CREATING MARKETS FOR THINGS THAT DON'T EXIST

The Truth About UK Government R&D and How the Success of SBRI Points the Way to a New Innovation Policy to Help Bridge the Valley of Death and Rebalance the UK Economy

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Foreword by Lord Adonis

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Special thanks must go to Matthew Bullock, who first introduced me to the idea of the soft start up in 1982, Gerald Avison who enabled me to work and invest in one, Anne Campbell who helped me campaign about their economic importance and Alan Hughes who gave me the opportunity to augment my personal experience with structured academic research. Thanks also to Claire Ruskin and Andy Harter at Cambridge Network, Robert Doubleday and David Cleevely at CSAP and Simon Deakin and other colleagues at CBR who have provided invaluable help and encouragement over many years, and to the many entrepreneurs whose stories have helped me improve my understanding of how the innovation process works in different sectors.

I am grateful also to Jocelyn Probert for reading the report and helping to improve it.

The analysis and opinions expressed are solely my own, as of course is responsibility for any errors or omissions.

Lord Adonis

Lord Adonis is a reformer, writer and Labour Peer

He was a journalist at the Financial Times for five years (1991-96) before moving to the Observer as a political columnist. He joined Tony Blair's Number 10 policy staff in 1998, first as education adviser then, after 2001, as Head of the Policy Unit. He later held office as Minister for Schools from May 2005 until October 2008, Minister of State for Transport from October 2008 until June 2009, and Secretary of State for Transport from June 2009 until May 2010.

His review of economic growth policy for the Labour Party, *Mending the Fractured Economy, Better Jobs* was published in July 2014. Amongst its proposals, it called for Government departments to mobilise their R&D budgets to promote innovation in the key industries they sponsor and use public procurement to help small businesses scale up in a far bolder way.

Lord Adonis studied history at Keble College, Oxford, followed by a PhD in modern history and a fellowship at Nuffield College, Oxford,

David Connell

David Connell has worked in the technology and venture capital sector for 30 years and was cofounder and Chief Executive of TTP Ventures. He is Chairman of Archipelago Technology and a Non-Executive Member of the NHS SBRI Management Board.

Alongside his business interests, since 2006 he has also been a Senior Research Fellow at the Centre for Business Research, where he has been involved in a wide range of projects on innovation and innovation policy. His publications draw on both this research and his personal experience as a participant or investor in a wide range of science and technology start-ups and as a consultant on innovation to multinational companies.

David has championed lead customer and procurement based innovation policies for a decade and his work has had an important influence on the creation of both the UK Small Business Research Initiative and the new €3 billion SME Instrument introduced by the European Commission as a part of Horizon 2020.

David has a BSc in Physics from Bristol University and Masters Degrees in both Operational Research and Economics, each with Distinction, from the Universities of Lancaster and London respectively.

ABOUT THE PUBLISHERS

Centre for Business Research

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Cambridge Network is a membership organisation based in the vibrant high technology cluster of Cambridge, UK. It was founded in 1998 by an influential group comprising the then Vice-Chancellor of the University of Cambridge, now Lord Broers, with businessmen and entrepreneurs Hermann Hauser, David Cleevely, Nigel Brown, Fred Hallsworth, and Anthony Ross then head of 3i Cambridge.

The mission at Cambridge Network is simple – to encourage collaboration for shared success by bringing people together - from business and academia - to meet each other and share ideas, encouraging collaboration and partnership for shared success. It helps raise Cambridge's game, to compete on the world stage.

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Foreword

This is the latest report from one of the leading experts on innovation policy in the UK and internationally. David's research has informed government policy over the past decades and his continued campaigning on this agenda will continue to do so in the future.

As this report highlights, approaches based on simply correcting "market failures" and avoiding "picking winners" will not deliver the innovative economy we need to boost living standards. This ignores the randomness of innovation, as it is often unclear what market a particular innovation will end up serving – something governments around the world are alive to. The US government has led the way in using R&D to create markets to address challenges in the public sector, including most notably for the US military and space programme. This demand-led, or "technology-pull", process has spawned innovations which create all sorts of new markets and world-leading companies – and the UK should continue to learn from this approach.

The main political parties are currently developing their manifestos for next year's general election. And the government's ten year investment framework for science and innovation, which was pioneered by Lord Sainsbury when he was Science Minister, comes to an end this year.

Cross-party commitment is crucial given the long timeframes required for innovation. The Coalition has retained key policies from Labour's time in office, including Catapult Centres, the Small Business Research Initiative (SBRI) and the Technology Strategy Board. The next government should look to build on this further. My recent review recommended scaling up SBRI by focusing on getting departments more engaged, a new ten year innovation strategy and five year budgets for science and the Technology Strategy Board. This report has further proposals which also need to be considered, including a cross-government SBRI programme for major IT projects.

Beyond political commitments, government must become much smarter and more entrepreneurial in the way it works. As the report makes clear, government departmental R&D budgets are in many cases falling but still relatively large. Yet within the funding which is labelled as "R&D" very little makes it to innovative companies to develop commercial products. Much more can be done to exploit the underexploited potential of government procurement and R&D, not least in health given the size of the NHS's budget.

There are many successful companies cited throughout this report which have benefitted from R&D contracts – whether publicly or privately funded – in the early stages of their development. This underlines the size of the prize if the UK can back another generation of world-leading companies.

Andrew Adonis

November 2014

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SUMMARY

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SUMMARY

Chapter 1. Introduction

In December 2004, Anne Campbell, then MP for Cambridge, and I launched a campaign to introduce a radical new innovation policy into the UK, based on the successful US Small Business Research Innovation programme. The idea was that government departments and agencies could play a key role in building the high technology economy by funding the development of the products they themselves need as *lead customers*. In doing so they could help fill an important funding gap, obtain the technology they need more quickly, reduce imports, give new firms the credibility they need to win export orders, and create jobs.

The proposal was rapidly adopted in principle by the Government of the day and has been endorsed by all subsequent governments and major political parties. In the UK it is known as the Small Business Research Initiative (SBRI), though it is open to companies of all sizes and is concerned with developing new technologies and products rather than research per se. Spending is currently running at about £70m a year.

But despite SBRI's successes, implementation has been fraught with difficulties, and major departments, including the MOD, and the Department of Transport, are still not participating in any real sense. SBRI spending in 2014/15 is likely to fall far short of the £200m a year to which the Government committed in the 2013 budget.

By putting emphasis on *customer pull* rather than *technology push*, SBRI represents an approach which is very different to traditional UK innovation policies. Rather than trying to address *market failure*, a concept that is more or less irrelevant to very early stage technology companies, it operates by *creating markets for things that do not exist*.

This report explains why this approach is so important, discusses innovation policies in the US and Germany that help to bridge the *Valley of Death*, and documents what SBRI has achieved so far. It also examines what further challenges remain to make it fully effective. It then looks at the broader policy context, in terms of other UK government R&D programmes and innovation policies. Finally it offers a series of costed proposals to enable government innovation spending to make a more cost effective contribution to rebalancing the economy, by better reflecting how innovation works in practice and the challenges involved.

Chapter 2. The Role of R&D Contracts in Creating New Science and Technology Companies

Start-ups and small companies play a vital role as engines of innovation in any economy. The conventional wisdom implicitly assumes that all new technology companies pursue a *hard start-up* model, with a team forming to commercialise an invention, scientific breakthrough or new product idea, writing a business plan and raising venture capital to fund the development and marketing of the product until the business becomes profitable. Universities are portrayed as having a major role in this process through the intellectual property arising from their research.

But in practice, the most successful UK science and technology-based companies, in terms of employment and sustained growth, tend to have pursued a much *softer* trajectory. *Soft start-ups* are based much more on the expertise of their founders, and seek to earn revenues from the start by selling consultancy and R&D contracts to larger companies and government organisations. The process of creating and marketing a standard product comes later.

As Britain's foremost high technology cluster, Cambridge provides a useful insight into the importance of these different models. Here the research shows that variants of the soft start up and R&D contracts for customers represent the dominant model behind its most successful firms. And, whilst companies benefit from being able to recruit talented Cambridge University alumni, very few of its most successful firms are based on university inventions. Instead, it is solving customer problems and developing technology to meet their needs from within a business environment that has provided the stimulus for innovation.

The same process can be seen elsewhere. Vodafone, the UK's most successful start-up since the Second World War, was created as a spin out from Racal, a soft start-up company built on wireless technology contracts for the MOD. Microsoft was a soft start up. So was Porsche

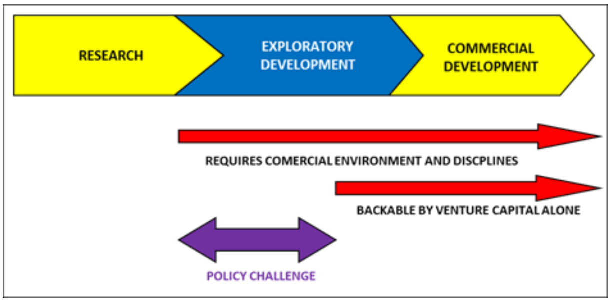
The pattern amongst VC funded start-ups based on university research is very different. Whilst such companies often receive a great deal of publicity based on the promise offered by the research when they first raise venture capital, very few go on to be successful commercially. Those that deliver a good return for their investors, usually through an early trade sale, rarely create many jobs.

When it comes to commercializing research, the most important opportunities are generally based on new *technology platforms,* with multiple commercial applications. In these situations, hard start-ups face a huge *Valley of Death*, the gap between starting a business and achieving high enough revenues to make it cash positive on a month to month basis.

To define and evaluate the different applications involves working with a range of potential users, in an exploratory manner, progressively focusing on those that look most promising. Blind alleys are common. Lead customers, prepared to pay for initial feasibility studies and the development and trialing of new technologies and products again play a crucial role.

To create the deep technological expertise, IP and core teams upon which a new business can be built, the *Exploratory Development Phase* must be undertaken, not in a university, but in a business orientated R&D environment, working to commercial standards and timetables.

The Three Phases in the Commercialisation of Research



In the UK the natural industrial partners in many areas of technology are foreign companies, who may have little inclination to commercialise here. So start-ups and small and medium sized UK companies have a particularly important economic role.

However, the risks associated with this phase are usually too large, and the timetables too long to attract venture capital, particularly as the financial returns delivered by UK funds have for many years been too low to attract investors. The challenge for policy makers is how to fill this funding gap in a way which maximizes the economic impact nationally and regionally.

Two successful policy responses to this dilemma are practiced in other countries. The first is for public sector agencies to fund development to demonstrator or prototype stage in companies. The second is to establish *Intermediate R&D Organisations (IROs),* largely funded by government and specifically designed to conduct the kind of mission orientated work needed during exploratory development.

Chapter 3. Innovation Policy Role Models and the US Procurement Based Innovation System

The US and Germany are the two most important innovation policy role models of relevance to the UK.

The principle way in which the German state supports innovation is through the 67 Fraunhofer

Institutes and research centres that undertake industrial R&D on behalf of industry. The Fraunhofer Institutes employ some 23,000 thousand people and are roughly 65 per cent funded by Government. In essence this provides a subsidy underpinning the R&D contracts the Institutes carry out for commercial customers. However, the Fraunhofer Institutes have so far been rather unsuccessful in spinning out new companies. So commercialisation of their IP takes place mainly through the many established German companies with which they work.

This is a model which works well in Germany because of what innovation economists call the *absorptive capacity* of the economy, in other words the strength of its existing industrial base across a wide range of science and engineering sectors. The UK's Catapult Centres are loosely based on the Fraunhofer model, though there is a question mark over how they will achieve their objective in the many sectors where the UK's industrial base is limited and its absorptive capacity is weak.

The UK's style of capitalism is much closer to the US model than it is to Germany's. But despite its free market credentials, the US Government plays a very active role in the national innovation system, much more so than the UK. It spends a very much higher proportion of GDP on R&D than the UK, 0.9 per cent, compared with 0.6 per cent in the UK, and this is focused much more on technology development as opposed to academic research. US universities absorb just 31 per cent of total US Government R&D expenditure compared with 46 per cent in the UK.

The difference is accounted for by three factors.

First, the US has a large network of government R&D laboratories, particularly covering defense, nuclear energy and space technologies.

Second, Federal agencies like Defense and Energy also use a network of not-for-profit R&D organisations, like SRI International and the Battelle Memorial Institute, to undertake large scale, early stage projects requiring a mixture of applied research and development.

Third, 25 percent of the Federal government R&D budget goes to private industry, compared with 19 per cent in the UK. Much of this expenditure relates to defence and security, but, like R&D programmes in government and not-for-profit labs, the technologies that emerge often open up civilian applications as well.

The most visible US policy to support innovation through procurement is the Small Business Innovation Research (SBIR) programme, first established in 1982. Underpinned by legislation, the US SBIR requires that all Federal agencies spend a defined percentage of their external R&D budgets with small businesses. Since its creation SBIR has awarded 100% funded R&D contracts worth nearly $40 billion. Today it provides around $2.5 billion a year in seed funding to start ups and small businesses. This is almost three times the value of seed investments by US venture capital firms.

The SBIR programme is just the first step on the procurement ladder for small science and technology-based firms. Larger R&D contracts are available through a variety of other mechanisms, and there are also significant opportunities for small businesses to participate as subcontractors on R&D projects led by larger companies. Through these mechanisms, early stage technology companies can receive significant levels of financial support from the US government.

A second well-defined US procurement based innovation programme is operated by the Defense Advanced Research Projects Agency. DARPA's mission is "*to prevent strategic surprise from negatively impacting US national security and create strategic surprise for US adversaries by maintaining the technological superiority of the US military*". It describes itself as the DoD's *"primary innovation engine".* Many of the projects it has funded have had later civil applications.

DARPA's flat, non-bureaucratic organisational model, and the entrepreneurial mechanisms through which it uses its $3 billion a year budget to fund longer term, larger projects, is also of relevance to the UK.

Chapter 4. The UK Small Business Research Initiative Today

Two early attempts to get SBRI established failed. It was relaunched in its current format, closely modelled on the US SBIR, in April 2009. Topics are announced at intervals during the year and the award process is aimed at being quick and unbureaucratic. Phase 1 contracts are worth £50-100k and Phase 2 contracts can be up to £1M. Though the expectation is that most will be at the upper end of the range.

SBRI competitions have so far been run by over 70 public sector bodies, and by March 2014 some 1,700 SBRI contracts had been awarded worth £189m in total. Tangible evidence is growing of the benefits the programme brings to both the companies awarded contracts and their public sector customers.

One of the most promising innovations funded by SBRI so far is the development of a treatment to prevent blindness amongst sufferers from diabetes and age related macular degeneration (AMD). PolyPhotonix, the company involved, is based at the National Centre for Printable Electronics in Sedgefield, County Durham, part of the TSB's Manufacturing Catapult. Unlike monthly injections directly into the eye, the main approach today, PolyPhotonix's treatment is non-invasive. It works by directing low levels of light, at a controlled wavelength, into a patient's eyes through a mask worn while sleeping.

Savings to the NHS are estimated at £1 billion per annum and the world market for PolyPhotonix' product, the *Noctura* 400 is thought to be worth several billion pounds a year.

A very different example is provided by Chichester based start-up, MOST (AV) Ltd. A National Environmental Research Council SBRI contract in 2012 enabled it to develop a prototype, unmanned, marine research vehicle capable of spending long periods in the high seas collecting data. As a result it has already secured two substantial orders for fully operational systems from UK and US customers. The technology developed also has much wider marine applications.

Responsibility for funding and managing SBRI competitions lies with spending departments like the NHS. Guidance and oversight is provided by a team at the Technology Strategy Board.[1] Over the last five years, it has done a laudable job in explaining the programme to government spending departments, helping them set up SBRI competitions and championing the philosophy. The value of contracts awarded has increased from around £22m a year in the first three years to £78m in 2013/14. Though this still falls short of the £100m spending commitment made by the Treasury and its £200m commitment for 2014/15 looks very problematic.

Despite the TSB's commitment to the SBRI programme it has faced considerable difficulty in persuading spending departments to participate. As a result, many early competitions were poorly funded and individual contracts were too small for companies to achieve much. Some departments are now awarding contracts in line with the SBRI model, but others have failed to engage with the programme.

