf) shows, by 2018 only France amongst OECD countries committed more funding to R&D tax credits as a percentage of GDP than the UK. And with changes since then, the UK is probably now ahead.

Most of the European and other industrial economies that we would regard as role models make little or no use of this mechanism as an instrument of industrial policy. They include Germany, Sweden, Switzerland, Finland and Israel. And R&D tax credits in the US cost only a third of the UK's in relation to GDP, being mainly linked to increases in a company's R&D spending from year to year.

Despite this, the Confederation of British Industry continues to lobby, claiming in August 2019 that the, £3.4 billion R&D tax credits cost the Treasury (in 2015/16) supported the UK's entire business R&D expenditure of £25 billion giving "a return of more than seven times the cost to the government." It called on government to "turbo charge the current programme of research and development tax credits ensuring that the R&D tax credit keeps pace with the changing nature of R&D and our international competitors to help spur private sector investment" to help achieve the Government's 2.4% target.[23]

The picture does not look much different when direct government support for business R&D in the form of grants is added in Exhibit 4 (overleaf). The changes made to UK tax credits since 2006 resulted in total support for business R&D being nearly trebled as a percentage of GDP. By 2018 the UK figure was exceeded only by France and Russia.

Exhibit 3 Indirect (Tax) Support for R&D as a Percentage of GDP

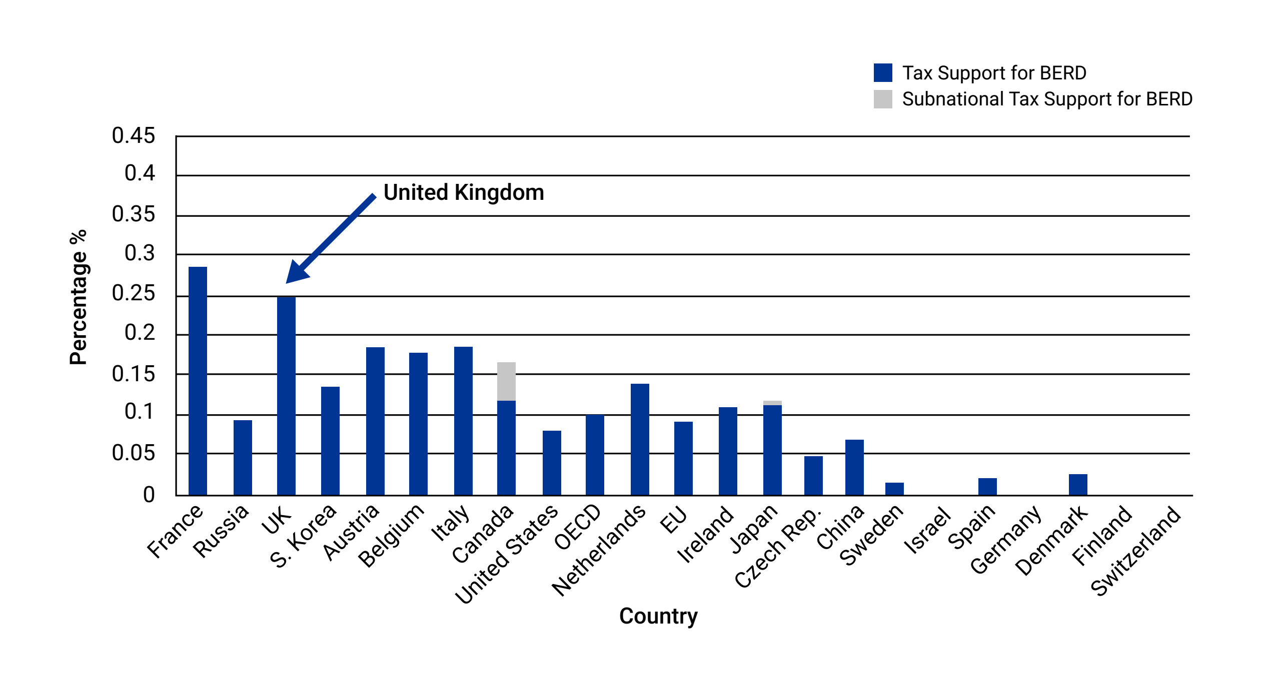
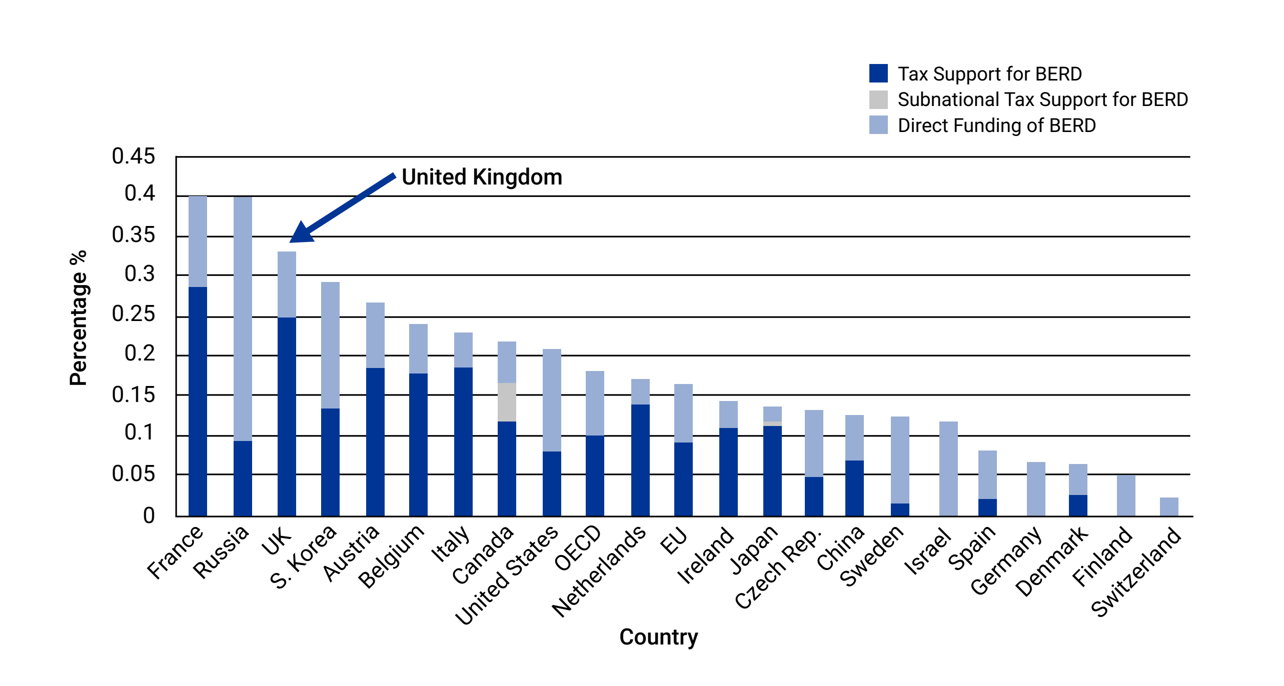


Exhibit 4 Total Direct and Indirect (Tax) Support for R&D as a Percentage of GDP



The two role models most commonly referenced in discussions of UK innovation policy are Germany and the US. In both cases, neither grants nor R&D tax breaks are the key instruments in their governments' innovation policy armouries.

In the case of Germany this role falls to the Fraunhofer Gesellschaft network of intermediate research organisations.[24] Founded in 1949, by 2021 it had 29,000 employees, and an annual budget of €2.8 billion. The Fraunhofer institutes' focus is on "*developing key technologies for the future and enabling the commercial exploitation of this work by business and industry*". Whilst government funding and EU collaborative project grants fund the early stages of this process, commercialisation takes place through contract R&D, licensing and spin-outs.[25]

This is a business model with some similarities to the private sector funded Cambridge technology consultancies, such as Cambridge Consultants and the Technology Partnership, which have played a pivotal role in the cluster's development, but made little or no use of collaborative grants.[26]

The Fraunhofer institutes provided the inspiration for the UK Catapult Network. However, the Catapults' operating model is much more focused on facilitating collaboration and innovation amongst its client businesses through testing and scale up services, and the provision of facilities. Unlike the Fraunhofer-Gesellschaft, the Catapult Network's latest annual report makes no mention of the kinds of in-house R&D projects or patent, licensing and spin-out performance metrics that drive the Fraunhofer Institutes.[27]

The US innovation system is driven mainly by 100% funded procurement contracts, with the Department of Defense and NASA playing a key role. Companies are important beneficiaries of this funding.[28] Grants from the National Institutes of Health are also 100% funded.

The OECD data show that the UK tax system for R&D companies is now probably more generous (i.e. "competitive") than any of its peers, but that the most successful role model economies have taken a very different approach to innovation policy.

Have R&D Tax Credits Led to the UK Becoming a More Preferred Location for Companies to Carry out R&D?

We can address this question partly by examining the balance of international trade in business R&D funding. Exhibits 5 and 6 (see page 16) show that the increasing level of R&D funding available to companies through tax credits has been associated with a long-term decline in the balance of trade in business R&D funding.