The recent upward trend in overall SBRI spending looks very positive. But examining participation levels for individual departments reveals that many are either failing to participate at all or are struggling to match the level of funding to which the Treasury has committed them. Furthermore, some of the apparent growth is due to large, one-off competitions of a kind which are unlikely to be repeated, and which do not strictly fall within the SBRI template. So there has arguably been some over-reporting of true SBRI expenditure.

The Department of Health and the NHS have together been the most active participants in SBRI programmes since it was relaunched in 2009, with around 120 companies awarded contracts over the five years. NHS England is currently the only government department operating a rolling long-term programme, and the way it does so should be seen as a role model for other departments.

Its budget for 2014/15 is £20m, up from around £10m in 2013/14. However this is still only a third of the amount to which the Treasury has committed.

The Ministry of Defence is not currently participating in any meaningful way in the SBRI programme. In 2013/14 it reported £7.7m in SBRI contracts, 15 per cent of the Treasury commitment. At least a third of these were to universities, for which SBRI is not intended. Contracts averaged around £60k a project, barely enough to undertake a desk research study, and there have been virtually no Phase 2 awards in five years.

Defence provides one of the earliest applications for a whole range of new technologies involving the physical sciences – materials, electronics, software,

[1] The TSB has recently been rebranded as Innovate UK. The official and, at present, better known name is used in this report.

and engineering systems. The MOD's lack of engagement with SBRI today is seriously undermining the UK's ability to rebalance the economy by building new science and technology businesses.

The Department of Energy and Climate Change has run two SBRI competitions over the last five years. Contracts have been much larger than SBRI guidelines, but there is no ongoing programme and future spending is likely to be sporadic.

The Technology Strategy Board has itself been an important funder of SBRI competitions, especially in years when there has been political pressure to increase overall spending. Some of this has been co-funding to help the spending departments run competitions. Spending in 2013/14 was around £14m. TSB cannot itself play a lead customer role and does not expect its own spending to increase.

Since 2006, the UK Research Councils have had a policy of not participating in SBRI. The successful NERC competition described above is an exception.

Funding the development of new *Research Tools* to meet the needs of UK scientists as lead customers represents the easiest way to create new businesses around the UK's research assets. So the lack of participation in SBRI by most of the UK Research Councils represents a significant missed opportunity to boost economic development.

Other departments like the Home Office, DEFRA and the Department of Transport, for which the Treasury has quantified SBRI spending expectations, have made only occasional use of SBRI, and show little sign of trying to respond to the Chancellor's commitment.

Lack of participation by key departments and low levels of funding in others means that significant new steps will be needed if the Chancellor's spending commitments are to be realised. But before detailing these, it is important to try to understand why they have found it so difficult to find SBRI budgets.

Chapter 5. The Truth About UK Government R&D Spending and The Bigger UK Innovation Policy Picture

Concern about Britain's innovation performance goes back decades. As a percentage of GDP, total R&D spending declined from 2.4 per cent in 1981 to 1.8 per cent in 1996 and it has since fallen to 1.7 per cent. Reduced government expenditure accounts for most of this decline, and it has been particularly focused on spending with companies. In real terms there has been a 65 per cent decline since 1986: 54% per cent in civil R&D and 69 per cent in defence R&D.

So there is a strong argument to be made that the decline in government funded R&D has provided less exploratory R&D for companies to build on during the commercial phase of R&D, perhaps even increasing the tendency to innovate through acquisitions abroad.

Major spending departments, like the MOD, Health and Transport, which might, prime facie, be expected to be an important source of innovation contracts for business, have together reduced their R&D spending from two thirds of the total in 1986/7 to half in 2001/2 and a third in 2011/12. Furthermore detailed investigation shows that the official R&D spending statistics are in many cases overstated.

Office of National Statistics figures show MOD R&D expenditure falling by around 70 per cent in real terms over the last twenty-five years. Expenditure is now running at less than a third of levels in the 1980s. But an MOD analysis in 2005 showed that only 42% of reported R&D spending was directed towards *innovative science and technology solutions and technology development*. Reprioritisations forced by budget cuts since 2010 have resulted in the role of MOD R&D being even more heavily focused on support and advice, with virtually no effort to fund the development of longer term technologies. As a result, the MOD is now incapable of playing a meaningful role in the UK's national innovation system.

In contrast with the MOD, reported R&D expenditure by the Department of Health (including the NHS) has increased steadily, up from £575m in 1995/6 to £904m in 2012 in real terms. The NHS is responsible for over 95% of this spending through the National Institute of Health Research (NIHR). However, this is essentially a *research* organisation with a strong academic ethos. Nearly its entire budget is devoted to clinical research. Only one or two per cent of its budget is specifically devoted to the development of new technology, including through licensing NHS innovations to foreign companies.

The Department for International Development's reported R&D expenditure has grown from £57m in 1986 to £236m in 2011/12. However, most of DFID's *Research and Evidence* expenditure does not qualify as R&D under the Frascati definition. The 14% of its budget which is used to support product development is almost entirely spent overseas.

Like DFID, the Department for Environment, Food and Rural Affairs no longer refers to an R&D programme, but to an *Evidence Investment Strategy.* Its £161m budget is managed through 27 other agencies and partners so the details are hard to establish. DFID classes only 55% of its Research and Evidence budget as R&D, suggesting that official ONS figures are significantly overstated.

Reported R&D expenditures in the Department of Transport, Home Office and Department of Energy and Climate Change are around £30-40m each. Fragmented responsibilities mean that it is difficult to establish quite what is included, but it is unlikely that it is all R&D within the Frascati definition.

In contrast to the decline in R&D in most spending departments, since 1986 Research Council R&D expenditure [2] has increased from 28% of total Government R&D spending to 46% in 2002/3 and 60% in 2011/12. Most of this is of course focused on research to find out *how things work* and publication, rather than technology development.

The decline in reported R&D that has taken place in spending departments, and the shift in focus to academic research, policy studies and work that is not R&D at all, like support for procurement decisions, is one of the main reasons why they have been slow to take up SBRI.

It is also important to look at other ways in which government funds R&D in companies to assess whether they do the same job as SBRI and how cost effective they are generally.

The most costly of these is R&D tax credits. In 2012/13 R&D tax credits cost the Treasury £1.4 billion, roughly five times as much as much as the combined value of TSB grants and SBRI contracts to businesses over the same period

R&D tax credits have the benefit of not requiring choice, so there can be no criticism of *picking winners.* However they do not require any change in behaviour, and Britain's enthusiasm for them is not shared by many of the nations we regard as innovation role models. R&D tax credits are not offered by Germany, Sweden, Finland or Switzerland. And in the US, they are linked mainly to growth in companies' R&D spending.

Unlike SBRI, R&D tax credits can only cover a small proportion of an R&D project's costs. For most small companies, they do not provide enough to make a significant difference to their ability to innovate.

For this and other reasons they represent bad value for money.

The TSB, BIS's principal channel for funding business R&D, currently spends around £400m on R&D projects. Most of this goes on multi-partner collaborative grants linking companies to universities. SMEs receive about a third and must provide match funding. The much smaller *Grant for R&D* programme, aimed at SMEs, does not require collaboration, but grant values are much smaller than SBRI contracts and, again require match funding.

Chapter 6. Conclusions and Policy Implications

The decline in the UK's industrial base goes back many decades and successive governments have tried to increase national R&D spending without tangible results.

The rhetoric of UK innovation policy continues to place its emphasis on academic research and Silicon Valley style venture capital. The benefits to society, from our investment in research, and the benefits to international financial investors, through venture capital backed start-ups, have tended to be implicitly equated with benefits to the British economy.

Policy interventions have mainly been aimed at correcting *market failure* through supply side subsidies to business.

Innovation is fundamentally about problem solving, and most science and technology based products are sold to specialist users or system integrators within a complex supply chain. This means that innovative companies seeking to develop new products can only

[2] Including HEFCE funding

do so if customers define their requirements in detail. Second guessing rarely works. A paid R&D contract concentrates the minds of both, and can play a key role in getting new companies established.

For this reason, a nation can only ever be as innovative as its customers.

The best entrepreneurs want to retain their independence and grow a substantial business. These people are of a different breed to most of the professional managers who help venture capitalists build product lines to sell to established companies.

Some, like Bill Gates, Sir Richard Branson and Sir James Dyson start young and learn fast. They are often unbackable when they start in business. For others, the opportunity comes later, when the need to support a family and pay off a mortgage may make starting a business impractical.

So helping entrepreneurs without significant experience or capital to develop and test out their ideas with real customers is vital if we are to create businesses with a commitment to continuing growth in the UK, rather than temporary R&D subsidiaries for companies headquartered overseas.

The established mechanisms to encourage R&D, BIS grants and Treasury R&D tax credits, do little for such businesses. The amounts involved are insufficient to make a difference, and small firms often lack the financial resources to provide match funding. SBRI contracts are much more useful, providing 100% funding in amounts that are enough to make a difference. They also provide endorsement for further customers and partners, at both R&D and finished project stage, and for investors.

SBRI is also geographically agnostic. Companies in Penzance or Inverness have as good a chance of winning contracts as those in Oxford, Cambridge or Silicon Roundabout.

From the point of view of its customers, SBRI contracts harness new technology and creative individuals to develop solutions to intractable problems than can improve our public services and quality of life. In departments where SBRI is in operation, its success is already proven.

However, contrary to what official statistics suggest, funding technology development for their own benefit is no longer anything that UK government departments are engaged in to any significant or systematic degree. So extending SBRI across government will not happen without further measures to ensure that departments have the finance and organisations to do the job.

Chapter 7 Detailed Proposals for Putting Lead Customer R&D Contracts at the Centre of UK Innovation Policy

Increasing SBRI Commitments by Departments

To ensure that annual SBRI spending reaches the £200m figure to which the Treasury has committed it must identify specific departmental SBRI budgets and make it clear that this component of their overall budgets is non-transferable. It should also require departments to put in place rolling three year SBRI programmes, rather than allowing annual budgeting to disable the SBRI process. Total SBRI spending should be increased to £250m a year, a figure broadly in line with the US SBIR given the relative sizes of the economies.

The NHS SBRI management approach should be adopted by all departments, with balanced portfolios of R&D projects covering technologies and products that departments expect to buy and those which are needed to meet their broader policy objectives. Programmes should include developments with short times to market and higher risk projects with longer timescales.

A New Larger Innovation Contracts Programme

The Treasury should create an additional fund, the *Larger Innovation Contracts* programme for projects costing more than £1 million, SBRI Phase 3s and other ad hoc lead customer R&D contracts. Its annual budget should increase to £250m over four years.

Ministry of Defence

A *Mini-DARPA* should be created adopting key features of the US model. Its budget should increase to £200m a year over 4 years. Half of this would be for SBRI and half for larger innovation contracts including SBRI Phase 3s. It should involve people from across the industry with expertise at component, and subsystem level in specifying SBRI topics.

Research Councils

The Research Councils should re-introduce SBRI through a *Research Tools* programme covering new instruments, process equipment, software and consumables aimed at the research market. Like other SBRI's this should be aimed at companies, with scientists from the academic research community acting as lead customers.

The budget should be increased to £30m per annum over a three year period.

Interdepartmental SBRI Programme for IT and Digital

A new interdepartmental SBRI programme should be created for information technology and systems projects. It should be aimed at departments, like the Department of Work and Pensions, which are major users of IT, but for which a full scale SBRI programme might not be appropriate.

The budget for this programme should be increased to £30m over 4 years.

Role of The Technology Strategy Board

The TSB should continue to promote and coordinate the SBRI programme across government and it should produce an annual report on progress.

A condition of any SBRI contract should be that basic information is made publicly available through a separate TSB database, as in the US.

Role of Universities

SBRI is not designed for universities, which have substantial sources of research funding already. As in the US, award winners should be allowed to subcontract up to 35% of the value of a project to a university department.

An "SBRI" for Private Sector Lead Customers

A parallel programme to SBRI should be established to encourage more private sector organisations to act as lead customers for new technologies developed by SMEs. This should use TSB's collaborative R&D grant mechanism to fund bilateral partnerships between SME suppliers and large company customers.

The aim should be to increase funding to £100m a year.

Paying for the Changes

The balance of overall government R&D funding to businesses including innovation contracts like SBRI, grants and tax measures should be refocused to maximize its cost effectiveness.

The additional cost of the measures proposed rises to £600m in four years' time. To pay for this, the R&D tax credit should be restructured along the lines of its US equivalent, so that tax credits for larger companies are linked to growth in their R&D spending, rather than the absolute value.

A Change in Philosophy

For decades UK innovation policy has been aimed at increasing the **supply** of R&D in order to address what economists call *market failure*. It has tried to achieve this by increasing research funding in universities and by subsidising business R&D through grants and R&D tax credits. But when it comes to the early stages of trying to create and commercialise very innovative technologies, when there is still no clear idea of a product, and no market exist, the concept of market failure is largely irrelevant.

Since 2001, when government began a massive increase in expenditure on these subsidies through R&D tax credits, net UK business R&D expenditure[3] as a percentage of GDP has actually fallen by around 14%.

Clearly we need to adopt a different approach. Policies that create customer **demand** for innovation, as practiced extensively in the US, offer an important part of the answer.

[3] Business R&D expenditure net of R&D tax credits.

CREATING MARKETS FOR THINGS THAT DON'T EXIST

The Truth About UK Government R&D and How the Success of SBRI Points the Way to a New Innovation Policy to Help Bridge the Valley of Death and Rebalance the UK Economy

David Connell

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1. Introduction

Ten years ago, Anne Campbell, then MP for Cambridge and I launched a campaign to persuade the Government to introduce a radical new programme to foster the development of innovative products in small companies. The idea was very simple; namely that government departments and agencies could play a key role in building the high technology economy by funding the development of the products they themselves need as *lead customers*. In doing so they could help fill an important funding gap, obtain the technology they need quicker, reduce imports, give new firms the credibility they need to win export orders, and create jobs. Our aim was to replicate a highly successful US policy, the Small Business Innovation Research programme, that had been in operation for over thirty years, and which represents just one component of a procurement-based innovation system very different to UK policies.

We were by no means the first advocates of this approach in the UK. Indeed they included Lord Sainsbury, Minister for Science and Innovation at the time. His Small Business Research Initiative (SBRI) was launched in 2002 with a similar aim. However, the Department of Trade and Industry was unable to persuade any other UK government departments to adopt the measure, and apart from a few small-scale contracts awarded by one or two branches of DTI itself, the programme was a failure.

The US SBIR, worth at the time nearly $2 billion a year, had been enshrined in law since 1982, with each US government agency required to spend two and a half per-cent of its external R&D budgets through the programme. So the cornerstone of our campaign was a Private Members Bill designed to achieve a similar result.[4] This was supported by a 'White Paper' describing the rationale, an Early Day Motion to enlist cross party support from MPs and a series of meetings with Government Ministers and advisers in DTI and the Treasury.[5]

We argued that an effective US-style programme, funded at a level that mirrored the relative sizes of the UK and US economies, had the potential to transform the success rate of science and technology based start-ups and small companies. And we received wide support from senior individuals from across the enterprise, investment and university research communities.

By carefully studying EU Regulations on State Aids and Procurement we were able to refute the assertion by some officials that the approach we proposed would be illegal. Having achieved this, our proposals were widely regarded as a 'no-brainer' and within four months the principle, though not the legal underpinnings, was adopted by the Government of the day, with Gordon Brown, then Chancellor of the Exchequer, announcing that he would *"stimulate technology intensive companies with a guaranteed £100m share of public sector research contracts"* in his 2005 budget.[6]

It rapidly became clear that the plans to implement this announcement lacked teeth, and, once again this commitment failed to turn into reality, as individual government departments were allowed to report whatever they wished from their existing expenditure

[4] *Procurement of Innovative Technologies and Research Bill*, March 2005
[5] *Exploiting the UK's Science and Technology Base: How to Fill the Gaping Hole in UK Government Policy*, David Connell, with a Foreword by Anne Campbell MP, TTP Ventures, December 2004.
[6] *Budget speech* 16th March 2005

patterns against targets they themselves established. Within a year virtually all departments were claiming to exceed their targets, yet none was able to list any individual SBRI contracts awarded.[7]

Only in 2009 did a genuine US style programme get off the ground, after further political campaigning. This included a second Private Members Bill by Kitty Ussher MP[8] and a supporting letter published by the Financial Times and signed by leading figures from the business, venture capital and academic communities.[9]

Within government the 2009 version of SBRI was championed by Lord Sainsbury[10] and John Denham, Secretary of State for Industry, Universities and Skills. Its design was largely based on proposals made in a report by the author.[11] The name Small Business Research Initiative was retained, though it is really concerned with development rather than research, and large companies are eligible for awards, providing they involve high levels of innovation, typically with technologies or products outside the scope of their existing businesses.