Prior to 2013, UK companies received more funding from overseas, probably predominantly from overseas parents or subsidiary companies, than they spent on R&D undertaken outside the UK. In 2014 this trend reversed, with the net outflow broadly similar in magnitude to the increased cost of R&D tax credits.

Have the Objectives of R&D Tax Credits Been Complemented by the Patent Box?

Assessing the impact of the Patent Box is much more challenging than doing so for R&D tax credits, not least because the desired output – "*Encouraging companies to "invest in the UK by retaining and commercialising their intellectual property and locating skilled employment in the country*" – cannot be easily measured.

A recent micro-level analysis undertaken by HMRC attempts to do so using an econometric approach. It uses an increase in the value of a company's balance sheet as a proxy for an expansion of operations made to bring a product to market or increase market share as additional capital items or IP are acquired.[29] The approach compares firms using the Patent Box with those that do not.

Exhibit 5 UK Trade Balance in Business R&D Funding (£ billions)

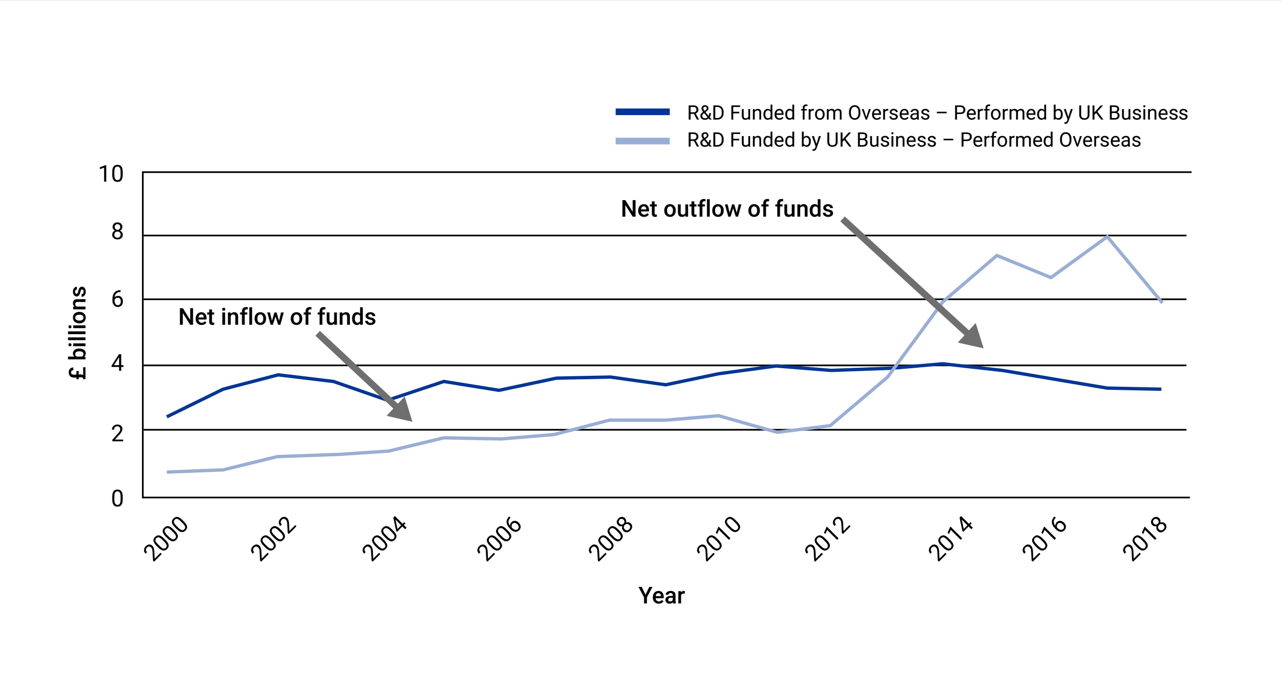
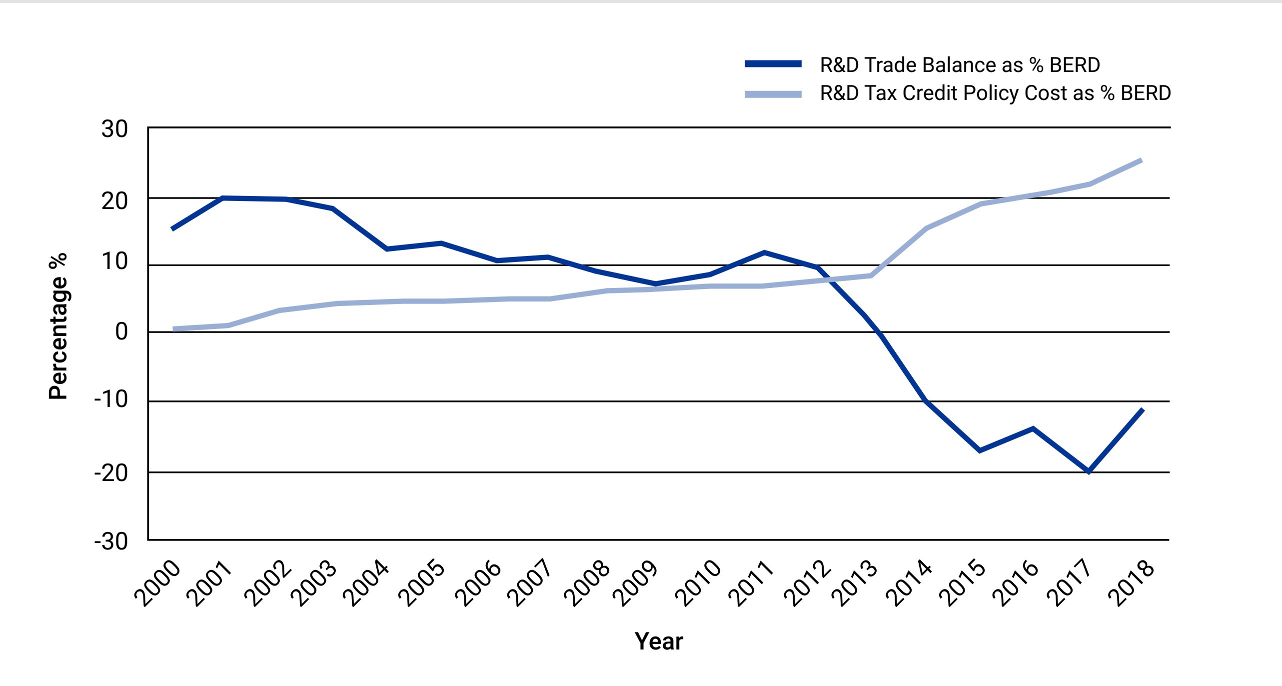


Exhibit 6 Relationship Between R&D Tax Credits and Business R&D "Trade Balance"



The analysis is extremely thorough and uses a variety of approaches to correct for biases. It concludes that Patent Box users increased investment by around 10% more than non-users. However, the authors point out that the field is fraught with difficulty and there remain many possible sources of error.

Self-selection bias is the most obvious one within the context of the econometric analysis. The rules are complex and the accounting cost of submitting a claim is a good deal higher than for R&D tax credits. The average annual tax benefit to Patent Box claimants is nearly £1m. This might suggest that a company's propensity to submit a claim is linked to its success as a business, the amount of commercialisation revenue it can justify and whether it has access to the relevant tax accounting specialism.

It is more important to assess the impact of the Patent Box against its aim of encouraging the location of geographically mobile investment in the UK, than incentivising companies to commercialise IP per se. The evidence on R&D funding flows shown in Exhibit 5 (see page 16) suggests that the Patent Box has not had the desired influence on some aspects of R&D location decisions.

But two specific situations need to be considered:

(i) where an established multinational corporation has to decide whether to locate R&D and/or UK IP based manufacturing and other operational units in the UK or other countries.

(ii) where an overseas based company acquires a UK company predominantly for its IP and has to decide the extent to which it should build on it by expanding its R&D footprint and investing in manufacturing, operations, and business development in the UK, or whether to focus on integrating these activities into its non-UK operations.

A detailed examination is beyond the scope of this report, but some case studies highlight the issues.

Solexa Case Study

Founded in 1998, Solexa is arguably the most significant new company to have originated within the Cambridge cluster in the last quarter of a century. It was based on a new gene sequencing technology invented by Cambridge University chemists, based a few miles away from the Wellcome Trust Sanger Centre. The Sanger Centre had been set up in 1992 as part of the international Human Genome Project and it made the greatest single contribution to the project.

The UK continues to play a leading role globally in gene sequencing. It carried out more Covid virus sequences than any other country during the first nine months of the pandemic.[30]

Solexa's technology had the potential to speed up gene sequencing by five orders of magnitude, making possible the "$1000 genome". It was financed initially with seed funding from the university, followed by venture capital funding rounds.

In November 2006 Solexa was sold to San Diego based Illumina Inc. for $650m, giving a 10x return to the VC investors and much less for Cambridge University's significantly diluted seed fund investment of £100k. Solexa's first sequencer product had just been launched at the time of the acquisition.