Responsibility for implementing SBRI was given to The Technology Strategy Board. This had been spun out of DTI as an independent body in 2007 and, by 2009, was staffed largely with people from an industry rather than a civil service background. A key feature of the new SBRI approach was that only contracts resulting from competitions complying with SBRI guidelines, and promoted through the TSB website, could be included

Since then the TSB team has done a laudable job in explaining the programme to government spending departments, helping them set up SBRI competitions and championing the philosophy. The value of contracts awarded has increased from around £22M a year in the first three years to £78M in 2013. And tangible evidence is growing of the benefits SBRI brings to both the companies awarded contracts and their public sector customers.

However, persuading individual spending departments to commit funding to SBRI has been extremely difficult and the increase has only been achieved following the direct, personal intervention of the Prime Minister and Chancellor of the Exchequer.

In the March 2013 Budget, George Osborne, announced that SBRI expenditure would be increased to £100M in 2013-14 and £200M in 2014-15.[12] The overall commitment was broken down by key departments to make it easier to enforce.

If the Chancellors 2014-15 commitment can be achieved, SBRI spending will come close to matching the US programme given the relative sizes of the two economies. But to do so will require significant changes in approach within some departments.

This is because attempts to persuade them to introduce SBRI, and the research in this report, have revealed an almost complete lack of commitment by any Government department other than BIS to funding technology development of any kind. It appears that not only are reported government R&D figures low by the standards of our international competitors, but they also overstate the amount of real R&D undertaken. Much of what is claimed is focused on policy studies, academic research and procurement support rather than the development of the new technologies Government needs.

Furthermore, R&D expenditures are usually fragmented across different groups within departments, with little coordination and weak strategic management of the whole. So not surprisingly, the TSB has found it hard to find individuals with sufficient budgets or influence to run SBRI competitions. The problem has been exacerbated by spending cuts and the uncertainties and changes of responsibility that have accompanied them. And whilst the recent growth in SBRI expenditure looks encouraging, key departments, including the MOD, are not participating in any meaningful way.

[7] Over the next four years, a government website established to advertise forthcoming contracts to SMEs listed various *"SBRI Opportunities"*, including the supply of Chinese library books, lawnmower maintenance and academic research grants. None were for technology development open to businesses.

[8] *Procurement of Innovative Technologies and Research Bill* February 2006

[9] *Letter to Editor of Financial Times*, 19th December 2005

[10] *The Race to the Top, A Review of Government's Science and Innovation Policies*, Lord Sainsbury of Turville, October 2007

[11] *Secrets of the World's Largest Seed Capital Fund: How the United States Uses its Small Business Research (SBIR) Programme and Procurement Budgets to Support Small Technology Firms*, David Connell, Centre for Business Research, University of Cambridge, 2006.

[12] *Budget 2013,* HM Treasury.

This lack of commitment to genuine R&D in Government raises concerns that go far wider than SBRI and should be deeply disquieting to those interested in rebalancing the British economy.

SBRI now has strong endorsement from all the main political parties. The issues are not about party politics, but about how to harness the government machine as a whole to support the growth of science and technology based employment in the UK.

SBRI represents a radical approach to UK innovation policy. It borrows from one of the world's most successful innovation economies and it reinforces the way in which innovation works in practice. It enables Government to play an active role in industry policy by harnessing the competitive process, rather than trying to pick individual winners. In effect it is the same process that Sport England uses to prepare for the Olympics by investing around £80m a year in our most promising young athletes.[13]

The purpose of this report is to document what has been achieved, identify the challenges that remain and propose additional policies that will realize and extend the full potential of the SBRI approach.

But first it is necessary to explain why R&D contracts for customers play such an important role in the innovation economy, and why procurement based innovation policies like SBRI have so much to offer.

[13] *Sport England Annual Report and Financial Statements 2013-14*

2. The Role of R&D Contracts in Creating New Science and Technology Companies

Start-ups and small businesses have a special role to play in any industrial economy. According to the US Small Business Administration firms with less than 500 employees[14] generate 65 per cent of net new jobs, hire 43 per cent of high tech workers, and generate 31 per cent of US exports. They produce 16.5 times more patents per employee than large patenting firms.[15] These are statistics to which we should aspire in the UK.

Whilst large corporations are at any one time the dominant employers and responsible for most of a country's business R&D, their main objective is to maintain or expand their share of existing markets. And as their markets mature, cost pressures tend to squeeze out longer term investments to create radically new products. Most companies will only embark on a new projects, if top management are convinced that it will deliver a minimum annual revenue target - £100 million, £500 million or £1 billion depending on the company's size. Most innovations cannot offer that prospect at the start. The quote attributed to IBM's President, Thomas J. Watson in 1943 that *"I think there is a world market for maybe five computers"* is probably apocryphal, but there are many real and more recent parallels. Large companies also suffer from slow decision-making, risk aversion, *not-invented-here* and difficulty in stopping unpromising projects to release funding for new ones.

For these and many other reasons, big companies tend to be rather poor at innovation. And they are inherently slow at responding to discontinuities in their markets or technologies, and in reacting to new opportunities. Increasingly they rely on open innovation, acquiring technology from other organisations when they need it. Purchasing small science and technology-based firms whose products they can sell through their existing distribution channels is especially important.

"Hard Start-ups", "Soft Start–ups" and the Role of R&D Contracts

New science and technology-based firms start in a number of ways. The conventional wisdom is based around the idea of a team forming to commercialise an invention, scientific breakthrough or new product idea, writing a business plan and raising venture capital to fund the development and marketing of the product until the business becomes profitable.

This has become known as the *hard start-up model*, because the product idea is very well defined prior to raising venture capital. And it can be difficult to change it once the money has been raised. Universities are portrayed as playing a major role in this process through the intellectual property arising from their research.

A key challenge for the hard start up is crossing the *Valley of Death*, the gap between starting the business and achieving high enough revenues to make the business cash positive on a month to month basis.

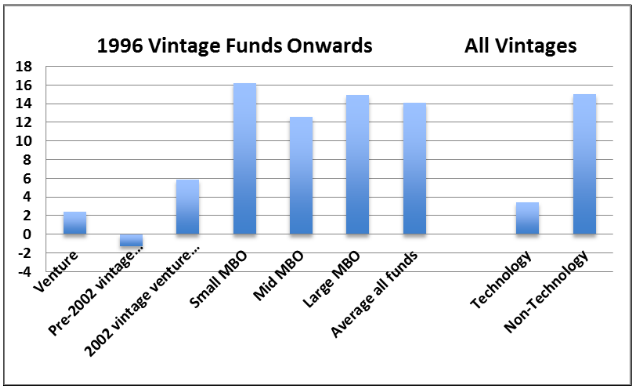
The width of the valley of death depends on the time and cost of developing the product and setting up production, and the time it takes for customers to evaluate the product, design it into their own products or business processes, and purchase it in volume. Both of these can bring long delays, high levels of uncertainty and periodic cash crises.

Though many hard start-ups are attempted, few achieve commercial success and those that do are usually sold to larger corporations relatively early in their development. More often than not, the entrepreneurial founders move on within a year. In the UK most acquirers are based overseas with the result that employment stops growing and closure may follow.

[14] The UK and EU defines small and medium sized firms (SMEs) as those employing less than 250 people. The US defines small firms as those employing less than 500.

[15] *Frequently Asked Questions*, US Small Business Administration Office of Advocacy. Data refer to a 17 year period.

Exhibit 1: Venture Capital Fund Returns Since Inception (Per Cent Per Annum)



Data published by the UK private equity industry shows just how unattractive venture capital is to investors as an asset class. Financial returns have consistently been much lower than other private equity asset classes, generally regarded as lower risk, like development capital and management buyouts. Apart from occasional short-lived speculative booms, offering mainly paper profits, average long run VC returns have been at most a few percentage points above inflation. For most of the last decade they have been negative. There has been some minor improvement recently, but at present there is no indication that UK venture capital will become an attractive asset class for the vast majority of financial investors.[16]

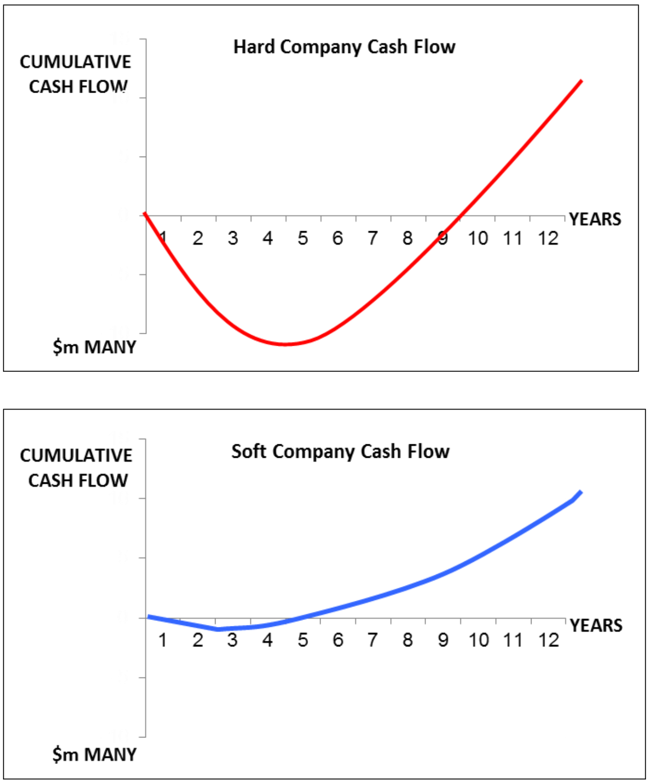
Not surprisingly, levels of VC investment are small, totaling only £166m in technology companies of all kinds in 2012, of which probably around a third is in the seed and start up stage. Medical equipment and pharmaceuticals received just £8m and £19m respectively.[17]

Even if venture capital backed businesses tended to remain in the UK, it does not represent an adequate, or sufficiently consistent, source of startup finance for innovative firms.

In contrast to the conventional wisdom, the most successful UK science and technology-based companies, in terms of employment and sustained growth, tend to have pursued a much *softer* trajectory.[18] *Soft start-ups* are based much more on the expertise of their founders, and seek to earn revenues from the start by selling consultancy and R&D contracts to larger companies and government organisations. The process of creating and marketing a standard product whose IP the company owns itself is delayed until risks – technical, market and financial are reduced and the most promising product opportunities become clearer.

Bootstrapping, as this process is sometimes called, is familiar to entrepreneurs in all areas of life. For science and technology companies, R&D contracts are the means of achieving this.

Exhibit 2: Hard and Soft Company Cash Flows



Of course some companies never make the transition, but remain R&D services businesses, usually with less growth potential than a successful product business.

A soft business can often structure its contracts around proprietary *platform technologies*, that is to say technologies or inventions with the potential to

[16] *BVCA Private Equity and Venture Capital Performance Measurement Survey* 2013
[17] *BVCA Private Equity and Venture Capital Report on Investment Activity* 2012

[18] The terms *hard start-up* and *soft start up* were originally adopted by a UK banker who specialised in the high technology sector in the UK. See *Academic Enterprise, Industrial Innovation and the Development of High Technology Financing in the United States*. Matthew Bullock, Brand Brothers, 1983.

support the creation of a range of possible products, processes, or applications. In this model, licensing and development contracts are negotiated with different customers, each interested in a different application. These provide revenues whilst contributing to advancing the generic technology. This strategy can be seen in businesses as diverse as digital printing and biotechnology. The Photobit, iRobot and PolyPhotonix case studies presented later in this report, all concern the commercialisation of platform technologies.

There may well be a small level of private investment at the start, and it may be sensible to raise larger amounts of venture capital later on to accelerate growth once the potential becomes clearer and the cost of capital is lower.

Entrepreneurs that pursue the soft start-up model have more freedom to continue developing and growing their business, rather than being forced into an early trade sale by their VC investors. As a result, successful soft start-ups, with their greater ability to generate employment and exports as they move into products, are inherently likely to be better for a national economy. This is especially true for an economy like the UK where strong, UK based companies are absent from many sectors of industry, so that trade sales are almost inevitably to overseas acquirers.

The soft start-up route is also more generally appropriate to founding teams who have neither strong enough business propositions nor personal track records to attract venture capital. Finding the *big opportunity* can come later, once they are more familiar with their technology and markets and they have learnt how to build and manage a business.

As Britain's foremost high technology cluster, Cambridge provides a useful insight into the importance of these different models.[19] Here the research shows that variants of the soft start up and R&D contracts for customers represent the dominant model behind its most successful firms.

Particularly important are a group of technology consultancies whose core business is developing new products and process equipment for third parties on a fee basis. Besides employing close to 2,000 people in their core service businesses, these have spawned a whole series of successful product businesses built on the intellectual property and technical competences they have generated.[20]

Cambridge Consultants, the longest established of the consultancies, has produced 20 spin-off companies over 25 years. The largest are Cambridge Silicon Radio plc. Domino Printing Sciences plc. and Xaar plc. all listed on the London Stock Exchange. Together they have combined annual revenues of £1.1 billion.[21] Venture capital played a key role in accelerating the growth of these businesses, but it was the incubation of both the technologies and the teams within the parent that made this possible.

Arm, the world's leading semiconductor IP business, and probably Cambridge's best known company, was created from an internal project for its parent Acorn Computers in the 1980's. Another early R&D customer was Apple. Today, its partners ship ten billion chips a year containing Arm IP.

The key role played by customer R&D contracts can be seen in many of Cambridge's most successful software companies.

An IT laboratory owned at different times by Olivetti, Oracle and later AT&T, and led for 16 years by Andy Hopper has produced a string of successful spin outs. Rather like the consultancies it worked by developing and trialing technologies with its parent companies as customer.[22] Andy Hopper now heads up the Computer Laboratory at the University of Cambridge, which was a prime source of the Olivetti/AT&T lab's recruits.[23]

Aveva a leading specialist industrial software business has its origins as the Government owned CAD Centre, a progenitor of the UK Catapult Centres, and projects carried out there for industrial customers.

[19] *Exploding the Myths of UK Innovation Policy: How "Soft Companies and R&D Contracts for Customers Drive the Growth of the Hi-Tech Economy*, David Connell and Jocelyn Probert. Centre for Business Research, University of Cambridge, February 2010.

[20] Connell and Probert, op.cit.

[21] Most recent annual accounts. In October 2014, the Board of CSR accepted a $2.5 billion acquisition offer from Qualcomm, the world's number one mobile semiconductor company.

[22] Connell and Probert, op.cit.

[23] Connell and Probert, op.cit.

Autonomy, now part of HP (Hewlett Packard) was spun out of Neurodynamics, a soft start-up founded by Mike Lynch. Neither raised venture capital. [24]

The soft start up model has also played a key role in the development of Cambridge's computer games sector.[25]

And Cambridge Antibody Technologies, the UK's most successful biotech business, now as Medimmune part of Astra Zeneca, was also essentially a soft-start, having been unable to raise venture capital to commercialise its antibody platform technology in the UK. Antibody based drugs have since become one of the most important areas of development for the global pharmaceutical industry.

All of these companies have benefited from being able to recruit talented scientists and engineers who were Cambridge University alumni. But with the exception of CAT, none of these companies are based on university inventions. Instead, it is solving customer problems and developing technology to meet their needs from within a business environment that has provided the stimulus for innovation.

This pattern is not restricted to Cambridge. Wolfson Microelectronics plc. in Edinburgh and one of Scotland's most successful new technology firms, is a soft start.[26] So is Andor Technology in Belfast and Oxford Instruments.