Illumina had also been started in 1998, raising $26m in venture capital and a further $96m through an IPO in 2000, despite only having 1999 revenues of $474k, almost all from US government grants.

By the time of the Solexa acquisition, annual revenues had grown to $350m.

Illumina's subsequent growth has been almost entirely based on Solexa's technology, and by 2018 its revenues were $3333m, around eight times those of its nearest competitors. It employed 7300 people.

UK corporation tax rates have been a good deal lower than US rates, and in 2015 Illumina Inc's UK subsidiary, Illumina Cambridge Ltd reported that annual intergroup sales, excluding royalty revenue, had been increased to $778m compared with $88m the previous year.

By 2018, 74% of Illumina Inc.'s global revenues, including $264m in royalties and $2009m in inter-group sales, together with a broadly equivalent proportion of global costs were booked to the accounts of Illumina Cambridge Ltd, though it only had around 7% of the parent company's employees. In the five years to 2018 Illumina Inc's global R&D spending increased by 126% to $623m with $486m of this booked to Illumina Cambridge. However, the size of the Cambridge based team had only increased by 65%, to 177 people, and R&D tax credit receipts remained a modest $1.5m, reflecting the small proportion of Illumina's global R&D operations actually based in the UK. In contrast the number of non-R&D employees increased considerably, up from 49 to 347.

During 2018 Illumina Cambridge increased the rate applied to generate intergroup royalty income from 12% to 25.2% in 2019. Patent Box receipts increased, from $20.6m in 2018 to $39.6m in 2019. This is equivalent to an annual subsidy of $66k (around £50k) for each of Illumina Cambridge's 599 employees.[31]

Cambridge Silicon Radio Case Study

CSR was founded in 1998 as a spin off from Cambridge Consultants Ltd to take advantage of the expertise it had developed in wireless CMOS chip development through contracts for Ericsson and other customers. It became the dominant supplier of Bluetooth technology to the mobile phone industry, and Cambridge's most successful STEM based company after ARM.

In 2015 CSR was acquired by Qualcomm Inc., a much larger mobile communications technology company that had been founded in San Diego in 1985. It now has around 41,000 employees worldwide. The CSR subsidiary was renamed Qualcomm Technologies International Ltd and integrated into the parent's accounting structure. QTI's latest available accounts, for 2019, report a profit before tax of $151m on revenues of $1526m.[32]

During the five years from 2015 to 2019, QTI received $67m in subsidies from the Patent Box and $46m from R&D tax credits. Together these are equivalent to an average subsidy of around £23k a year for each of its employees. Total head count fell from 783 to 692 between 2015 and 2019, with the number involved in R&D down from 570 to 503. In 2018/19 it made a profit after tax of $169k per employee and received R&D tax credit and Patent Box subsidies totalling $36k per employee.[33]

By the standard of Cambridge companies, businesses employing 600 to 700 employees are arguably fairly large, and both Illumina's and Qualcomm's Cambridge businesses are valued members of the STEM community.

But the scale of the Patent Box and R&D tax credit subsidies received seems neither to have been reflected in these companies' R&D footprints in the UK, nor to have required them to commit to significant additional commercialisation activities in keeping with the Patent Box policy objectives, beyond what might be expected from a commercial office in a key market, in the case of Solexa, or a continuing R&D resource in the case of Qualcomm.

Perhaps more important, these examples raise the question of whether the real policy challenge for the UK is not how to encourage companies to do more R&D, but far more fundamental and linked with loss of UK ownership and local business development responsibility. This issue is discussed in Section 7.

Have R&D Tax Credits Increased UK Productivity and Growth?

Innovation increases productivity in two ways; it can increase operational efficiency and it can lead to better product and service differentiation compared with competitors, and hence higher unit prices and gross margins. The number and complexity of other factors, together with the long timescales involved, makes it impossible to quantify the influence of R&D tax credits on UK productivity and growth. Though the disappointing impact of R&D tax credits on R&D spending as a percentage of GDP makes it unlikely that the policy has had a meaningful impact.

According to a recent analysis by Cambridge University's Institute for Manufacturing, between 2007 and 2018 the UK's labour productivity grew somewhat more slowly than other developed economies and was barely above its 2007 level. This was at least partly explained by an increase in the share of the economy contributed by sectors with low value added per hour worked, notably "other services" (e.g. retail, hospitality and administrative services) and a decrease in the share contributed by high added value sectors, such as "medium to high-tech manufacturing", including pharmaceuticals, aerospace and automotive, and "other production", including oil and gas extraction.[34] These are, of course, exactly the sectors which would be expected to flourish if R&D tax credits had the desired impact.

5. WEAKNESSES IN HMRC ECONOMETRIC EVALUATIONS

Key Features of Econometric Models

There is an extensive academic literature on the effectiveness of R&D tax credit policies in different countries, and a more or less standard approach has evolved for econometric analysis. It is based on the neoclassical economics assumption that a firm's R&D spending is significantly influenced by its unit cost. This approach was used for recent HMRC evaluations of both the RDEC scheme and SME scheme.[35, 36]

Both evaluations use HMRC tax credit data for all companies and years of the analysis period. A number of estimates of additionality are made with different econometric approaches and data exclusion rules.

Most econometric evaluations of R&D tax credits, including those discussed here, are based on the assumption that the resulting reduction in the "user cost of capital" will lead to an increase in R&D spending as projects with lower risk adjusted returns become viable to undertake. The methodology therefore involves two stages.

The first entails estimating the "user cost of capital" for each company and year, reflecting corporation tax rates, R&D tax credits, interest rates and capital depreciation rates. Different rates are estimated for profit and loss making companies.

In practice there is only a small difference between user costs for different classes of company and years.[37]

In the second step, regression analysis is used to estimate the "user cost elasticity of R&D", that is to say the percentage by which R&D expenditure increases for each 1% fall in its cost. This leads directly to an estimate of scheme additionality – the estimated additional R&D spending resulting from every increase in £1 of the cost of the scheme arising from increasing the level of subsidy, e.g. from 12 to 13%.

Both the 2019 RDEC and 2020 SME scheme evaluations explore variations around this theme to eliminate the effect of other variables and unwanted effects.

In the case of the RDEC evaluation, the authors' preferred approach gives an additionality ratio of between 2.4 and 2.7, implying that each £1m of government RDEC expenditure stimulates £2.4 to £2.7 million pounds of business R&D, i.e. £1.4 to £1.7m of additional spending on top of the £1.0m subsidy itself.

It should be emphasised that this kind of econometric modelling is extremely challenging. The regression on which the 2020 RDEC additionality ratio is calculated explains only 5% of the variability in the data.[38]

The SME evaluation concludes that the additionality ratio is between 0.75 and 1.28 for tax deduction claims and between 0.6 and 1.0 for credit claims. This represents a considerable reduction on estimates of 1.88 and 1.53 made by an earlier HMRC evaluation in 2015.[39] The additional R&D expenditure by SMEs generated by the scheme is now on average less than its cost.

Supporting evidence comes from the research team's survey of SME scheme beneficiaries. 71% of claimants reported that a hypothetical increase in the deduction rate of 10% would not affect their level of R&D expenditure. In qualitative interviews, some businesses suggested that an increase of between 20% and 60%, depending on the respondent, would be required to encourage further R&D spending.[40]

Possible Reasons for Inconsistency Between Econometric Studies and Aggregate Data

There are a number of reasons why the econometric studies may have overestimated additionality ratios.

(i) Additional Categories of R&D Expenditure Allowable for Tax Credits

The annual value of business R&D expenditure used in claims to HMRC has exceeded the BERD value since 2015. By 2018 it was £9.5 billion, or 38%, higher. The divergence since 2005 is shown in Exhibit 7. In its 2020 report on R&D tax credit statistics, HMRC identifies two R&D expenditure categories which are not included in BERD, but allowable for tax credits. These are R&D by the financial industries, which accounted for £2.4 billion in 2017/18, and overseas R&D expenditure, which it estimates at £4-7 billion. Exhibit 5 shows that annual UK business funding of overseas R&D increasing by roughly £4 billion in the seven years from 2011.

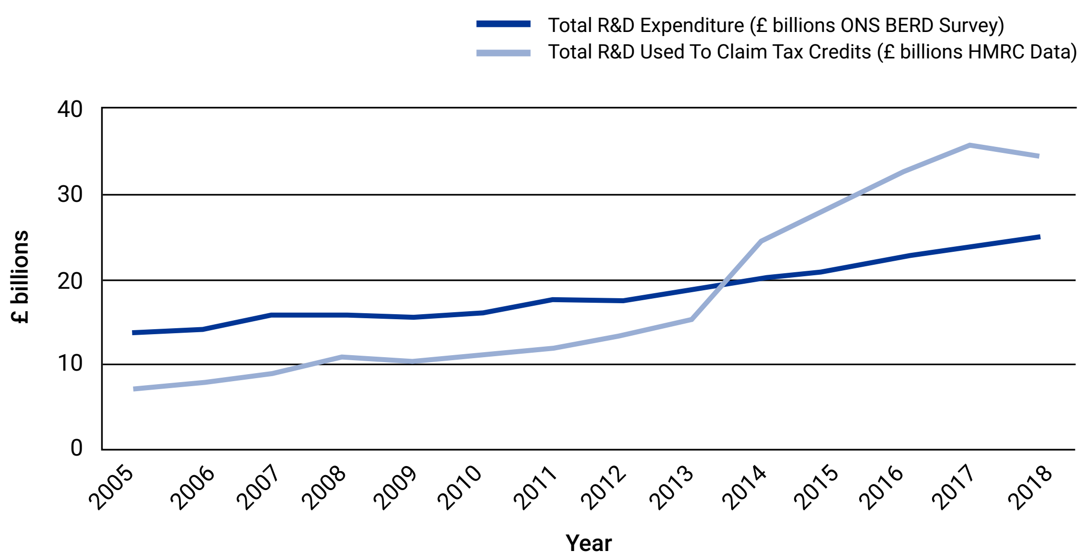
It is arguable that neither of these categories of R&D expenditure should be targets for R&D subsidy.

(i) Definitional Creep, Fraud and Errors

The definition of what constitutes an R&D project and what are legitimate R&D expenses is subject to an element of interpretation and, unlike the ONS BERD survey, there is an incentive for companies to maximise their claims for R&D tax credits. Advisers have become skilled at assisting this process. It is hard for an HMRC inspector, or any other outsider to make an independent judgement.

In its most recent Annual Report, HMRC made its first estimate of the level of error and fraud involved in R&D tax credits, putting this at 3.6% of total scheme claim costs – 5.6% for the SME scheme and 1.0% for the

Exhibit 7 Impact of Non-BERD R&D Expenditure on HMRC Claims (£ billions)



RDEC scheme.[41] This is equivalent to businesses over-reporting R&D by around £1.8 billion in 2019/20. This represents a preliminary estimate by HMRC, based on an "insufficiently developed understanding of the error and fraud risks arising from the scheme".[42] It seems likely that the true number is larger.

Together, these two sources of claimed R&D, and which are both inconsistent with BERD, account for around £10 billion pounds per annum, equivalent to roughly 35% of claimed expenditure which is additional to the BERD figure.

(ii) Gradual Growth in Awareness and Use of Scheme

Exhibit 7 (opposite) shows that even in 2005, four or five years after R&D tax credits became available to companies, claims were submitted representing R&D expenditure of only around half of recorded BERD. Subsequent growth is likely to be largely due to the number of companies claiming, which has increased by a factor of around ten since then, but it is also probable that companies became more careful to claim for every expense to which they were entitled.

If so this would lead to an upward bias in estimated additionalities and could contribute to explaining the decline in the estimated additionality ratios for SMEs.

(iii) Impact of Oversimplifications in Theoretical Framework

The user cost elasticity approach used for the HMRC evaluations implicitly assumes:

- that company boards can estimate the risk adjusted DCF return of different possible R&D projects and the annual funding commitments required to undertake them;

- that they can, and do, estimate changes in the user cost of R&D as a result of small changes in the R&D tax credit formula from year to year, and can estimate differences between the user costs of R&D in the different countries in which they can undertake R&D

- that they can do so with sufficient reliability to make rational decisions on whether to increase R&D spending to cover items with lower risk adjusted rates of return if the user cost of R&D is reduced slightly, or to shift R&D spending to the UK from other countries

- that companies already have internal funds available to increase R&D spending or, if not, that they can borrow money at commercial lending rates, and that it makes sense in all other respects to do so.

OR, if these rational decision processes are not in place, that the decisions made in practice are, in aggregate across the corporate sector, broadly consistent with the economic theory.

Section 6 discusses why these assumptions are flawed.

6. A MORE REALISTIC MODEL OF COMPANY BEHAVIOUR

There are many reasons for challenging the assumptions underlying the HMRC models. This is partly because the potential returns and risks associated with any R&D project are usually extremely difficult to estimate, not just because of the technical difficulties and uncertain timescales often involved, but because success also depends on the actions of competitors.

To get closer to actual practice we need to consider the factors that affect decision making in four different categories of target company:

(i) Established UK corporations

(ii) Venture capital backed "hard start-ups"

(iii) "Soft start-ups" and small companies without venture capital or cash reserves to match fund subsidies

(iv) Potential inward investors and UK companies with internationally mobile R&D.

Established UK Corporations

For large companies, often with several different business units, budgeting tends to start as a top down process, with Group management calling for proposals from each subsidiary. Indicative targets are often set for short term financial performance, such as profit margin and revenue growth. Group boards have to decide how to allocate the investment funds available across a range of activities, including expanding operations in different business units and markets, capital investments in IT, offices or manufacturing and acquiring new businesses to give access to new markets, lines of business, products or technologies. Proposed increases in R&D spending must compete with all of these, and boards often find it difficult to judge the merit of proposals put forward by scientists and engineers.

There is more pressure to cut R&D spending when profits are hit by recession than there is to increase it when times improve.

R&D tax credits are typically the responsibility of the group finance function and are aggregated with the many other sources of funds on which the group budgeting process can draw.

Most large corporations effectively practice "open innovation". That is to say they seek to acquire the new technologies and products they need from wherever they are available in the world, through licensing, partnerships, imitation or acquisition, not just internal R&D. In many cases, acquiring an early stage company with a proven technology, demonstrable market opportunity and entrepreneurial R&D team is a much quicker way of innovating than in house R&D, particularly for the kind of higher risk R&D that R&D tax credits are designed to encourage. It also gives companies much more flexibility, allowing management to scout across a range of innovations and new business opportunities before committing significant sums.[43]

Furthermore, acquisitions are preferable from a financial and investor point of view, as they initially have a neutral effect on the value of net assets in a company's balance sheet. In contrast, R&D spending reduces profitability, and usually market capitalisation, at least in the short to medium term.

For all of these reasons large corporations often set R&D budgets at a fixed percentage of revenue, using competitors or industry norms as a guideline. So growing companies will automatically increase R&D spending each year.

This can contribute to an upward bias in the estimates of additionality derived from the HMRC econometric models. For example, a company with an annual turnover growth rate of 9% and R&D subsidy rate from tax credits of 10% would give a calculated additionality ratio of 1.9, even if the impact of the R&D tax credit was neutral, i.e. it had a true additionality ratio of 1.0.

Venture Capital Backed "Hard" Start-Ups

Companies set up to develop and bring to market a new technology or product, and funded entirely by venture capital, such as most university spin outs, initially spend the majority of funding on research and development. Conventional bank finance is usually unavailable.

Such companies are sometimes called "hard start-ups" as the business plan is fixed at the start around a specific technology or product.[44]

As early stage venture capital firms can only expect a small proportion of their investments to be profitable they must invest only in firms offering a very high potential rate of return, typically of around 50% per annum. So, this is the effective annual cost of new capital, rather than the interest rate of around 10% assumed in the HMRC evaluations to calculate the overall user cost of capital.[45] Indeed, for founders and existing investors it may, in practice, be higher as, with each new investment round, incoming investors structure their deals to penalise non-participating shareholders.

On this basis, one would expect 100% (or close to 100%) of cash from R&D tax credits to be spent on increased R&D, but with little or no direct impact on the amount of venture capital raised to spend more than this. This would give an additionality ratio of 1.0 or less, consistent with the HMRC's 2019 SME evaluation.

However, in the longer-term average UK venture capital returns might be expected to increase as each pound of actual investment is enhanced by the R&D tax credit subsidy. This should lead eventually to higher institutional and private office commitments to UK venture capital as an asset class, as investors in VC and other "alternative asset" funds base their allocations to different asset classes on the average returns to each asset class over the long term.[46] Average long term UK venture capital returns have been consistently below that of other, less risky, asset classes over several decades.[47] So this could be an important benefit, as UK government VC programmes have not traditionally addressed the low UK IRR problem adequately. However, it is too early to say how much difference R&D tax credits have made, if any.

A feature of the venture capital funding model is that most VC backed companies struggle to raise more money for most of their existence. R&D tax credits tend to be regarded by entrepreneurs as a bonus. The most common comment from CEOs is how the arrival of the HMRC cheque provided their company with a lifeline during periods of crisis, rather like the unexpected legacy from the great aunt in Australia.

As a result, R&D tax credits are greatly valued by this part of the business community, even though the economic impact may be low.

Soft Start-Ups and Small Companies Without Venture Capital or Cash Reserves to Match Fund Subsidies

The founders of many of the UK's most economically significant STEM based companies have adopted a "soft start-up" business model, with early revenues from consulting, contract R&D or systems integration projects for different customers, based on their founders' expertise. They may lack the proprietary IP and differentiated business proposition needed to raise venture capital when first setting up their business, or may wish to avoid it in order to retain entrepreneurial control.[48]

Smaller amounts of angel investment may be available as this is a more judgemental and less time consuming process than raising venture capital. It also entails less loss of entrepreneurial control.

The opportunity to create IP and develop innovative new products or services often comes later, as it does for other profitable SMEs without an R&D activity.