Sir James Dyson also adopted a soft start to create his domestic appliance business, having experienced the disadvantages of venture capital in a previous start up. Funding for the development of his cyclone based bagless vacuum cleaner came from his savings and "*front money"* paid by established domestic appliance manufacturers who contracted him to develop vacuum cleaners to sell under their own brands.[27] It was revenues from these companies which enabled him to go on to manufacture and market his own product whilst retaining control. Today Dyson Ltd remains a highly profitable, privately owned business with annual revenues of £6 billion and a strong commitment to investing in innovation in the UK

Vodafone, the UK's most successful start-up since the Second World War, was created as a spin out from Racal, a soft start-up company built on wireless technology contracts for the MOD.

And the soft start-up model is not just limited to the UK. Microsoft was a soft start, only moving into products after providing an operating system for IBM's new Personal Computer and negotiating a contract which enabled it to retain IP rights and sell to other customers. This helped create the PC clone market on which Microsoft's success was built.

Though Intel was venture backed, the single chip processor which made it successful was developed under contract for Busicom, a Japanese calculator company. Under pressure financially, Busicom negotiated a reduction in the invoice for the chip's development in exchange for granting Intel the rights to sell it outside the calculator sector. It later went bankrupt.[28]

Porsche was a soft start.[29] So was SAP, Europe's largest software company.[30]

Of course, venture capital has played a key role in the success of some of the world's best known, high technology ventures – like Google, Facebook, Amazon and PayPal. And some of these were founded by university student entrepreneurs. But these were generally software and internet applications of existing technology using novel business models or algorithms, rather than being based on scientific breakthroughs. So the time to market was short and the risks were principally around speed and effectiveness of execution. The same could be said of many of the software and computer hardware firms that typified previous high technology booms. Each new generation of semiconductors offers similar opportunities for entrepreneurial fast movers.

The pattern amongst VC funded start-ups based on university research is very different. Whilst such companies often receive a great deal of publicity based on the promise apparently offered by the research when they first raise venture capital, very

[24] A replacement capital investment was made by VCs prior to Autonomy's IPO.
[25] Connell and Probert, op.cit
[26] Interview with David Milne, Wolfson Microelectronics cofounder and Chief Executive until 2008.
[27] *Against the Odds*, James Dyson, Thomson 2002

[28] *The Microprocessor turns 40: Intel's Monumental Accident*, Forbes Magazine, November 2011
[29] *Porsche AG historical Background 1948-2007*, Porsche corporate website
[30] *1972-81, The Early Years*, SAP corporate website.

few achieve profitability. Plastic Logic Ltd, once one of Cambridge's flagship technology companies, with huge media coverage over many years, has raised $500m since it was started in 2000. Though it continues to carry out ground breaking exploratory development on plastic electronic based devices, in May 2012 it announced it was abandoning plans to manufacture its own e-reader devices, focusing instead on licensing the existing technology. Annual revenues in 2012 were less than £300k.[31]

Those that deliver a successful return for their investors rarely deliver many jobs. Solexa, probably the most successful start-up based on Cambridge University IP over the last 25 years, was sold in 2007 for £400m, returning ten times the money invested to its VC's. The product it produced went on to underpin most of the $1.4 billion revenues of its San Diego acquirer, Illumina. However, after acquisition, the role of the 170 strong Solexa team in Cambridge was limited to R&D.

The obsession by policy makers, politicians and the media with venture capital backed university research spin-outs has reinforced the tendency towards *technology push* innovation policies to which the UK has long been prone.[32] The evidence shows clearly that *demand pull* innovation, based on R&D contracts for lead customers, is at least as important and probably much more so. Unlike the UK, US innovation policies are largely based around this concept.

Challenges of Commercialising Academic R&D

In recent years, a good deal of emphasis has been placed on trying to modify the university model to make it easier to spin out companies. Alongside the strengthening of university technology transfer offices, academics have been encouraged to work more closely with companies in the research they undertake. However, a unique EPSRC funded study, carried out by the author, Dr Andrea Mina and Professor Alan Hughes has helped understand better the weaknesses of this approach.[33] The study involved tracking in real time over 5 years a family of materials and engineering research projects for which substantial EPSRC funding had been provided to try to encourage partnerships with industry and accelerate commercialisation.[34] It showed that whilst such an approach can help stimulate research collaborations, there remain major difficulties in trying to accelerate commercialisation within a conventional university research setting:

(i) Most externally funded research projects in universities are undertaken by teams staffed by PhD students and post-docs who tend to move on quickly. As a result it is very hard to retain competence in depth or build the core technology team required to create a spin out business. This is exacerbated by the dominance of short term grants and employment contracts

(ii) The time that must be devoted to writing publications, teaching, supervisions and giving papers at academic conferences means that R&D during a pre-venture stage can only be advanced in fits and starts

(iii) IP is often not managed throughout a project. Past leakages of various kinds and competitor positions may only become apparent when commercialisation is being considered. The problem is particularly acute for the long lead-time technologies which typify much academic research, as there may be an accumulation of IP over successive projects involving many different individuals and corporate partners.

(iv) The pressure on academics to collaborate with industry, coupled with frequent changes in the graduate students and post-docs on whom they rely for lab work, means that exploitation rights are not always properly thought through or managed over

[31] *Plastic Logic to Shut US Operations*, Financial Times 16th May 2012 and annual accounts. The best vehicle for commercializing the founders' platform technology would almost certainly have been through a Catapult type of vehicle, permitting a slower and more exploratory approach. Neither this, nor SBRI, was an option at the time, forcing the founders to pursue a hard start-up strategy with the inevitable pressure to focus on a single application too early.

[32] *Innovation policy as cargo cult: Myth and reality in knowledge-led productivity growth*, Alan Hughes, in *Creating Wealth from Knowledge. Meeting the innovation challenge*, eds. J. Bessant, J. and T. Venables, Edward Elgar, Cheltenham.

[33] The work was undertaken as part of a £6.5m EPSRC grant to the Cambridge Integrated Knowledge Centre between 2007 and 2012

[34] *The Role of TICs in Rejuvenating British Industry; Submission to House of Commons Committee on Science and Technology Enquiry on Technology Innovation Centres Submission to House of Lords Enquiry on Technology Innovation Centres*, December 2010 David Connell, Professor Alan Hughes and Dr Andrea Mina, Centre for Business Research, Judge Business School, University of Cambridge.

the long term. Poorly negotiated agreements with industrial sponsors can restrict the potential for later spin-offs or licensing deals.

(v) It is very difficult to accelerate the pace of R&D prior to the stage when a technology becomes ripe for exploitation. As a result any competitive advantage can be eroded at this critical stage.

(vi) Universities are not normally equipped with the expertise or resources to take technologies to the demonstrator stage required to attract investment or customer interest

The Cambridge technology consultancies, which might be expected to provide the natural partners for academics wishing to exploit their IP, all report repeated failures in their attempts to engage with the university's academics to commercialise their research.

It is difficult to see how these issues could be addressed within a conventional UK university research setting.

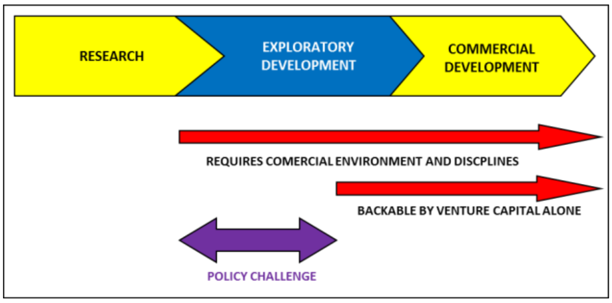
The challenge for innovation policy is compounded in the UK because in many areas of technology the natural industry collaborators are foreign companies with little inclination to commercialise in the UK. Start-ups, rather than joint development agreements and licensing must therefore play a disproportionate role if there is to be significant economic benefit to the UK.

The Commercialisation Process and Industry Differences

The process by which research is converted into businesses and jobs is unpredictable and non-linear, but it can usefully be divided into the three broad phases shown below.

The initial, *Research Phase* is typically carried out in universities, and sometimes in government funded laboratories and the laboratories of large corporations. It typically concludes with the discovery of a new material, phenomenon, device, process, algorithm or methodology and a laboratory proof of principle demonstration.

Exhibit 3: The Three Phases in the Commercialisation of Research



The final *Commercial Development Phase* encompasses the work of completing the development of commercial products and bringing them to market. This is the domain of companies – particularly start-ups, together with new ventures within existing companies.

By this point, new companies are usually in competition with others addressing the same customer need, and the size and homogeneity of the US market means that companies based there can grow revenues much more quickly than UK firms. This enables them to spend more on R&D and marketing as markets mature, and to make acquisitions earlier to consolidate their position. The time taken to make the first sale is a critical factor in how successful a firm is ultimately, as this makes it easier to close every subsequent sale, as well as to attract investment to accelerate growth. Policies to encourage lead customers therefore have an important role to play in reducing the width of the *Valley of Death.*

In between the *Research* and *Commercial Development* phases is the process of *Exploratory Development*, during which potential applications of the research are conceived, demonstrated, turned into prototype products and trialed with lead customers.

In the case of software and some information technology hardware this process can be quite short as there is minimal technical risk. Facebook, Google and Cisco, formed by undergraduates, doctoral students and university computer services managers respectively, illustrate this. In each case successful, large-scale product demonstrators, involving real, university users, were produced in just a few months.

The venture capital backing that enabled these businesses to be scaled up rapidly followed.

However, in the case of the physical and biological sciences, the exploratory development phase can take years or decades. The most important opportunities are generally based on new *technology platforms,* with multiple commercial applications. To define and evaluate them involves working with a range of potential users, in an exploratory manner, progressively focusing on those that look most promising. Blind alleys are common. Lead customers, prepared to pay for initial feasibility studies and the development and trialing of new technologies and products again play a crucial role.

Often the first applications are in specialised high value markets like defence, research tools, and even TV or the movies. As the technology gets cheaper and better, other high volume applications become accessible. The US firms iRobot and Photobit, described in Chapter 4, both illustrate this process.

In the UK the volume semiconductor companies Cambridge Silicon Radio and Wolfson Microelectronics in Edinburgh both have their origins in teams undertaking specialist chip development projects for the MOD.

The long-term development of technological expertise and IP that takes place through these early projects for customers can lead to unexpected opportunities. The team and IP that created Domino Printing Sciences was built on the back of a Cambridge Consultants' project for ICI aimed at printing digitally on fabric. At its peak this project employed nearly a quarter of CCL's staff. [35] A couple of years after ICI decided to axe the project, the introduction of food product date stamping regulations opened up a much less challenging market.

PolyPhotonix, described in Chapter 4, was set up to commercialise organic light emitting diode technology in lighting; using it to treat age and diabetes related blindness was not on the radar, and would never have been pursued if it had not been for a customer contract from the NHS.

To create the deep technological expertise, IP and core teams upon which a new business can be built, the Exploratory Development Phase must be undertaken, not in a university, but in a business orientated R&D environment, working to commercial standards and timetables. Careful management of IP and commercialisation rights is essential. However, the risks associated with this phase are usually too large, and the timetables too long to attract either venture capital or corporate backing.

The challenge for policy makers is how to fill this funding gap, sometimes described as the *Valley of Death* in a way which maximizes the economic impact nationally and locally.

Two successful policy responses to this dilemma are practiced in other countries.

The first is for public sector agencies to fund the development of demonstrators as lead customers, based on their own requirements for innovative technologies as users or specifiers. This is the US model and enables start-ups and other innovative companies to operate more easily during the exploratory development phase.

The second approach is to construct R&D institutions specifically designed to conduct the kind of mission orientated work needed during exploratory development. These are typically not-for-profit organisations funded through a mixture of public and private sector R&D contracts, sometimes with some core government funding. Examples include the 67 German Fraunhofer Institutes, VTT in Finland, ITRI in Taiwan and a diverse range of US organisations, including Battelle and SRI International, originally the Stanford Research Institute[36]. The UK's *Catapult Centres*, introduced from 2010, are based largely on the Fraunhofer model.

The Cambridge technology consultancies operate in a very similar way to the Fraunhofer Institutes on which the Technology Strategy Board's new Catapult Centres are based, but with two differences. First, the Cambridge consultancies have had little or no

[35] *The Emergence and Development of the Cambridge Ink Jet Printing Industry* Garnsey E, Stam E, Thomas B. (2010), in Fornahl, D., Hen S., Menzel M., *Emerging Clusers, Theoretical, Empirical and Political Perspectives on the Initial Stage of Cluster Evolution,* Edward Elgar, Cheltenham, UK and *Funding Breakthrough Technology: Case Study on Inkjet Printing*, Jonny Thompson, Centre for Business Research, University of Cambridge 2009

[36] *Models of Technology Development in Intermediate Research Organisations,* Andrea Mina, David Connell and Alan Hughes, Centre for Business Research, University of Cambridge, 2009.

government funding. They have therefore tended to operate closer to market. Much less investment is available for funding the development of platform technologies or product concepts to the point when a paid contract can be signed with a customer. Second, they have been much more successful than the Fraunhofer Institutes in generating jobs in product spin-out companies.[37] Indeed, most other IROs seem also to have been rather ineffective at creating spun-out companies based on their IP.[38]

Government innovation policy has much to learn from these businesses. To be successful Intermediate Research Laboratories like the Catapults also need contracts from informed lead customers, just as early stage private sector R&D companies do. So, on its own, Catapult Centres may not provide a complete solution. The PolyPhotonix story shows how both the Catapult model and SBRI programme can complement one another.

[37] *The Role of TICs in Rejuvenating British Industry; Submission to House of Commons Committee on Science and Technology Enquiry on Technology Innovation Centres Submission to House of Lords Enquiry on Technology Innovation Centres*, December 2010 David Connell, Professor Alan Hughes and Dr Andrea Mina**,** Centre for Business Research, Judge Business School, University of Cambridge.

[38] ITRI in Taiwan is an exception, but its most successful spin outs, like TSMC are based on licensing in technology as part of a catch-up strategy. Apart from Intuitive Surgical and Siri, SRI has been fairly unsuccessful in spinning out successful companies.

3. Innovation Policy Role Models and the US Procurement Based Innovation System

The US and German Innovation Systems

Amongst role models for a UK industrial renaissance, the US and Germany are without doubt the two most important. Both have high wage costs, high levels of investment in R&D and vigorous science and engineering sectors. Of course both economies are also much larger than the UK, in the case of the US, around seven times as big, and this conveys scale advantages both in terms of government spending and the size of their home markets. This, together with the strength of their industries, means they have many more large companies than the UK capable of placing R&D contracts with SME's as lead customers or acting as system integrators to provide them with indirect access to global markets.

The US and Germany economies also embody very different styles of capitalism. The German model has provided much more stability, with takeovers less common and a style of governance and banking industry that allows longer-term planning and investment. At the same time Germany is also less entrepreneurial. People tend to stay with employers longer and start-ups tend to be seen as difficult and less attractive. The principle way in which the state supports innovation is through the 67 Fraunhofer Institutes and research centres that undertake industrial R&D on behalf of industry. The Fraunhofer Institutes employ some 23,000 thousand people and it is 65 per cent funded by Government. [39] In essence this provides a subsidy underpinning the R&D contracts that they carry out for commercial customers. However, they have so far been rather unsuccessful in spinning out new companies. So commercialisation of their IP takes place mainly through the many established German companies with which they work.

This is a model which works well because of what innovation economists call the *absorptive capacity* of the German economy, in other words the strength of its existing industrial base across a wide range of science and engineering sectors. The UK's Catapult Centres are loosely based on the Fraunhofer model, though there is a question mark over how they will achieve their objective in the many sectors where the UK's industrial base is limited and its *absorptive capacity* is weak.

The US economy operates in a very different way. It is the free market economy par excellence, with quarterly reporting and a range of aggressive investment institutions driving a vigorous market for mergers and acquisitions and a high level of short termism. People change jobs easily and *starting your own business* is the goal of many young Americans. Failure is tolerated and there is a long history of investing in start-ups by both individuals and venture capital firms. The UK's style of capitalism is much close to the US model than it is to Germany's.