To sustain growth of the core business, successful companies of these kinds need to continue to invest ahead in recruitment, facilities and other assets, but as a result profit levels may be low. Commercial bank lending can provide working capital to enable the growth rate to be raised. However, the founders of such business are often reluctant to raise venture capital to fund any additional R&D, as this increases risk, reduces entrepreneurial control and can jeopardise the growth of the existing business.

The continuing need to invest in the core business means that companies have only a very limited opportunity to take advantage of the lower user cost of capital theoretically delivered by R&D tax credits. So R&D spending remains at a low level, attracting minimal amounts of R&D tax credits. If this limited R&D spending grows in line with growth in revenues, it will nevertheless create an additionality artefact within the HMRC's econometric analysis as discussed earlier.

In 2018/19 19,000 R&D tax credit claims, 30% of the combined total of both schemes, were for £10,000 or less, in most cases insufficient to have a significant impact on the companies involved.

The key policy question is whether there could be modifications to R&D tax credits or other, more cost-effective policies to fund R&D and accelerate the growth of the most promising companies in this category. This is discussed further in Section 7.

Inward Investors and the Location of Internationally Mobile R&D

It is in the interests of any multinational company considering a high-profile R&D investment in the UK, or with an internationally mobile facility already in place, to argue for public subsidies. The potential role of government inducements is often amplified by politicians, other local interest groups and in media coverage. So, it is difficult for government to assess how important R&D tax credits really are in influencing these decisions.

The academic evidence is fairly clear. A major study of multinational companies by the US National Academies lists tax breaks as ninth in importance in a list of factors influencing choice of site for investment in R&D facilities in developed economies outside the home country. Quality of R&D staff and IP protection were first and second in importance. Access to academic expertise and ease of collaboration with universities were third and fourth. Costs were eleventh in importance. For sites in emerging economies, tax breaks were listed twelfth in importance.[49]

A study for the European Commission concurs with this view of tax breaks, stating that; "*there is a consensus in the literature that special incentives to foreign-owned firms are not an appropriate instrument to attract R&D of foreign owned firms*".[50]

The importance of access to a pool of high-grade research talent is illustrated by Astra Zeneca's 2013 decision to rebase almost its entire UK R&D operations in Cambridge, closing its existing Cheshire and Loughborough R&D facilities. Access to a large pool of scientific talent for recruitment, the existence of a large cluster of other life sciences firms and not-for-profit research centres, and the possibility of increased levels of collaboration with the university outweighed the huge costs involved. As the move was within the UK, R&D tax credits could have had no influence on the decision.

University collaboration is particularly important to innovation in pharmaceuticals, where, for example, research on disease processes at the cell and protein chemistry level can identify new targets for commercial drug discovery. This intimate relationship, and the role of VC backed start-ups and other SMEs in maximising the number and variety of approaches to commercialisation, is much more important than in other industries.

But Astra-Zeneca's wholesale relocation of R&D is atypical. Furthermore, multinationals increasingly operate an "open innovation" approach to R&D, rather than relying on corporate laboratories. The acquisition of UK companies with strategically important technologies or expertise before they have achieved profitability is therefore now one of the most important mechanisms through which both UK and overseas based corporations invest in UK R&D operations. And it is difficult to see how R&D tax credits might influence such asset purchasing decisions to any degree.

The more important policy question is the extent to which change of ownership influences the subsequent growth of an acquired operation in the UK, both as an R&D location and as a fully rounded business with ongoing production, marketing, technical support and business development functions.

UK based companies also acquire overseas based companies of course, many also with R&D operations.

Exhibit 5 (see page 16) shows that the overall balance of trade in R&D funding has declined significantly in recent years, with the funding of overseas R&D by UK based companies now significantly exceeding foreign funding of R&D in UK businesses. Given the high level of UK R&D tax credits compared with other countries, this trend suggests that they are not an important contributing factor in R&D location decisions.

7. THE REAL POLICY CHALLENGE; HOW TO GROW AND RETAIN SUCCESSFUL STEM BASED COMPANIES WITHIN AN OPEN UK ECONOMY

The original aim of R&D tax credits was to encourage more UK R&D spending by businesses already in the UK, and more net inward investment in R&D from abroad. The policy's failure to deliver against either of these objectives is disappointing.

But we must also consider a more fundamental problem, the UK's failure to grow and retain new STEM based companies to replace industries in decline.

For example, why is it, given the UK's strength in medical and other areas of research that it has:

- Only two of the world's 41 largest biotechnology and pharmaceutical companies (Astra Zeneca at No 12 and GSK at 14)[51]
- Just one of the 50 largest medical devices companies (Smith and Nephew at number 24)[52]
- Only one of the top 20 scientific instruments companies (Spectris at number 13)?[53]

The UK's declining position in pharmaceuticals is particularly symbolic given the UK's university, charity and NHS research commitments. In 2018 UK pharmaceuticals sector companies accounted for 18% of overall business R&D. Between 2008/9 and 2017/2018 the sector slipped from 5th to 18th in terms of trade balance, its value added per employee declined by 9.5 per cent and its R&D spending declined by 3%. It employs just 32,000 people.[54]

Our failure to use the size and purchasing power of the NHS and Research Councils to support the creation and growth of new companies in these industries as lead customers adds emphasis to the sense of missed opportunity.

And if we look at the Cambridge cluster, the UK's best known centre of STEM based business creation:

- Why have only four companies been created in the Cambridge cluster in the last thirty years that now employ more than a thousand people, with only two of these, Arm and Abcam having achieved profitability?[55]
- Why have just six Cambridge businesses been created over this period with more than 500 UK employees, including two, Qualcomm and Illumina's UK subsidiaries, built around the Cambridge companies they have acquired, and with only two of the six, Abcam and Darktrace, remaining independent?

And given the emphasis placed in policy statements on academic spin outs, should we be concerned that only one of these companies, Illumina (Cambridge) Ltd, is based on inventions by Cambridge University scientists, through the US parent's acquisition of Solexa, just after it had launched its first product.*

The question this raises for policy makers, is whether this represents the best outcome that might be

*. Cambridge Antibody Technology, founded in 1989, and arguably the UK's most successful biotechnology company was acquired by Astra-Zeneca in 2007 and forms a key part of its Medimmune Division.

expected given the expertise in the Cambridge area and the level of public investment it has received. Or whether other policies are available which would increase the percentage of start-ups in Cambridge, and across the UK, that go on to become sizeable UK based companies.

The Role of Foreign Acquirers and Venture Capital

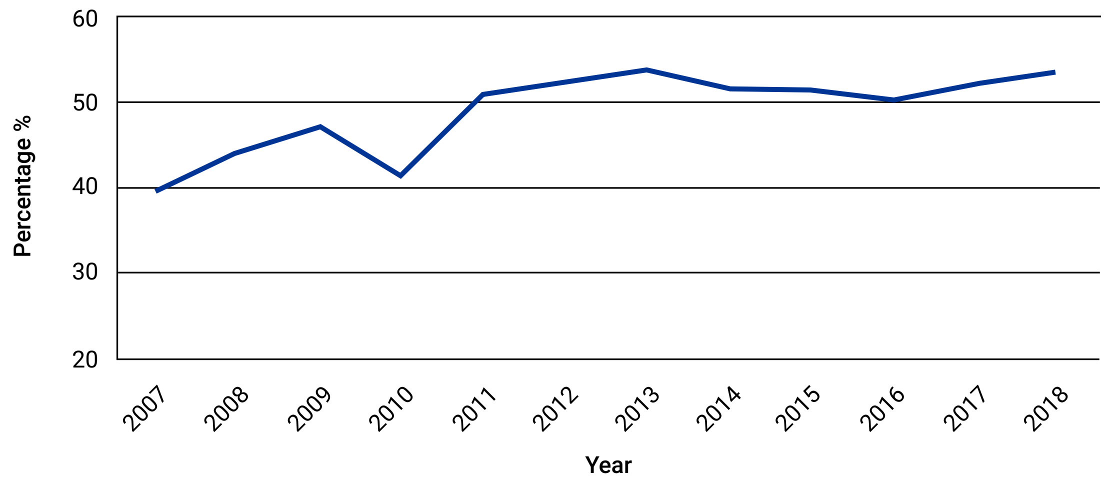
Increased attention has recently been focused on the impact of foreign acquisitions of UK companies, most notably as a result of the proposed sale of Arm to Nvidia, a large US based semiconductor corporation.[56]

Acquisitions have played an increasing role in the global economy since the mid 90s[57], with US corporations the main acquirers, and the UK probably the most attractive country in which to make them. This is an inevitable result of its open economy, strong financial sector, legal system and business friendly employment legislation. The fact that people speak English, the international language of business and science, also makes it easier for foreign multinationals to identify, evaluate and assimilate UK companies than those in other countries.

The steady increase in the percentage of BERD undertaken in foreign owned companies, up from 32% eighteen years ago, is shown in Exhibit 8.