But despite its free market credentials, the US Government plays a very active role in the national innovation system, much more so than the UK. In a recent book Mariana Mazzucato paints a detailed picture of how the US Federal Government has financed mission driven technologies across a wide range of industries, and how by putting large amounts of money into highly challenging projects with long gestation times it has helped US industry establish leadership positions.[40]

However, the key lesson from the US innovation system is not the proportion of GDP that the government commits to R&D, and which the UK would find hard to match. Rather it is the proportion of US government R&D spending that goes into exploratory development, particularly in companies, capable of developing real products, rather than academic research institutes focused on publication, together with the use of 100% funded contracts. These are provided in amounts that are large enough to make a difference, in stark contrast with the UK tradition of providing small scale grants requiring match funding, usually involving collaborations with academic institutions, and which are frequently rather artificial.

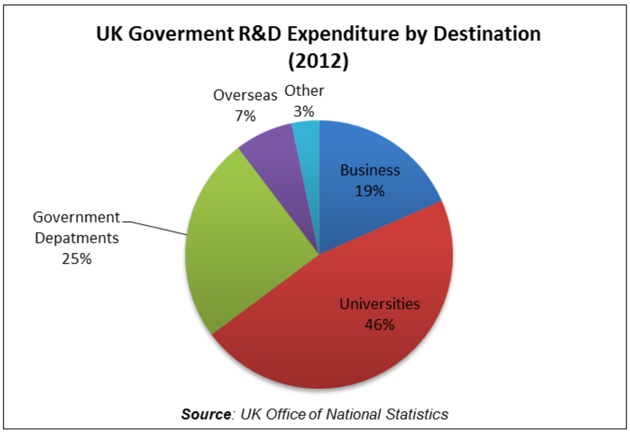
[39] Fraunhofer Gesellschaft publications and interviews carried out by the author.

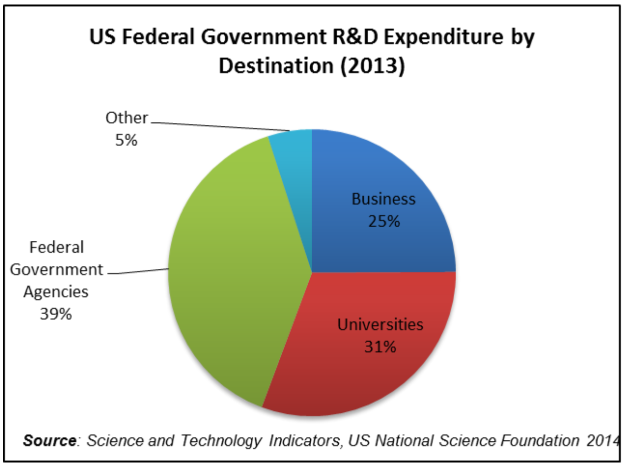
[40] *The Entrepreneurial State*, Mariana Mazzucato, Anthem Press 2013.

US Federal Government R&D Spending

The US Government spends a very much higher proportion of GDP on R&D than the UK. 0.9 per cent compared with 0.6 per cent in the UK. Spending is also much more focused on technology development rather than academic research. This is illustrated in Exhibit 4, which shows that US universities absorb just 24% of total US Government R&D expenditure compared with nearly twice as much in the UK.

Exhibit 4: US and UK Government R&D Expenditure by Performing Sector





The difference is accounted for by three factors.

First, the US Government maintains a large network of Government R&D laboratories, particularly covering defense, nuclear energy and space technologies. They include such famous names as Lawrence Berkeley, Los Alamos, Sandia, Lawrence Livermore, Argonne, Oak Ridge and the Jet Propulsion Laboratory. A 1995 report identified 720 government laboratories, employing 100,000 people.[41] The number has reduced since then, but the Federal laboratories still represent a huge commitment to mission oriented R&D, with flow-through benefits in terms of expertise and technology into the broader economy.

Second, Federal agencies like Defense and Energy also use a network of not-for-profit R&D organisations to undertake large scale, early stage projects requiring a mixture of applied research and development. Two of the best known are SRI International, originally set up as part of Stanford University, and the Battelle Memorial Institution, which developed the Xerox photocopier. Many of the technologies developed are dual use, with civilian applications emerging later when costs are reduced. SRI spin-offs include Intuitive Surgical, the world's leading robotic surgery company, and Siri, whose speech recognition technology was bought by Apple to power the iPhone.[42]

The nearest equivalent to these independent not-for-profit labs in the UK is the emerging network of Catapults.

Third, and most significant in terms of Federal R&D expenditure is R&D contracts with private sector companies. These play a major role in developing and implementing the technologies the US Government believes will be needed in the future. Much of this expenditure relates to defence and security, and the technologies involved are often difficult to develop, with lengthy gestation times before they can be applied in real applications. But, like those emerging from government and not for profit labs, they often open up civilian applications as well as defence uses.

[41] *Technology Transfer Systems in the United States and Germany*, Ed. H. Norman Abramson et al National Academy of Engineering, Washington 1997

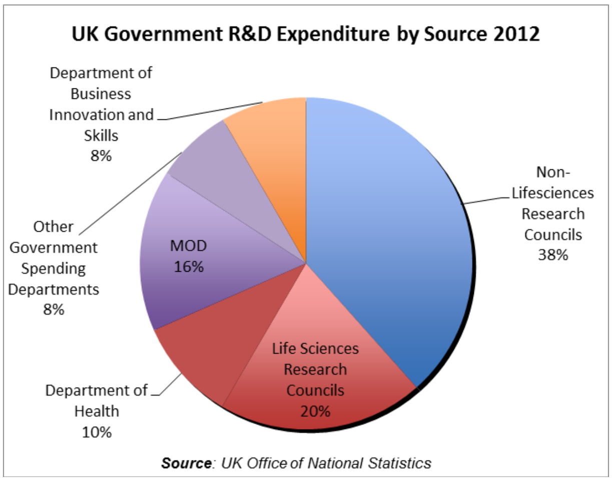
[42] Both Intuitive and Siri have their origins in Department of Defense funded projects at SRI. The R&D behind Intuitive was originally aimed at allowing surgeons based in the US to carry our automated surgery on wounded soldiers in war zones. Instead Intuitive focused on pinhole surgery in a normal hospital environment, using automation to give surgeons much higher levels of precision. This was a much easier challenge and Intuitive grew rapidly. Revenues in 2013 were $2.3 billion. Siri has its origins in an ambitious DARPA funded speech technology project. The aim of *CALO* was to develop a *Cognitive Assistant that Learns and Organizes* for soldiers in the field. Siri was acquired by Apple in 2010 and is incorporated in the iPhone. SRI continues to undertake projects on automated battlefield surgery and speech technology for the DoD.

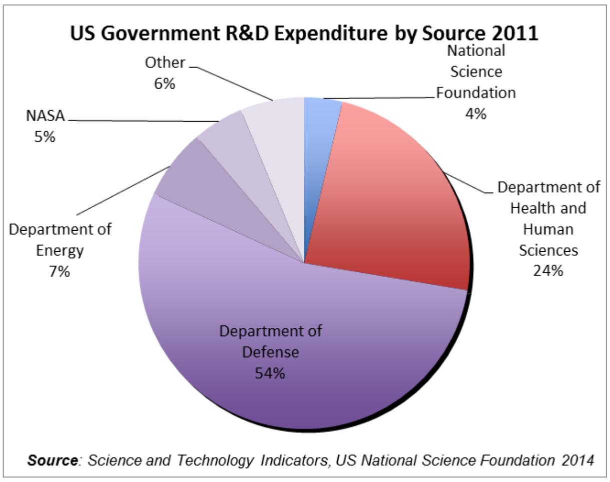
A quarter of the Federal government R&D budget goes to private industry, compared with 19 per cent in the UK.

The two main systematic programmes through which the US government funds innovative R&D in companies are described later in this chapter.

These differences mean that a much higher proportion of US government R&D funding goes into mission driven, exploratory development than in the UK.

Exhibit 5: UK and US Government R&D Expenditure by Source





Analysing Government R&D expenditure by source provides further insights into the differences between the two innovation systems. Exhibit 5 shows the dominance of Research Council funding in the UK. The Research Councils are responsible for nearly twice as large a share of Government R&D funding as their US equivalents (the National Science Foundation and National Institutes of Health[43]). The ratio is even greater in the engineering and physical sciences – probably around 10 to 1. Instead it is Defense, Energy and NASA which dominate R&D spending in the US.

Federal Funding of Universities

Exhibit 4 showed that only 31 per cent of US government R&D funding goes into the university sector, roughly two thirds of the percentage in the UK. But the source of this funding is also very different. Federal agencies with operational roles play a key part in funding research in US universities. For example, only 30 per cent of MIT's $670 million in annual research funding comes from the equivalent of the Research Councils - the National Science Foundation and National Institutes of Health, while some 40 per cent comes from other Federal Agencies like the Department of Defense, Department of Energy and NASA.[44]

Whilst this is partly a result of history and academic excellence is still a key criteria for projects, there can be little doubt that it leads to a greater focus on government customer needs rather than pure curiosity driven research. And this can lead over time to the creation of intermediate R&D organisations with a technology development rather than academic research orientation.

Today MIT gets around 19 per cent of its R&D funding from the Department of Defense, and it hosts a small, specialised, defence research centre, the Institute for Soldier Nanotechnologies. But MIT's involvement with defence was much closer in the past. During the Second World War and the early stages of the Cold war, MIT spawned a series of independent defence R&D organisations.[45] These were focused, not on research, but on developing and implementing technologies the DoD needed. They include the Lincoln Laboratory whose work on air defense led to the creation of Digital Equipment Corporation, which pioneered the mini computer.

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[43] NIH R&D represents by far the largest part of total R&D spending by the US Department of Health and Human Sciences. The NIH is broadly equivalent to the UK's MRC together with some MRC and BBSRC programmes.

[44] *MIT Facts* 2014

[45] They include the Lincoln Laboratory together with its spin-offs Mitre Corporation and Noblis, and the Draper Laboratory. Student protests during the Vietnam War led to MIT's defence research labs being spun out as separate R&D organisations during the 1970s.

Today the Lincoln Laboratory has over 3000 employees working predominantly on defence and security technologies. MIT still has a close relationship with the Lab, which it manages at arms-length on behalf of the Department of Defense. The Lincoln Laboratory and the other independent defence R&D labs that MIT helped create, mean that it is surrounded by organisations with the capacity to develop and implement new technologies for customers, in this case mainly government agencies, complementing MIT's role as one of the world's leading research universities.

Interestingly there is a parallel to be found in Cambridge in the UK. TWI, previously the Welding Institute started life as a university research group working on ways of raising shipbuilding productivity during World War 2. It was spun out as the British Welding Research Association in 1946 to help aid economic recovery. Today it employs nearly 1000 staff and has revenues of nearly £600m, much of it derived from overseas.[46]

US Small Business Innovation Research Programme

Whilst academic excellence and the thirst for new knowledge is highly valued and well-funded in the US, Federal Government R&D funding is primarily geared to meeting its need for innovation, as a potential user and to achieve its policy goals. Private companies are seen as playing a critical role in delivering these innovations with Government funding. The principal mechanism for doing so is through procurement.

The most visible US policy to support innovation through procurement is the Small Business Innovation Research (SBIR) programme. This was established under legislation enacted in 1982 and was expanded in scope through subsequent legislation in 1988 and 1992. It has played a major role in funding early stage US science and technology companies.[47]

The SBIR legislation requires that all Federal agencies with R&D expenditures over $100m spend a defined percentage of their external R&D budgets with small businesses through the phased SBIR process. The percentage was gradually increased to 2.5%, where it remained for 15 years until 2010. Since then is has been increased further and will rise to 3.2% by 2017.

An additional 0.4% is set aside for the closely related Small Business Technology Transfer programme, in which businesses partner with a university or research institute.

Since its creation SBIR has provided nearly $40 billion in innovation funding for start-ups and small businesses. Together with STTR it is currently providing around $2.5 billion a year in seed funding. This compares with total seed investments by US VC funds of around $900m in 2013.[48] *Phase III* SBRI funding adds perhaps another $2 billion or more.

The way in which the SBIR programme is structured and managed is an important reason for its success. Key elements are as follows:

(i) Agencies advertise topics (solicitations) in groups, typically twice a year; each topic relates to an agency's requirements for new technology, either for its own use or to meet its broader objectives. Only majority US owned for-profit businesses are eligible and the R&D must be undertaken in the US.

(ii) Awards are made on a competitive basis in two phases:
   i. *Phase I*, typically $150k for a feasibility study,
   ii. *Phase II*, typically $1m for development of a demonstrator, awarded to roughly 50 per cent of Phase 1 winners

(iii) SBIR projects that subsequently receive government funding from non-SBIR budgets are defined as entering Phase III.

(iv) SBIR awards cover 100 per cent of firms' project costs plus a profit element; this is especially important for cash-strapped smaller firms, for which grants that fund only a percentage of project costs, as in the UK, are insufficient to get new projects underway.

(v) There is no requirement for collaboration with any other organisation, unlike the majority of UK and EU programmes.

(vi) Companies own any IP generated.

[46] Connell and Probert, op. cit.

[47] *"Secrets" of the World's Largest Seed Capital Fund: How the United States Government Uses its Small Business Innovation Research (SBIR) Programme and Procurement Budgets to Support Small Technology Firms;* David Connell, Centre for Business Research, University of Cambridge, July 2006.

[48] *National Venture Capital Association Yearbook*, 2014.

(vii) Companies can apply for and win multiple awards for different projects, in sequence or in parallel. This is common practice.

(viii) There is complete transparency in terms of information on solicitations, timescales, award winners and contract values, all of which is detailed on public web sites. The legislation requires that the process is timely and efficient.

The majority of SBIR award winners employ less than 25 people, though firms with up to 500 employees, including NASDAQ listed companies, can also win contracts.

The SBIR programme is just the first step on the procurement ladder for small science and technology-based firms. Larger R&D contracts, particularly from the Department of Defense, are available through Broad Area Announcements (BAAs) and other mechanisms. There are opportunities for small businesses to participate, either directly, or as a subcontractor to a larger firm.[49]

Through these mechanisms, early stage US firms can receive significant levels of financial support from the government.

Each agency operates SBIR in a slightly different way, and the National Institutes of Health and National Science Foundation designate awards as *grants,* rather than procurement *contracts*. This reflects greater openness to company ideas rather than tightly specified requirements. It should be noted that the term *grant* does not carry the same connotations as it would in the UK. (Under EU State Aids rules, a *grant* to fund 100 per cent of a firm's project costs would be illegal). In fact, even where SBIR *grants* are awarded, they are for directed research and development and therefore represent procurement contracts in all but name.

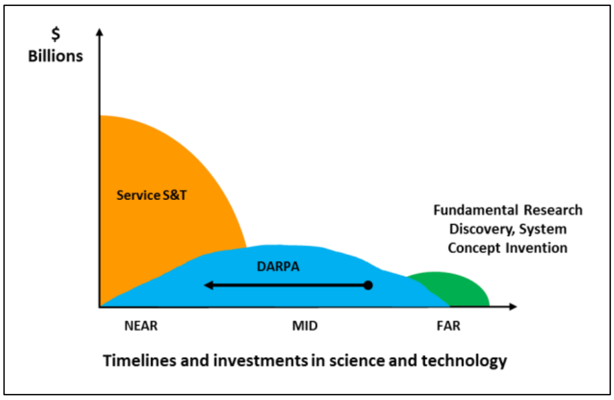
The US SBIR programme has been endorsed by Congressional committees and independent reviewers at intervals throughout its 32 year history, and is highly regarded by government agencies, entrepreneurs and policy makers.[50]

Defense Advanced Research Projects Agency

A second well-defined US procurement based innovation programme is that operated by the Defense Advanced Research Projects Agency (DARPA).

Originally set up in 1958 in response to the launch of Sputnik by the Soviet Union, DARPA's mission today is "*to prevent strategic surprise from negatively impacting US national security and create strategic surprise for US adversaries by maintaining the technological superiority of the US military*". DARPA describes itself as the DoD's *"primary innovation engine".*

Exhibit 6: DARPA's Position in the Innovation Process



Whilst DARPA's focus in on the needs of its *"customers"* within operational branches of the DoD like the Army and Navy, the sweep of technologies and applications in which it is interested is very broad, ranging from the manufacture of titanium to the production of artificial blood. Many have civilian applications, or at least lead on to them.

[49] There are typically some 50 pages of BAA announcements on the FedBizOpps.gov website, representing around 500 separate R&D opportunities.

[50] See *"Secrets" of the World's Largest Seed Capital Fund*"; op.cit. and also *"An Assessment of the SBIR Programme",* ed. Charles W. Wessner, National Research Council of the National Academies, Washington 2008.

Photobit: from Missile Testing to Camera Phones

Photobit Technology Corporation was founded by Dr Eric Fossum and associates from NASA's Jet Propulsion Laboratory in 1995 to commercialise the CMOS image sensor technology he had invented there as a programme manager.

Photobit's early development was largely funded through government R&D contracts. These included an SBIR contract from the US Army to develop high-resolution, high speed image sensors for recording test missile launches, and other SBIR awards from DARPA, NASA, the US Navy and the Ballistic Missile Defence Organisation.

As the power of the technology increased it became increasingly used in a range of commercial applications. Photobit's non-defence contracts included industrial machine vision, high-speed scientific imaging, a pill-camera for medical imaging, and animation systems for motion pictures, television and video games. Cameras using its technology were used in several Hollywood films, including *Star Wars Episode II.*

By 2000 Photobit had annual revenues of $20M, and further improvements in performance and reductions in manufacturing costs had begun to open up opportunities for volume applications in digital cameras and mobile phones. As a result, the company was able to attract a $26M venture capital investment from Intel, Hitachi and Basler A.G. The following year, Micron Technology Inc. a major specialist US semiconductor company, acquired Photobit to enable it to enter this fast growing market.

"I am a strong advocate of the US SBIR programme as I think there need to be channels other than traditional venture capital to seed new technology businesses. SBIR awards help companies that wouldn't otherwise attract venture capital funding because they have a slow growth profile, or a niche market appeal.

"They help entrepreneurs because they allow more 'self-start' and less dilution for the founders of such companies. But they are also very helpful to the government on many levels, seeding businesses that are developing technologies useful to government agencies – and, often, to us all."

Professor Eric Fossum, Thayer School of Engineering, Dartmouth College

Whilst DARPA's focus in on the needs of its *"customers"* within operational branches of the DoD like the Army and Navy, the sweep of technologies and applications in which it is interested is very broad, ranging from the manufacture of titanium to the production of artificial blood. Many have civilian applications, or at least lead on to them.

DARPA's flat, non-bureaucratic organisational model, and the entrepreneurial mechanisms through which it uses its $3 billion a year budget to fund projects, are of particular relevance to the UK. It includes the following important elements.

(i) It recruits programme managers who are leading experts in their field of technology on three plus two year contracts and allows them to design programmes, bid internally for DARPA funds to run these programmes, and manage individual projects on a quasi-venture capital basis.
(ii) Funding for individual projects is usually awarded competitively in phases. A typical Phase 1 might involve two teams in competition, each receiving $2m, followed in Phase 2 by a $20m contract awarded to single, possibly restructured team. Subcontractors and consultants, including any university academics, are accountable to the lead contractor, rather than individually to DARPA, as would be the case in most EU and TSB collaborative projects.
(iii) Intermediate deliverables are tightly specified in terms of testable, and usually quantified, functional targets.
(iv) Lead contractors are normally companies or not-for-profit IROs like SRI.
(v) Projects are monitored closely, typically with weekly conference calls between the DARPA programme manager and the prime contractor and six monthly face-to-face progress meetings involving the whole team. Projects can be terminated at any time.

As with the SBIR programme, this *weeding out* process focuses funding on the best projects, helping to address the important challenge facing all R&D organisations – how to terminate weak projects to make funding available for new ones. But the management style is much more proactive and in many ways similar to a hands-on venture capital investor or highly engaged commercial customer. This approach improves the quality and speed of project delivery.

DARPA projects focus on very demanding technologies and the goals they set for contractors are tightly specified and measurable, both at intermediate and final stages.

Occasionally UK companies get involved in DARPA projects as subcontractors. One such is TAPBiosystems, an automated cell biology equipment company, which received significant DARPA funding as part of a project to make artificial blood for battlefield medicine. As the TAPBiosystems project manager explains: *"Unlike TSB, DARPA is a customer; they want our company's output".*

iRobot; From Bomb Disposal to Floor Cleaning

iRobot Corporation was founded in 1990 by Colin Angle and Helen Greiner who had studied together at MIT's Artificial Intelligence Laboratory. After a year or two in industry they teamed up with Rodney Brooks, the academic who led and continued to head the Laboratory, to found the company. Initially based in Angle's apartment, funding came from personal credit cards and $100,000 in bank loans.

For the first 12 years iRobot undertook a range of development projects for different customers and built many different products without achieving financial success. Its initial product (Ghenghis) was a $3,000 robot designed for university researchers. Some of its parts were built in MIT's machine shop.

The company's first big government contract was in 1993 and entailed developing an underwater minesweeper for the Office of Naval Research. This enabled iRobot to scale up its operations. It also took on industrial contracts, including developing a robot to make repairs in oil well bore holes several miles underground. However, for the first ten years, the bulk of the business remained focused on developing products for the military.

A key breakthrough was when it won a DARPA contract to develop the iRobot PackBot, a mobile robot for reconnaissance, surveillance and bomb disposal tasks. PackBot was used at the site of the World Trade Center in the aftermath of 9/11 and was deployed with US troops in the field from 2002.

Contracts were the mainstay of iRobot's funding until 1998 when it raised $1.5m of external capital, followed by a further five rounds of investment and an IPO in 2005. By this time the total investment raised was $34m, but the soft start-up model ensured that founders, directors and management still owned two-thirds of the company's shares.

Alongside its defence contracts, iRobot began to develop consumer and industrial robots that could be sold in higher volumes. Its first floor-cleaning robot, Roomba, was launched in 2002, and within two years it was deriving 75 per cent of its $95m annual revenues from consumer products.

Overall revenues in 2009 were $298m, 37 per cent of which came from the US Federal Government, and the company made a profit of $3m. It had been only marginally profitable since IPO.

iRobot has always been a beneficiary of government R&D contracts. Between 2001 and 2009 it won at least nineteen separate SBIR awards from the DOD, totaling $8.6m.

As the company grew larger, mainstream (i.e. non SBIR) R&D contracts became more important. Between 2007 and 2009 it received $65M in Government R&D contracts. Only 40 per cent of its total R&D spending was funded out of revenues.

By 2014 iRobot employed 528 people and had become much more oriented to consumer products, which were now responsible for 88 per cent of its $487m revenues. Altogether it has sold over 10 million home floor-cleaning robots and has launched pool cleaning and gutter cleaning robots. It has also become a much more global business, with exports accounting for some 60 per cent of sales.

R&D expenditures remain high at $64m, with 15 per cent of this expenditure covered by development contracts, mainly for the Federal Government.[51]

iRobot fully acknowledges the benefits to its broader business of its Government R&D contracts.

"We leverage our research and development across all of our products and markets. For example, we use technological expertise developed through government-funded research and development projects across our other product development efforts…This strategy helps us in avoiding the need to start each robot project from scratch, developing robots in a cost-effective manner and minimizing time to market........We retain ownership of patents and know-how and are generally free to develop other commercial products, including consumer and industrial products, utilizing the technologies developed during these projects".

[51] iRobot 10-K Annual Reports

4. The UK Small Business Research Initiative Today

How it Works

After a small-scale pilot involving the Department of Health and the Ministry of Defence, the SBRI was relaunched in its new format in April 2009. From this point onwards the objective has been to model it closely on the US SBIR. Topics are announced at intervals during the year and the award process is aimed at being quick and non-bureaucratic.

The original plan was to set funding parameters closely in line with the US, but the Technology Strategy Board has allowed these to be treated flexibly, mainly to reflect pressure on spending department budgets, but partly also to enable SBRI to be used for the kinds of project for which it was not originally intended.

Today, TSB guidelines state that Phase 1 contracts should be in the range £50-100k and Phase 2 contracts should be up to £1M, although most projects are expected to require the upper end of these ranges in both Phase 1 and Phase 2. Awards take the form of fixed price contracts and are expected to cover 100 per cent of costs. In practice, if projects are successful, most award winners are expected to continue with funding from customers, partners or their own resources beyond Phase 2, or to raise investment on the back of the progress and endorsement which SBRI brings.

As in the US the company keeps the IP.

SBRI is run under EU rules for *Pre Commercial Procurement*. These were codified in 2006 to encourage member states to adopt programmes like the US SBIR. Organisations of all sizes, and from anywhere in the EU are eligible to apply for SBRI contracts, though it is regarded as more appropriate for SMEs or occasionally for high risk new ventures within larger companies. In practice only around one per cent of contracts have been let to non-UK organisations, reflecting the importance of a close relationship with the UK customer, but also the importance of government being able to access the best technology from wherever it comes.

Responsibility for funding and managing SBRI competitions lies with the funding department. The TSB's role is to provide guidance and oversight, and to promote competitions to as broad a range of UK companies as possible.

Since 2009, the TSB has recruited a small and committed SBRI team, mainly from industry. And it operates a tightly run marketing programme to engage spending departments as well as public sector agencies, like the Environment Agency and Food Standards Agency, for which they are responsible. Where necessary it provides both technical and management support to help them run SBRI competitions.

Alongside the departments at which SBRI is primarily aimed, TSB has also used the SBRI model to fund some of its own programmes, alongside its more traditional collaborative R&D grant mechanism. This enables it to fund 100 per cent of an SME's costs. Under EU State Aid Regulations, 100% funding of R&D in businesses is not possible using grants.

Progress so Far

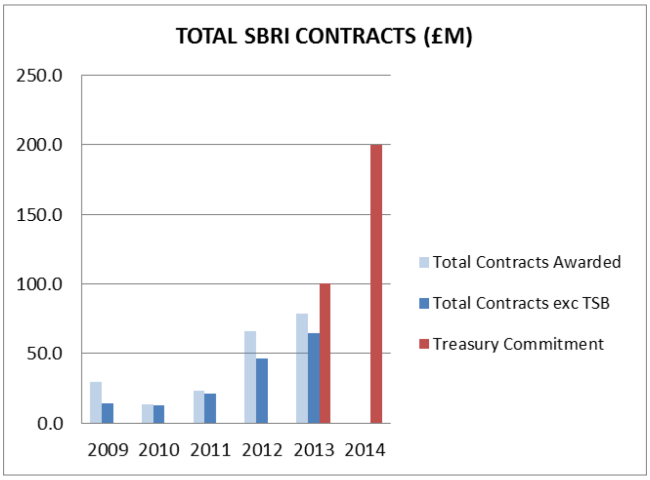
Despite the TSB's commitment to the SBRI programme it has faced considerable difficulty in persuading individual departments to commit to it financially. This is not because the key people in departments responsible for R&D have been unable see the value of SBRI, but because their R&D budgets are small, fragmented and committed to ongoing research activities.

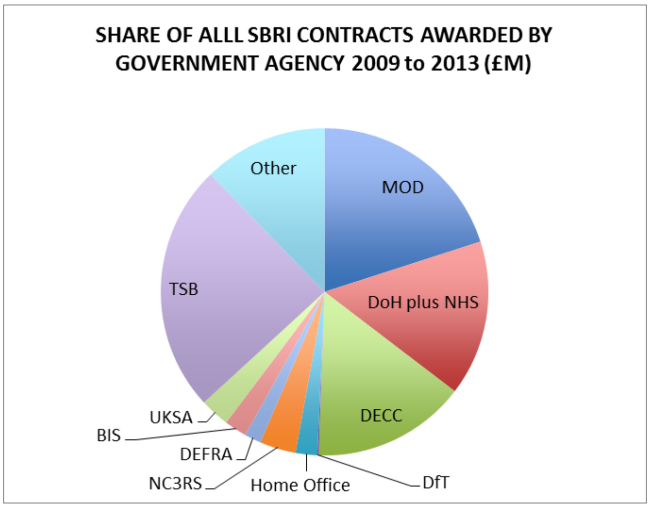
As a result, many early competitions were poorly funded and individual contracts were too small for companies to achieve much. Many competitions did not progress beyond Phase 1. To help get programmes started the TSB co-funded some early competitions. It continues to do so occasionally.

Despite this, competitions have so far been run by over 70 public sectors bodies and by the March 2014 some 1,700 SBRI contracts had been awarded worth £190M in total.

Exhibit 7 shows the total value of SBRI contracts awarded each year since the programme was launched in 2009, together with the expenditure to which the Treasury committed in the April 2013 budget. It also shows the overall breakdown by department during the 5-year period.

Exhibit 7: Total Value of SBRI Contracts Awarded Per Annum and Breakdown by Government Department or Agency [52]





The average size of Phase 1 awards has increased from £39k in the first year of the programme to £77k in 2013. Phase 2 awards averaged around £180k in 2010 increasing to £460k in 2013.

One of the most promising innovations funded by SBRI so far is PolyPhotonix Ltd's development of a treatment for two of the most common forms of blindness in the western world; Diabetic Retinopathy and Macular Degeneration, the former a disease caused by blindness and the latter a symptom of ageing. Together these two diseases affect over half a million people in the UK and the numbers are growing rapidly.

The associated healthcare costs are currently estimated by the Royal National Institute for the Blind to be around £500m annually with as much again in public sector social care costs.[53] Current treatments are expensive and highly invasive, involving either laser photocoagulation or intra-ocular injections directly into the eye. In contrast, PolyPhotonix's treatment is much less expensive and non-invasive. It works by shining low levels of carefully controlled light into patients' eyes through a mask worn while sleeping.

PolyPhotonix was set up in 2008 to commercialise organic light emitting diode (OLED) technology in general lighting, automotive and design applications. It is based at, and closely associated with, the Centre for Process Innovation in Sedgefield, County Durham, now, part of the High Value Manufacturing Catapult. CPI has had some £30m in Government investment to create world-class prototyping and manufacturing facilities for thin film processing and other techniques for printing electronic devices. This collaboration provided the ideal facilities for a young high-tech company working in this field and also bought credibility with investors.

By 2009, PolyPhotonix' founder, Richard Kirk was looking for applications that were less demanding technically and offered better margins than lighting, and he reviewed a number of potential medical

[52] The analysis of SBRI expenditure in this Chapter is based on data provided by the Technology Strategy Board

[53] *Future Sight Loss (2) : An epidemiological and economic model for sight loss in the decade 2010 -2020*, Darwin Minassian and Angela Reidy, Royal National Institute for the Blind, 2009

applications. After a conversation with a research ophthalmologist who had studied the link between light and hypoxia in the retina during dark adaptation at night, Richard decided that the company should put significant efforts into developing the *Noctura 400* sleep mask, the first of a number of new medical products on which PolyPhotonix is working.

NHS East awarded PolyPhotonix its first £100k SBRI contract in 2012. Since then it has won a £480k Phase 2 award and a £ 1 million Phase 3 award.

In 2012, a clinical study was carried out in the Czech Republic with severely diabetic patients whose sight had already deteriorated to the point where they were registered blind. This showed remarkable results, with significant visual acuity improvement recorded in many of the patients and halting of disease progression in many others.

The Noctura 400 was launched for limited sales in September 2014 and PolyPhotonix is working closely with the NHS for eventual NICE approval, anticipated in 2015.

In the meantime, a large scale Phase 3 clinical trial is being led by Moorefields Eye Hospital. This targets early onset patients rather than those already suffering severe sight loss.

The combination of an entrepreneurial champion and the Manufacturing Catapult providing the *supply side* of this project and the NHS providing the *demand side*, through SBRI, offers many important lessons for innovation policy. The project would never have got off the ground without these elements combining to provide *a market for things, like Noctura, that don't exist*. The Appendix carries a more detailed case study.