The prevalence of foreign acquisitions is an inevitable aspect of the global market in which we now live. Though innovation may drive a company's early success, new companies based in larger markets, like the US or China tend to grow more quickly, and as product markets mature, and economies of scale become the main source of competitive advantage, they can spend more on R&D and marketing.[58] This inevitably means that smaller STEM companies based in the UK will usually be acquired by larger multinationals, their future role often being restricted, either to the technologies for which they were acquired or to providing regional customisation, customer support and distribution operations for the parent.

Exhibit 8 Percentage of UK Business R&D in Foreign Owned Companies



More important in the long run, absorption into the parent also reduces the ability of local UK management to use the profits generated to create further growth by diversifying out of their existing business.

Of particular concern from an industrial strategy point of view is not the acquisition of mature UK businesses that have achieved profitability, but then lost the ability to remain competitive as independent companies' long term, but foreign acquisitions of promising early stage companies which might otherwise have had the potential to become successful global players as independent UK businesses.

Venture capital investors almost always back start-ups with a view to exiting through a trade sale. And they seek businesses which will have a high *strategic value* to an acquirer. This could be because they have a product, such as a new drug, which can be manufactured and distributed through the acquirer's global business network; or a strong team with IP and expertise in a new field, like AI; or because the acquisition will enhance the acquirer's brand or shareholder value, for example by signalling a new growth or innovation strategy. Successful VCs must operate in this way if they are to deliver the returns sought by their own investors. Whenever possible they will recruit Chairmen and Chief Executives to run their investments who are motivated to pursue this goal. And they will use their voting power, board seats, and de facto control of future funding to persuade management to agree to sell up when a suitable acquirer appears.

The main alternative exit route for investors, listing a business on AIM or the London Stock Exchange, usually only allows investors to sell just a small percentage of their shares, and the low levels of liquidity for entry level companies usually means investors are locked in for some years, unless the listing just provides a route to a trade sale.

The impact on the economy of this process is obfuscated by the media focus on "Unicorns", start-ups that have reached a valuation of more than $1 billion, most before they have achieved profitability and originally VC funded. Lauded as a sign of the UK's economic vibrancy, achieving Unicorn status represents success for their investors and financial advisers. But it should be remembered that investors only value a Unicorn at $1 billion because they believe it will soon be valued much more highly by others, and probably acquired.

So acquisition by a large corporation is the usual end result for successful VC backed start-ups. And, for scientists and engineers seeking to commercialise a breakthrough technology, venture capital funding usually appears to be the obvious, or only, way forward. This is particularly the case for businesses created by academic scientists and engineers.

Because of these factors venture capital has a different economic impact in the UK compared with the US, where the downstream economic benefits of acquired business are more likely to be retained within the country.

For many businesses this may well be the best outcome for all involved. But there will always be some businesses which could deliver more value to the UK economy if they were able to retain their independence, and whose management team have the ambition to do so. It is essential that UK industrial policy gives as much support as possible to the minority of entrepreneurs with this goal.

To maximise the economic potential of the UK's scientists and engineers we must also learn lessons from those company founders who **have** been able avoid selling up early and gone on to build a substantial, independent UK company. It is largely the soft start up model that has enabled entrepreneurs to do this.

The Soft Start-up Model and Lead Customers: The Dominant Model Behind UK Successes

The founders of soft start-ups are either unable to raise venture capital because they do not have a sufficiently attractive business plan or choose not to because they wish to retain control of the business. Their focus is on using their expertise and market knowledge to earn revenues from day one and move to break even as soon as possible. Capital mainly takes the form of sweat equity – working without a salary – and money from savings and friends and family. Increasingly this has become available from angel investors assisted by the SEIS and EIS schemes.

Soft start-ups are strongly focused on satisfying unmet customer needs, even if founders have some specific IP around which they can tailor solutions. The initial emphasis is on what founders can sell quickly: technology consulting, development and integration contacts, and niche products and services supplied to order. They tend to be technology agnostic, focused on how they can combine already available technologies and components to meet each customer's requirements. Personal contacts and reputation drive early sales.

As soft companies grow they have opportunities to develop their own, standard products. This can be as a result of generating IP to meet a specific customer requirement with wider application, or from identifying a common unmet need across a range of customers.

The role of lead customers in funding the R&D involved, knowingly or unknowingly, plays an important part in the transition of a "soft", service orientated company to a "harder", and more scalable, product business. This may be achieved entirely with internally generated funds and government grants, or it may require more substantial venture capital investment. This can be into the original business or into a spin off company. Transitioning into a product business represents a time of risk for entrepreneurs. The investment needed is often underestimated.

Entrepreneurs have been using the soft start up model for decades. In the US they were often known as garage start-ups. Examples include Hewlett Packard, Apple and Microsoft. The MS-DOS operating system Microsoft developed for the IBM pc enabled it to transition from a soft company to a product company. It never raised venture capital. IBM was its unwitting "lead customer".[59]

In different forms, soft start-ups dominated the early development of the Cambridge cluster, being applied across a number of industry sectors. Nearly every new STEM based company set up since 1970 to have grown to employ more than a thousand people either followed this route or spun out of a company which had done so, with customer funded R&D providing the basis for the first products sold. By enabling founders, especially those without significant funds of their own, to avoid, minimise or delay raising venture capital they were able to retain management control, achieve sustained growth and the creation of a fully rounded, profitable UK business with high levels of exports.[60]

Other UK businesses that followed the soft start up model include Dyson, Oxford Instrument, Lotus, McClaren, and Renishaw. Vodafone, the UK's most successful start-up since the war, is essentially a spin out from Racal, originally set up as a two man radio consultancy working for the MOD.*

To create more businesses of this calibre, government must tailor its policies to support the soft start-up model better and encourage more businesses and public sector organisations to act as lead customers.

*. Short histories for some of these companies can be found at https://www.cbr.cam.ac.uk/people/research-associates/David-Connell/

8. MAXIMISING THE ECONOMIC IMPACT OF R&D TAX CREDITS AND OTHER GOVERNMENT POLICIES ON THE STEM BUSINESS ECONOMY

Today's Unbalanced Innovation Policy Mix

The R&D tax credit and Patent Box schemes together now cost the Treasury around £8.4 billion a year. As Exhibit 9 (below) shows, this is an order of magnitude more than the combined total of all other government programmes to fund innovation in UK companies.

The cost of the programme is also much larger than total venture capital investments in UK companies. In the thirteen years to 2019 this amounted to $20.4 billion.[61] In the thirteen years to 2018/19 R&D tax credits cost the Treasury £30.8 billion, twice as much as the value of venture capital over broadly the same period. This raises the question of whether the public money spent on tax credit subsidies might not have had a greater economic impact if invested in UK companies through an alternative venture capital mechanism.[62]

EXHIBIT 9 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
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

A Policy Mix to Address Weaknesses in the UK Innovation System

The scale of the failure of R&D tax credits to deliver against the objectives set for it needs to be considered in the light of six other important weaknesses in the UK innovation system:

- the loss of UK growth opportunities as a result of most successful VC backed STEM start-ups being sold at an early stage for their strategic value to foreign acquirers, an especially likely outcome for university research spin outs
- the almost complete absence of government R&D funding in a form suitable for companies pursuing a soft start up model without significant venture capital, and on which many of the UK's most successful STEM companies have been based
- the preoccupation of government policy makers with a linear model of innovation based on technology transfer from universities, at the expense of customer driven innovation, with expertise in combining existing technologies as the basis for innovations that address unmet needs
- a tendency of policy makers to focus on well known "grand challenges", with strong competition from start-ups and established companies globally, whilst neglecting the opportunity to build a new generation of specialised Mittelstand companies of the kind more suited to smaller economies like the UK
- the lack of policies to encourage the crucial lead customer funding of innovation which plays a transformative role for many start-ups
- the lack of non-dilutive R&D funding for start-ups by young entrepreneurs from a corporate background who lack capital, IP or the support of a university employer whilst raising money.

This means that we must not just look for ways in which R&D tax credits might be made more cost effective, but also at how the balance of funding across other policies could be changed to address these weaknesses.

The measures listed below offer some solutions which could be achieved at zero net cost to the Treasury.

Abolishing the Patent Box

There is no evidence that the Patent Box has bought benefits to the UK economy and it appears (a) that the main beneficiaries have been companies in sectors for which there is no case for this kind of government subsidy and (b) that a company's accounting treatment can be at least as significant in generating high levels of Patent Box subsidies as investment in commercialisation in the UK.

This would save the Treasury around £1.1 billion a year.

Restricting R&D Tax Credits Claims to R&D Spending in the UK

HMRC estimates that in 2017–18 between £4 and £7 billion of the R&D spending used by companies to claim R&D tax credits related to spending overseas.[63] R&D tax credits should be focused entirely on encouraging more R&D in the UK.

Assuming this expenditure all related to large company claims, eliminating these claims would have saved the Treasury £363 to £635 million a year.

Changes to the scheme since then mean the savings would now be greater.