> *"The biggest impact of SBRI funding has been in accelerating the commercial side of the business and to considerably increase the pace of activity within the NHS."*
>
> *Richard Kirk, Chief Executive, PolyPhotonix*

A very different example comes from an SBRI competition by the National Environment Research Council (NERC) in 2012. This was for companies to develop high-endurance unmanned marine surface vehicles that could use new sensor technology to gather data from the oceans. The requirement was for these vessels to operate autonomously for several months at a time. One of the winners was MOST (AV) Ltd, a small company set up by an experienced skipper alongside a small marine technology development and consulting firm, founded by senior ex-MOD naval engineers. Their £50k Phase 1 and £400k Phase 2 contracts were enough to take them *"three-quarters"* of the way to a fully commercial product, and this was followed by two contracts to deliver fully operational systems to Texas A&M University and the UK's National Oceanographic Centre. MOST's current AutoNaut is a specialised research tool, but a key feature is that it converts wave and hull motion directly into propulsive thrust, giving it very long endurance at sea with zero emissions. This has applications throughout the marine world.

NERC and the MOD are jointly running a follow on SBRI competition in 2014 to develop an *autonomous ocean sampling network* with even more ambitious goals.

> *"The SBRI scheme has been hugely helpful. It enabled us to take several quite big steps towards production and allowed us to launch ourselves in to the market. We wouldn't be where we are now without it."*
>
> *Mike Poole – Founder of MOST (AV)*

Participation by Key Departments and the Challenges Ahead

The upward trend in overall SBRI spending looks very positive. But examining participation levels for individual departments (See Exhibit 8) reveals that many are either failing to participate at all or are struggling to match the level of funding to which the Treasury has committed. Furthermore, some of the apparent growth is due to individual competitions of a kind which are unlikely to be repeated.

Meanwhile, the TSB has itself played an important role in funding competitions. As it is neither a customer nor a setter of government policies requiring new technology, this is not what was intended. In any event TSB SBRI funding is unlikely to increase, so further growth in the SBRI programme must come from the spending departments at whom it is primarily directed.

There are also some competitions, which, though laudable in themselves, are not strictly compliant with the SBRI model, leading to some over-reporting of true SBRI expenditure. A closer analysis by key departments is therefore required.

Department of Health and NHS

The NHS has been the subjects of frequent complaints regarding its openness to innovation and its procurement processes. As Dr Andy Richards, one of the UK's leading bioscience and healthcare technology angel investors, said in evidence to the House of Commons Committee on Science and Technology, *"any business plan, business model or business idea that* says*, 'the first thing we are going to do is sell into the NHS', just makes it uninvestable".*[54]

Recognising the major contribution that it could make to the UK's economic development, the NHS has made a significant commitment over the last three years to addressing this problem, and SBRI has been endorsed as a key part of the solution.[55]

The Department of Health and the NHS have together been one of the most active participants in SBRI programmes since 2009. In total around 120 companies have been awarded SBRI contracts, roughly ten per cent of those applying.

The National Institute of Health, part of the Department of Health, ran two of the first pilot SBRI competitions, prior to the national relaunch in 2009. Their aim was to develop technologies to reduce the transmission of infections like MRSA in hospitals. The total budget for these competitions was £5m.

Preventable Hospital Associated Infections cost the NHS around £4.5 billion a year. One of the 2009 award winners, Veraz Ltd.'s *Green Badge* technology received a further SBRI contract to support the trial and adoption of its product within the NHS in 2014.

> *"One opportunity for the NHS to support economic growth is by ensuring that the innovative products we need are developed and grown at home, and to NHS specified need. The SBRI does exactly that. The SBRI programme is still quite new, but the early signs are good, and early evidence suggests the NHS gets a good return on its investment – we are creating jobs, strong businesses and bringing new solutions to solve NHS challenges."*
>
> *Sir Bruce Keogh, NHS England Medical Director*[56]

One of the key pioneers of SBRI was the East of England Strategic Health Authority, where a team of local champions from within and outside the NHS, came together to create the programme and drive implementation forward. Funding for NHS East's first SBRI was raised from a variety of sources including the NHS, Technology Strategy Board and European Regional Development Fund. The first three competitions, held in 2009, had a total budget of just £2.5m. Funding remained limited for the next four years and whilst the NHS East was one of the first programmes to stick closely to the true SBRI model, the values of individual Phase 2 contracts were less than ideal.

Several other Regional Health Authorities went on to establish their own small-scale SBRI programmes, but individual contracts were too small to be compliant with SBRI guidelines or to make a real difference to the companies that were awarded them.

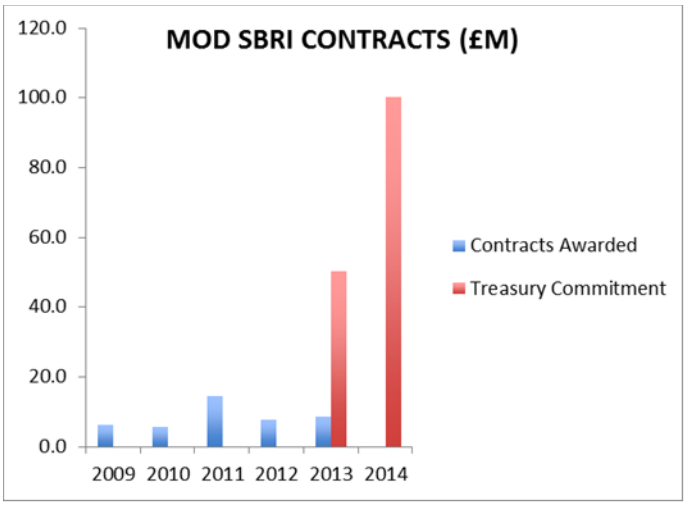
The original NHS East team, led by Karen Livingstone, is now responsible for managing NHS England's national programme, with an expenditure budget of £20m for 2014/15, up from around £10m in 2013/14. Spending by the Department of Health will add around another £8m. This compares with a Treasury expectation that Health would contribute £60m per annum to overall SBRI spending of £200m.

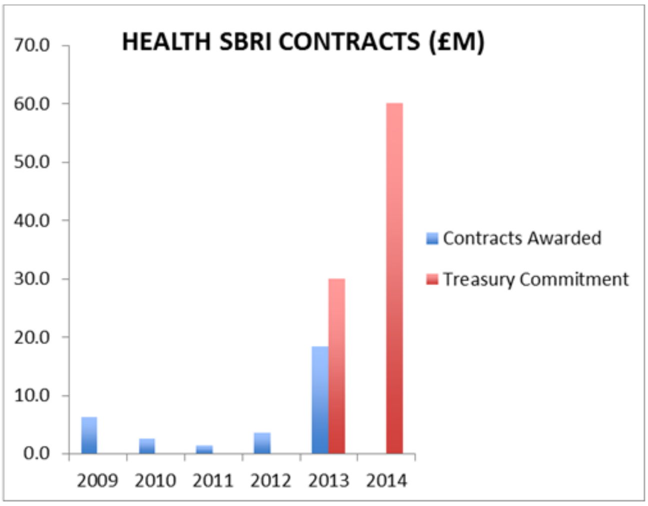
[54] Dr Andy Richards, Oral evidence taken before the House of Commons Science and Technology Committee Inquiry on Bridging *the Valley of Death: Improving the Commercialisation of Research,* Wednesday 18 April 2012.

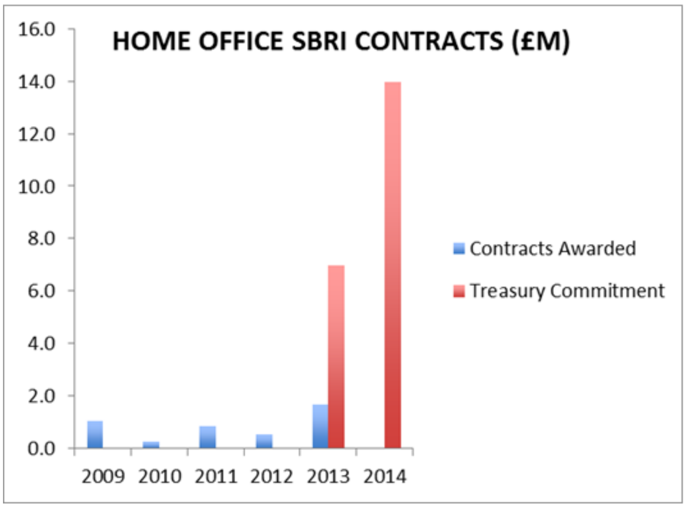
[55] See *Innovation Health and Wealth, Accelerating Adoption and Diffusion in the NHS,* NHS 2011.

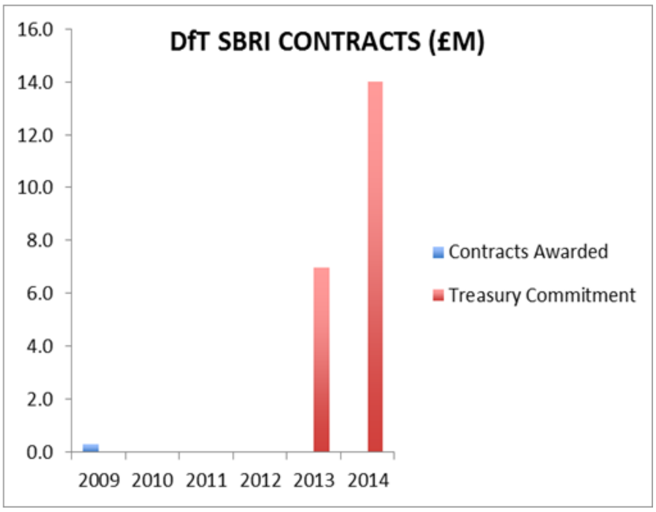
[56] *Health Service Journal* 7 November 2014

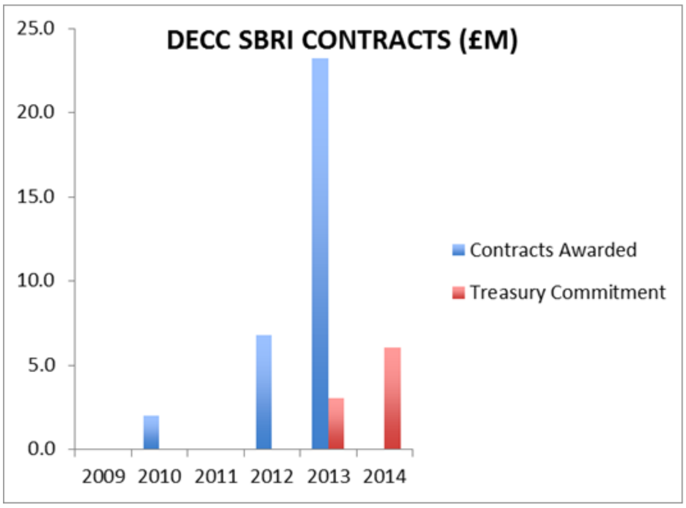
Exhibit 8: Value of Departmental SBRI Contracts and Treasury Commitments

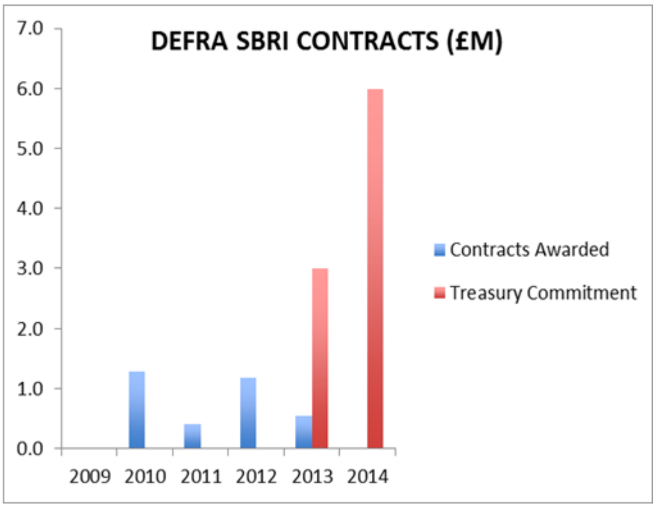












As for other government departments, converting the Treasury commitment into an agreed budget has been a major headache, as SBRI has to compete for funding within the NHS with a wide range of better understood activities every year.

Furthermore, financial management has been complicated by SBRI budgets not being decided until well into the financial year and uncertainties about whether contracts can be awarded for expenditure extending over more than a one year period. Restrictions imposed by the NHS have become more severe in the last two years. As each SBRI competitions triggers spending over a three year period, this is in danger of leading to programme inefficiencies.

The DoH has no plans to run SBRI competitions in 2015/16 and the NHS England SBRI team do not know if their budget will be axed or increased to meet the Chancellor's spending commitment.

These matters need to be resolved.

Despite these difficulties, the enthusiastic NHS SBRI management team, and the many clinical specialists around the UK that support them, continue to fund a steady stream of competitions addressing major NHS challenges. And through the phased SBRI model a growing group of promising young companies are emerging with products that the NHS wants AND the potential to become serious players in the world health technology market.

The Ministry of Defence

The MOD's SBRI programme is the responsibility of the Centre for Defence Enterprise, which was set up in 2008 as part of the MOD's Defence Science and Technology Laboratory.

CDE was designed to provide an open access portal for innovators outside the traditional defence industry, particularly SMEs. On average since then it has awarded 140 contracts totalling less than £9m a year, 44 per cent to SME's and most of the rest to universities.[57] . Most of these contracts are described by CDE as SBRI awards.

[57] Presentation by Dr Andy Nicholson, Head of CDE, September 2014.

Though MOD can argue that it has awarded more SBRI contracts than any other agency, the average value of reported MOD Phase 1's is only £64k and between a third and half of these have been awarded to universities, for which the SBRI is not intended. It has run virtually no Phase 2 competitions. Its contracts may provide enough to carry out desk research or simple experiments, but they provide nowhere enough to make any significant progress in developing new technologies or products.

So the reality is that the MOD is not currently participating in any meaningful way in the SBRI programme. Reported SBRI expenditure is running at only 10 to 15 per cent of the amount to which the Treasury committed.

Defence provides one of the earliest applications for a whole range of new technologies involving the physical sciences – materials, electronics, software, and engineering systems. The critical role that US Department of Defense funded R&D has played in the development of a wide range of non-defence industries in the US is well documented. [58] The UK's MOD has played a similar role in the past – in semiconductors, telecommunications and civil aviation.

Its lack of engagement with SBRI today is seriously undermining the UK's potential to build new businesses in many areas of science and engineering. A solution to this problem is proposed in Chapter 6.

Department of Energy and Climate Change

DECC has run two SBRI competitions over the last five years, the most recent being to demonstrate energy storage technologies that can address grid-scale storage and balancing. Contracts have been much larger than SBRI guidelines, with eight companies awarded around £0.5m each for Phase 1 and four awarded around £4.5m each for Phase 2. DECC's overall spending is far above the Treasury commitment, but there is no ongoing programme and future spending is likely to be sporadic. This raises the question of whether such large-scale demonstrators should be funded inside or outside the SBRI programme.

[58] See e.g. *The Biggest Angel of Them All: the Military and the Making of Silicon Valley*, Stuart W. Leslie in *Understanding Silicon Valley, Anatomy of an Entrepreneurial Region*, Ed. Martin Kenney, Stanford University Press, 2000.

How the NHS England SBRI Programme Operates

NHS England is one of the few government department or agencies running regular SBRI's on a systematic basis, and it has a dedicated team operating a rolling long-term programme. The way it does so should be seen as a role model for other departments.

The programme is led by a National SBRI Director, located within the Eastern Academic Health Science Network and supported by a competition management team in Health Enterprise East, a not-for-profit technology transfer organisation which spun out of the NHS in 2004. This brings together financial, IP, technical and healthcare expertise to assess and monitor projects. The programme also draws on expertise from the 15 regional Academic Health Science Networks from across England and Wales to design and champion individual competition themes.

An SBRI management board drawn from the NHS, AHSNs, academia, and industry helps provide strategic direction and oversight. Its role includes developing a rolling programme of competition topics covering key NHS objectives (e.g. improving patient safety), departments (e.g. intensive care), medical conditions (e.g. diabetes), and areas of technology (e.g. imaging). Coping with an aging population, delivering health care in the home, and reducing costs whilst improving quality of care are key drivers that run throughout most NHS SBRI programmes.