Restricting R&D Tax Credit Claims to Expenditure Within the Internationally Accepted Definition Used by the UK Government for Measuring Business R&D

In 2017/18 the financial sector was responsible for £2.4 billion of the R&D expenditure used to claim R&D tax credits.[64] R&D by the financial sector is not included in the official BERD statistics used for the Government's R&D targets. Financial services is one of the UK's strongest industries and R&D projects tend to be relatively rapid and low risk. There appears to be no absence of private sector funding for new ventures.

There is therefore no justification for an R&D subsidy.

Assuming claims were spread across both SMEs and large companies, this would have saved the Treasury £358m per annum.

Encouraging New Venture R&D by Large Companies

Unlike the US Federal Government R&D tax credit scheme, payments under the RDEC scheme are not linked preferentially to the rate of growth in R&D spending. And it includes no features to encourage companies to undertake higher risk R&D, such as those associated with diversifying into new businesses.

Creating a new venture within a large corporation can be as challenging for the *intrapreneur* as for the entrepreneur starting his own business, not least because new market opportunities rarely look large enough at the time to justify senior management attention.

Reducing the standard RDEC rate from 13% to 11% could make around £400m available to provide a higher level of support for R&D to develop new ventures.

Applying R&D tax credits at the SME rate to loss making new venture subsidiaries of large corporations employing less than 500 people, and with a minimum of, say 30%, of expenditure devoted to R&D would bring them in line with independent SMEs.

Modifying the RDEC Scheme to Encourage Open Innovation and Lead Customer Funding of Innovative UK SMEs in Corporate Supply Chains

Large companies increasingly rely less on in-house R&D, using open innovation to access new technologies, expertise and innovative products from SMEs. They do this both to increase the competitiveness and revenues of their existing businesses and as a stepping stone towards creating new ones.

R&D contracts are an important part of this process and they also fuel the growth of the STEM based SMEs which undertake them. These contracts often trigger the move from provider of R&D services to a much higher growth business based around the creation and supply of proprietary products. The Cambridge cluster is largely built on this process, with its technology consultancies playing a major role.[65]

At present UK R&D tax credits do nothing to encourage this process. Indeed, large companies wishing to subcontract R&D are penalised as the expenditure is not eligible within a large company RDEC claim.

There is also no logical reason why SMEs should be able to claim the RDEC benefit on R&D they carry out as a subcontractor, which would normally be at a full commercial rate. The £300m per annum of payments under this scheme probably include a large element for the routine R&D services associated with R&D projects, including clinical trials.

Cancelling the RDEC subcontractor scheme would release £300m per annum to support a more productive approach to open innovation.

In 2017–18 company payments of over £0.5 million accounted for £2.5 billion in R&D tax credit costs, roughly half the total. Some £1.9 billions of this was paid to large companies.

Making 15% of these payments to large companies at the SME rate, and in the form of vouchers to be used for placing innovation contracts with UK SMEs, would enable large companies to increase the open innovation aspects of their R&D strategy by £570m per annum.

Importantly it would support the soft start-up model on which many of the UK's most economically significant new STEM based companies are based. Pre-commercial lead customers of this kind play a key role in helping innovative suppliers focus R&D on real customer needs and they provide endorsement for subsequent customers, partners and investors, shortening the valley of death and speeding time to market.[66]

Features to ensure funding was focused on higher risk R&D bringing high levels of additionality could include:

- restricting voucher funded contracts to the development and testing of new technologies and products, rather than routine R&D services
- restricting the use of vouchers to contracts with SMEs with which the customer had not placed an R&D contract for 3 years
- restricting commercialisation rights, as below.

To give SMEs the freedom to develop their own businesses further, contracts funded, or part funded, with vouchers should not require SMEs to transfer IP ownership or provide a licence to the customer. This approach is regularly used by companies pursuing a soft start up strategy or hoping to spin out a product business on the back of R&D projects for customers. Commercialisation rights can always be negotiated after the voucher funded project, or stage in the project, is completed.[*]

This measure would cost the Treasury an additional £270m per annum.

Establishing a Complementary Scheme for Public Sector Innovation Contracts

Public sector contracts have played a key role in the development of new STEM based companies.[67] And there have been repeated UK government attempts to encourage this process, with innovation contracts seen as a win-win opportunity for both the public sector and SMEs.

However, spending departments have been extremely reluctant to play this role in a meaningful way, and my review of the existing, misnamed, Small Business Research Initiative, commissioned by 10 Downing Street, recommended the creation of a new *Tommy Flowers Fund* to enable them to do so on a systematic basis, rather than just in times of war and national crisis.[68]

The political turmoil of Brexit and need to deal with the Covid crisis has prevented this recommendation from being implemented. Though the role played by innovative SMEs in tackling the pandemic illustrates the potential of the approach.

Implementing the recommendations of this report would cost around £500m per annum.[69]

*. If Catapults were tasked with creating, developing and commercialising in-house IP and monitored against this goal in line with the German Fraunhofer institutes, which were the inspiration for their creation, they could also be useful beneficiaries of the voucher scheme, and more likely to act as nucleators for local cluster growth.

A Non-Dilutive R&D Funding Mechanism to Replace the EU's SME Instrument

The highly regarded "SME Instrument" was a competitive grant programme that operated under the EUs Horizon 2020 programme. It was designed to match the contract based, US Small Business Innovation Research (SBIR) programme in terms of award size, without breaking EU State Aid rules. The SME Instrument provided €50,000 in 100% Phase 1 funding and up to €2.5 million at 70% in Phase 2, making it much more generous than Innovate UK's single company grants in terms of both grant amounts and subsidy rate.[70]

Complementing Innovate UK's limited single company SMART grant programme with a scheme similar to the EU SME Instrument would provide a minimally dilutive funding mechanism for companies for which lead customer contract funding is not accessible.

A £300m per annum programme would be appropriate.

Aligning Venture Capital to the National Interest by Creating a New Class of Funds

Most developed countries, including the UK, have created policies to encourage more investment in venture capital.

For the UK though, the problem is not just the amount of VC funding available, but also the tendency for most successful investee companies to be sold, usually to an overseas company, with further growth in the UK truncated. This is an inevitable result of the way in which VC fund managers are rewarded – initially through a modest annual management fee, together with "carried interest", typically a 20% share in the capital gain delivered by the fund over a 10 to 13 year period.

Investing in start-ups is a long term process, but the need for fund managers to raise new funds every three years increases the pressure for early trade sales to demonstrate performance. A trade sale is often in the interests of all shareholders, including a company's founders. But VCs and financial investors can also use their voting power and control of a company's board to push through an early trade sale against the wishes of founders with the ambition to build a larger UK business over the long term.

Creating a new class of professionally managed funds, whose investment model gives company founders a veto on any change of control, would make it more attractive for entrepreneurs to use venture capital to accelerate the growth of their businesses. And it would increase the proportion of VC backed businesses able to grow into large UK based companies over the long term.

Fund managers could be compensated for the loss of flexibility by adding to the traditional reward mechanism an annual payment linked to the increase in jobs created in investees. A programme delivering £500m of investment per annum from early stage to pre-IPO would be appropriate.

Assuming this was all government money, the net cost to the Treasury would of course depend on the long term return on its investment.

The Bottom Line

The proposals in this report are designed to eliminate or improve underperforming policies and introduce new approaches that support the business models on which the UKs most successful new STEM based businesses have been built, whilst delivering a net annual cost saving to the Treasury (See Exhibit 10 overleaf).

Achieving the goal of successive governments to increase the UK's R&D spending to 2.4% of GDP will be impossible without new policies. It is time for radical new thinking, with a genuinely joined up, evidence based, approach to innovation policy across the Treasury, BEIS and key spending departments.

Exhibit 10 Summary of Proposed Policy Changes

POLICY	ANNUAL COST (£M)	ANNUAL SAVING (£M)
Abolish Patent Box		1130
Restrict R&D tax credits to UK expenditure		363 to 635
Restrict R&D claims to BERD expenditure		358
Reduce fraud and error in R&D tax credit claims*		250
Encourage new ventures by large companies	400	
Cancelling RDEC's automatic subcontractor subsidy		300
Encourage innovative SME subcontractor R&D funding through RDEC vouchers	570	
Implement Connell recommendations for innovation procurement funding	500	
Create UK version of EU SME Instrument	300	
Create new class of VC funds to enable greater entrepreneurial control and encourage long term UK business growth	500	
TOTAL	**2270**	**2401 to 2673**

*. This is a notional estimate of annual savings based on HMRC's recent estimate of the cost of fraud and error of £311m in 2019/20 and actions put in hand to reduce it, including the recruitment of 100 additional staff to work on R&D tax reliefs.

9. NOTES AND REFERENCES

1. *HMRC Annual Report and Accounts, 2019 to 2020*. In contrast with the detailed annual statistical report published by HMRC on R&D tax credits, neither Innovate UK nor BEIS publish statistics on R&D grant expenditure by number and type of recipient, grant model (collaborative or single beneficiary) and subsidy rate. ONS BERD data gives the value of Innovate UK grants to industry as £530m in 2018.

2. Based on Office of National Statistics BERD data and HMRC R&D tax credit statistics after adjusting for R&D tax credits paid for non-BERD expenditure as discussed in Section 5. The range of values reflects two assumptions: (i) that all non-BERD R&D is undertaken in large companies in receipt of RDEC; and (ii) that non-BERD R&D is spread across companies of all sizes.

3. Connell, D (1979) *The UK's Performance in Export Markets – Some Evidence from International Trade Data*, National Economic Development Office.

4. *International Price competitiveness, Non-Price Factors and Export Performance*, National Economic Development Office, 1977.

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6. Op. cit., Connell, D (2014) *Creating Markets*.

7. Julie Froud, Colin Haslam, Sukhdev Johal and Karel Williams 'Shareholder value and financialization: consultancy promises, management moves', *Economy and Society* Vol. 29 No.1 February 2000 pp 80-110.

8. Connell, D. and Probert, J. (2010), *Exploding the Myths of UK Innovation Policy: How 'Soft Companies' and R&D Contracts for Customers Drive the Growth of the Hi-Tech Economy*, Research Commissioned on Behalf of the East of England Science and Industry Council by the East of England Development Agency. Centre for Business Research, University of Cambridge.

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11. Benoît Godin (November 2006) ‘The Linear Model of Innovation: The Historical Construction of an Analytical Framework’, *Science, Technology and Human Values*. The paper argues that statistics is one of the main reasons explaining why the model is still alive, despite criticisms, alternatives, and having been proclaimed dead.

12. Timothy M. Collins and Thomas I. Doorley with David Connell (1991) *Teaming Up for the 90s, a Guide to International Joint Ventures and Strategic Alliances*, Business One Irwin 1991. In large measure the popularity of the collaborative R&D project model has its origins in the misreading of Japan’s MITI projects and in particular its success in catapulting Japanese semiconductor memory chip industry to a position of world leadership in the 1970s. Fear that MITI’s “Fifth Generation Computing” project might have a similar effect led to the UK’s Alvey Project and the EEC’s ESPRIT programme, both centred around multi-partner collaborative R&D projects. Collaborative R&D was also a model strongly favoured by the EU since Viscount Davignon saw it as a way of promoting European integration after his attempts to engineer cross border mergers were unsuccessful.

13. Connell, David co-author (2008) Answers to Parliamentary Questions by Mark Prisk MP in *Small Business and Government, a report for the Conservative Party*. Between 2004 and 2006, the Department of Trade and Industry paid out around £140m per annum in grants for collaborative R&D projects linking universities and industry, SMEs received 18% of this, large companies 55% and universities 27%. The budget for the separate “Grant for R&D” aimed at SME’s, and administered regionally was much smaller – about £30m for England and Wales combined. For both schemes, companies were required to pay between 35 and 60% of project costs. By this time grant spending was already dwarfed by the value of R&D tax credits, averaging around £600m per annum.

14. *Science and Innovation Investment Framework 2004 to 2014*, HM Treasury, Department of Trade and Industry and Department of Education and Science.

15. In the case of France and Germany, R&D intensity within sectors was far more important than sector mix. In the case of the US, it was slightly more important.

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25. In 2019, the Fraunhofer Institutes filed 623 patent applications and earned license fees of €107m Euros. Fraunhofer Ventures had a portfolio of 61 spin-offs financed partly through the venture funds it had raised since its creation in 2001. *Annual Report 2019*, Fraunhofer-Gesellschaft.

26. Op cit., Connell, D. and Probert, J. (2010).

27. Creating the Future Through Innovation, *Catapult Network Annual Report 2019–20*.

28. Connell, D. (2014) 'Innovation Policy Role Models and the US Procurement Based Innovation System', in *Creating Markets for Things that Don't Exist*, Centre for Business Research, Centre for Science and Policy and Cambridge Network.

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30. Yuki Furuse, 'Genomic Sequencing Effort for SARS-CoV-2by Country During the Pandemic', *International Journal of Infectious Diseases*, Vol 103, February 2021, pp 305-307.

31. Illumina Inc. 10K accounts and Illumina (Cambridge) Ltd. accounts.

32. Qualcomm Technologies International Ltd annual accounts.

33. Qualcomm Technologies International Ltd annual accounts.

34. *UK Innovation Report; Benchmarking the UK's Industrial and Innovation Performance in a Global Context*; Institute for Manufacturing, University of Cambridge, February 2021.

35. Georgia Scott and Tim Glinert (2020) *Evaluation of the Research and Development Expenditure Credit (FDEC)*, HMRC Working Paper 20, October 2020.

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37. In 2017/18, the user cost was 22.2% for profit making companies and 22.7% for loss making companies. Between 2010/11 and 2017/18 the average user cost varied between 22.1% and 22.8%.

38. The adjusted R^2 is 0.047 to 0.054 for the fixed effect, logarithmic, balanced models with data cleansing on which it is based.

39. Rigmor Kringelholt Fowkes, João Sousa, Neil Duncan (2015) *Evaluation of the Research and Development Tax Credit* HMRC Working Paper 17, March 2015.

40. Op. cit. Shaan Devnani, Rohit Ladher and Nicholas Robin.

41. *HMRC Annual Report and Accounts, 2019 to 2020*.

42. Gareth Davies, Report by Comptroller and Auditor General, National Audit Office, *HMRC Annual Report and Accounts for Year to 31st March 2020*.

43. Managers wishing to start a new venture within a large corporation generally find it at least as difficult as for independent entrepreneurs. The perceived potential of emerging markets is usually too small to be worth the management time or investment. Supporting existing profit generators takes priority.

44. The terms “Soft and Hard Company” were originally coined by Matthew Bullock, a UK banker to help guide lending decisions.

45. The user cost of capital reflects both the cost of new money and the annual rate of asset depreciation.

46. Specialist Advisers like Boston based Cambridge Associates play a key role in this process.

47. See *BVCA Private Equity and Venture Capital, Performance Measurement Survey 2019*, PWC.

48. Unlike academics, scientists and engineers working in the private sector have no rights to any IP created whilst employed and their contracts usually restrict them from competing. This makes starting a STEM based business much more difficult and riskier than for academic scientists as they must already have sufficient private funds to make the transition.

49. Jerry Thursby and Marie Thursby (2006), *Here or There? A Survey of Factors in Multinational R&D Location*, National Academies Press, Washington D.C. The survey covered 250 multinational companies across 15 industries. 44% gave the US as their home base, and 49% were based in Western Europe.

50. Berhard Dachs et al, (2012) *Internationalisation of Business Investment inR&D and Analysis of Their Economic Impact*, European Commission Directorate Genera for Research and Innovation, 2012.

51. Largest biotechnology and pharmaceutical companies ranked by market capital 2020, Wikipedia.

52. Largest medical device companies, ranked by 2019 revenue, *Healthcare Sales and Marketing July/August 2020*.

53. Largest scientific instrument companies by 2018 revenue, *Chemical and Engineering News*.

54. *UK Innovation Report; Benchmarking the UK’s industrial and innovation performance in a global context*; Institute for Manufacturing, University of Cambridge, February 2021.

55. These are ARM, with around 6000 employees globally, 40% in the UK, Abcam with around 1500 globally, 80% in the UK, GW Pharma with around 900 employees globally, 67% in the UK. Darktrace is growing rapidly and as of April 2021 had over 1500 employees globally, but was still loss making. It was initially financed by Invoke Capital a venture fund set up by Mike Lynch, the founder of Autonomy, and who continues to have a major shareholding.

56. Arm Holdings was a UK listed company until it was bought for $32 billion in 2016 by Softbank, a Japanese investment firm. Softbank negotiated to sell it to Nvidia, a US semiconductor company, 4 years later for $40 billion.

57. Value of mergers and acquisitions worldwide from 1985 to 2020, *Statista* January 2021.

58. This results in a virtuous circle. The competitive strength derived from starting a business in the US, and resulting track record of success for investors in earlier start-ups, also makes it possible to attract much larger amounts of venture capital than in smaller markets like the UK.

59. The Microprocessor turns 40: Intel's Monumental Accident, *Forbes Magazine*, November 2011.

60. Cambridge Ahead company database.

61. Op. cit., *UK Innovation Report*.

62. As a result of increases in the generosity of the scheme the difference is now significantly greater.

63. *Research and Development Tax Credit Statistics,* September 2020.

64. *Research and Development Tax Credit Statistics*, September 2020.

65. Connell, D. and Probert, J. (2010), *Exploding the Myths of UK Innovation Policy: How 'Soft Companies' and R&D Contracts for Customers Drive the Growth of the Hi-Tech Economy*, Research Commissioned on Behalf of the East of England Science and Industry Council by the East of England Development Agency. Centre for Business Research, University of Cambridge.

66. Op. cit., Connell, D. (2014), *Creating Markets*.

67. Connell, D. (November 2017), *Leveraging Public Procurement to Grow the Innovation Economy*, Department for Business, Energy and Industrial Strategy.

68. Op. cit., Connell, D. (November 2017), *Leveraging Public Procurement*.

69. £250 for the core fund plus £250m for Phase 3s.

70. The SME Instrument was relaunched as the EIC Accelerator Pilot in 2021.

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