Individual competition themes are worked up with top specialists in the field, including both clinical and nursing staff. These are expected to help award winners engage with the NHS as companies progress their products through to clinical trial.

Competitions are announced in groups twice a year and companies are have eight weeks to submit their applications. A simple application form is used, limiting submission preparation costs, and workshops are run with industry to help prospective bidders understand the requirements, competition process and contractual terms.

Submissions are reviewed by technical and clinical assessors and a short-list, of typically around one in three applicants, is invited for a half hour interview. Interview panels include relevant medical specialisms and individuals with business, technology and venture capital backgrounds. On average around 50 per cent of interviewed companies receive Phase 1 awards worth around £100k each. A basic due diligence process covers financials, legals, business plan, IP and any subcontractor costings. For start-ups this process obviously has to be quite limited. The aim is to sign contracts within 10 weeks of competition closing dates.

Phase 1 work programmes are expected to complete in six months at the end of which there is a one-hour review with the investment panel. Companies can also apply for Phase 2 funding at this stage.

Phase 2s last up to 2 years and as funding levels have increased, the value of contracts has moved closer to the £1m ideal.[59] This is typically the amount required to take a hardware product to pre-commercial prototype stage. Awards for software products tend to be lower.

For products incorporating new science, very innovative technology or difficult design challenges £1m may not be enough to get to the pre-commercial prototype stage. The aim then is to create an advanced demonstrator and to reduce key risks and uncertainties. In any event, companies must normally expect to have to seek additional commercial income or investment beyond Phase 2 to complete commercialisation.

[59] During 2013/14 and 2014/15 restrictions were imposed by the NHS finance team with the result that Phase 2 contracts are being awarded to cover a 12 month period only.

Contracts take a standard form and provide 100% funding. Payments are made quarterly in advance, an important benefit for cash strapped start-ups and SMEs.

Contracts are deliverables-based, rather than being based on reported hours worked or costs incurred, though the reasonableness of costings in relation to progress is assesses at intervals in the project. Full project accounts have to be signed off by the company's accountant at the end of Phase 1 and Phase 2.

Contractors may use subcontractors or consultants to support their R&D programme, but it is their responsibility to select, task, manage and, if necessary replace them. The contractor retains ownership of any IP created under the contract with limited rights of use for the NHS.

Companies are monitored closely through face to face meetings or conference calls every three months throughout Phases 1 and 2. Any concerns revealed at these meetings are examined in more detail, and very occasionally projects have be put on hold or halted, for example, if a company is unable to provide the resources to undertake the project within the contract time frame.

Selling new products to the NHS is a notoriously slow and difficult process, partly because of the need for clinical trials and safety tests and partly because of NHS procurement and commissioning processes. The issue is being addressed seriously at the top level within the NHS and the AHSNs and SBRI teams try to help individual award winners navigate the NHS procurement process and maximise the chances of promising products gaining early orders. All companies are given free consultancy on developing their health economics case.

In 2014 Phase 3 contracts were introduced on a trial basis. These were aimed at helping companies with the most promising projects to undertake clinical and pathway validation, making it easier to secure early sales to NHS Commissioners. Eight companies received Phase 3 contracts of between £600k and £1m.

The staged funding process and close monitoring approach adopted by the NHS combines elements of venture capital funding and the approach to managing projects adopted by DARPA. In this respect it is more *hands on* than many US SBIR programmes. Management and administration represents around 5% of total SBRI programme costs.[60]

"We keep our administration processes and due diligence 'light touch' where possible. It's important to recognise that many of these businesses are early stage, limited in resource and often without sophisticated management systems yet in place. So we keep our approach flexible and appropriate to the size of the risk and behave accordingly. We see our role more as a supportive parent than a bureaucratic administrator having companies fill in checklists for no reason. I think companies appreciate our support and the fact that our team has the technical skills to really understand what they are doing".

Dr Anne Blackwood
Chief Executive Officer
Health Enterprise East

In the five years since the DoH and NHS starting operating an SBRI programme, 21 different competitions have been run and around £26m in contracts awarded to companies from all over the UK. Most of these competitions have taken place since 2012, so it is too early to assess the full impact. Altogether NHS England has awarded 150 Phase 1 contracts, 30 Phase 2s and eight Phase 3s.

As with all high-risk product developments, the attrition rate can be expected to be quite high and the economic impact is likely to concentrate around just a few projects.

[60] SBRI Healthcare Annual Review, NHS England 2013/14

Research Councils

Since 2006, the UK Research Councils have been almost entirely absent from SBRI funding, despite the Biotechnology and Biological Sciences Research Council (BBSRC) and Engineering and Physical Sciences Research Council, being the only participants in the first attempt to establish an SBRI programme in 2001.

The only Research Council led SBRI between 2009 and 2013 was the very successful *autonomous ocean research vehicle* competition involving the National Environmental Research Council (NERC) with co-funding from the MOD and TSB. One of the award winners, MOST (AV) Ltd, was highlighted earlier in this chapter.

The demanding requirements of the defence and research industries often provide lead application markets for technologies that later become more pervasive. *Research tools* in particular represent the low hanging fruit in terms of opportunities to create new businesses around the UK's research assets. So the lack of participation in SBRI by most UK Research Councils represents a significant missed opportunity to boost economic development.[61]

The experience of Dr Curtis Dobson of the University of Manchester gives another indication of the potential impact that could be achieved.

Dr Curtis Dobson, BBSRC Innovator of the Year 2014

Ai2 Ltd, the spin-out company he established in 2005, won an £195k BBSRC SBRI award in that year to turn a peptide-based research tool he had developed at the university into a platform device for multiple clinical applications. These included an-infective coating for medical devices. A major deal with Sauflon Pharmaceuticals, a fast growing British contact lens company, later led on to a £1.75M venture capital investment and Ai2 Ltd is developing the technology for a range of other medical device applications.[62]

> *"About the time we were talking to contact lens companies we secured a two-year BBSRC SBRI grant and that really transformed things and allowed us to put serious effort into developing the peptides as coatings for medical devices and care solutions."*
>
> *Dr Curtis Dobson*

Dr Dobson was the BBSRC's Innovator of the Year in 2014. It has not funded any SBRI competitions since the one in 2005 that helped lead to his success.

Other Departments

Other important participants like the Home Office, DEFRA and the Department of Transport have made only occasional use of SBRI, and have so far failed to respond to the Chancellor's commitment. DEFRA has only awarded £1.5m in SBRI contracts during the last two financial years, the Home Office £1.7m and the Department of Transport zero. Funding has been spread thinly so individual companies have not received the amount needed to make a difference. Major changes will be needed if these Departments are to achieve the SBRI spending levels of £6m, £14m and £14m respectively to which the Chancellor has committed.

The National Centre for the Replacement, Refinement and Reduction of Animals in Research (NC3Rs) provides an example of how smaller agencies could use SBRI. It is a consortium funded organisation and was established in 2004.

NC3Rs has run SBRI competitions each year since 2013. However these competitions have so far had a very academic focus. The latest competition has

[61] *Scientists are Customers too; How the SBRI can Help Research Councils Drive Economic Growth*, David Connell. NESTA, 2010.

[62] BBSRC website.

some £7m is available, £2m coming from the TSB. In 2013 it awarded 17 Phase 1 awards of up to £100k each to fund the development of proof of principal concepts for alternatives to using animals in drug research and safety trials. All of these awards were made to consortia led by academic research organisations, four outside the UK. It is intended that this may lead to companies being formed for Phase 2. However, experience shows that this expectation is unlikely to be met.

Once again this project has a laudable objective and the job is a difficult one. However, funding university research groups is not the role of SBRI and it is surprising that no companies at all were thought suitable for Phase 1 contracts. SBRI's use here shows rather the benefits more generally of its phased competitive funding approach.

There have been a number of ad hoc one-off SBRI competitions by other smaller agencies. The Welsh Government has established a £1.5 to £2m central SBRI fund, though the small size of this budget means it is in danger of spreading this too thinly to make a difference to the companies awarded contracts.

Technology Strategy Board

The TSB has itself been a major funder of SBRI competitions in certain years, especially when there has been pressure to increase overall spending. The first TSB funded programme, *Retrofit for the Future*, was run in conjunction with the Department of Communities and Local Government (DCLG) in 2010. The aim was to stimulate the development of designs, technology and methodologies for reducing the carbon footprint of older social housing. The target was to reduce CO_2 emissions by 80 per cent and achieve significant improvements in energy usage.

192 companies were awarded Phase 1 contracts averaging £18k and 87 of these went on to receive Phase 2 contracts averaging £143k. A book published by the Royal Institute of British Architects includes 20 case studies aimed at catalysing the take-up of these approaches by industry.[63]

The Retrofit project addresses an important need and could not have been funded by TSB's traditional grant mechanisms. DCLG was unused to funding this kind of project on their own account. Strictly speaking Retrofit was not consistent with the SBRI model. It serves rather to illustrate the need for procurement-based innovation funding generally within Government Departments.

[63] *Residential Retrofit: 20 Case Studies*, Marion Baeli, RIBA Publishing 2013

5. The Truth About UK Government R&D Spending and The Bigger UK Innovation Policy Picture

The Historical Perspective

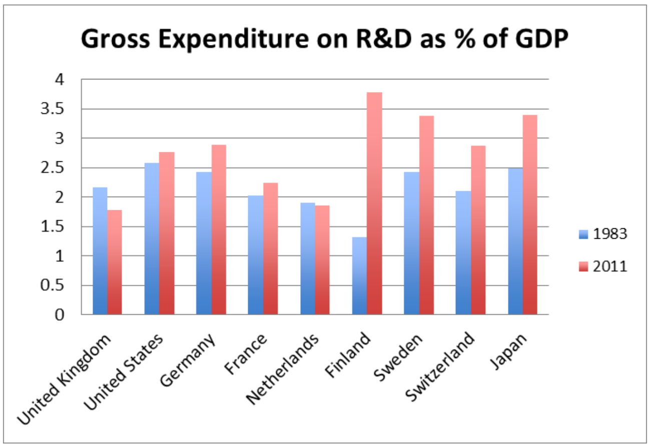
Concern about Britain's innovation performance goes back decades. Despite being one of the world's most R&D intensive economies in the 1960s and 1970s, by the late 1970's commentators saw inadequate or poorly managed investment in R&D and new technology as one of the reasons for the decline of many of the UK's industries. A good deal of the research at the UK's National Economic Development Office focused on *non-price competitiveness*, with technological innovation, and hence R&D, as a key component. A study on the mechanical engineering sector suggested that UK companies would have needed to reduce prices by four per cent per year compared with West Germany to have offset declining non-price competitiveness and maintained the UK's relative share of export markets. [64] Compared with France the figure was 8%. Inadequate investment in R&D was widely seen as a contributing factor.[65]

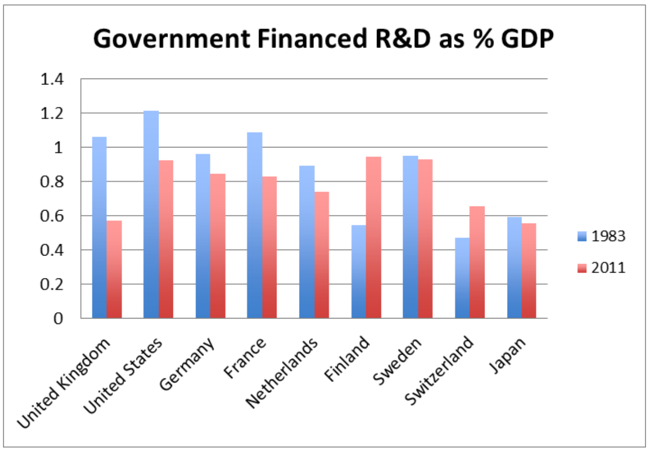
This picture was sometimes attributed to the impact of R&D spending in large Government R&D laboratories and expensive prestige projects in defence, aerospace and nuclear engineering. According to Chris Freeman, founding Director of the Science Policy Research Unit at Sussex University, *"The peculiar British paradox of the post-war period was thus one of a completely inappropriate allocation of government and industrial R&D resources at a time when the total R&D effort was temporarily greater than at of any of our major competitors except the US. Whereas the US at least derived substantial trade advantages from its dominance in military related technologies, British trade and industrial performance gained little from the heavy investment in these areas and may indeed have been weakened by it".*[66]

[64] *The UK's Performance in Export Markets – Evidence from International Trade Data*, David Connell, NEDO Discussion Paper No 6. 1980.
[65] *International Price competitiveness, Non-Price Factors and Export Performance*, National Economic Development Office, 1977.
[66] *Technological Innovation and British Trade Performance*, Professor Chris Freeman, in *De-Industrialisation*, ed. Frank Blackaby, National Institute of Economic and Social Research 1979

A much more recent paper by Richard Jones documents the privatisation, downsizing and closure of a string of public sector laboratories in the decade and a half that followed the advent of the Thatcher Government in 1979. It also highlights the closure of many large private sector laboratories by some of the UKs industry leaders like ICI and Marconi.[67] So by the end of the 80s a very different picture was emerging.

Exhibit 9: Decline in UK National R&D Since the Early 1980's





As a percentage of GDP, total UK spending on R&D has declined from 2.4 per cent in 1981 to 1.8 per cent in 1996 and it has since fallen to 1.7 per cent. Business R&D has fallen from 1.5 to 1.1 per cent and

[67] *The UK's Innovation Deficit and How to Repair it*, Richard Jones, Sheffield Political Economy Research Institute, 2013.

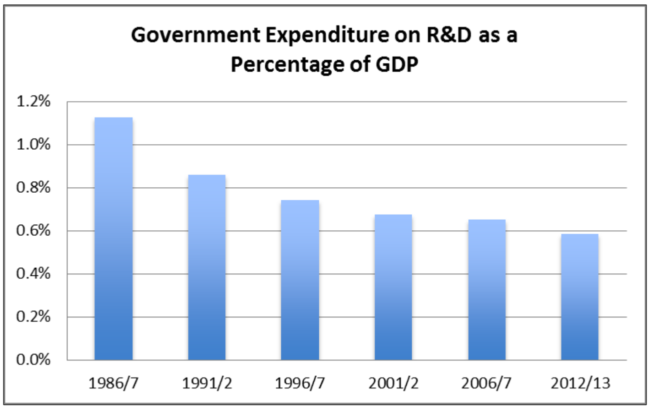
government expenditure on R&D is down from 1.1 to 0.6 per cent over the same period.

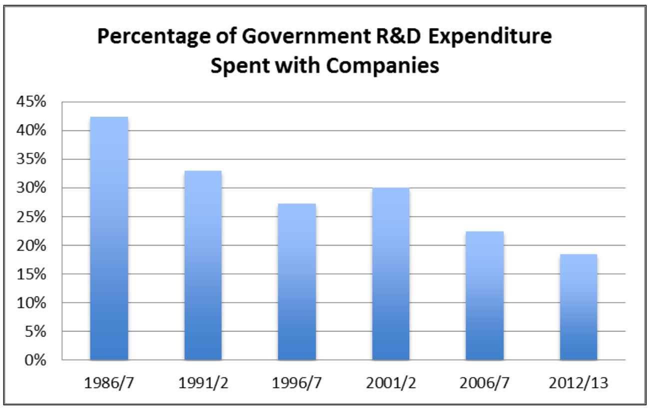
Exhibit 9 shows just how significant the overall cut in UK R&D has been compared with our closest competitors between 1981 and 2011. No other major advanced economy except the Netherlands has reduced R&D spending. But it also shows the significance of the reduction in government financed R&D. The government of the United States and all our closest European competitors all spend more as a percentage of GDP.

Government R&D Spending with Companies

Exhibit 10 shows how the decline in UK government R&D expenditure has been particularly focused on companies. In real terms, there has been a 65 per cent decline in government funding of R&D in companies since 1986 - 54 per cent in civil R&D and 69 per cent in defence R&D.

Exhibit 10: The Long Term Decline in Government R&D Spending in Companies





From a policy point of view, a fundamental question is whether the decline in business expenditure on R&D is partly a result of the decline in government expenditure on R&D, and more particularly on the reduction of government expenditure in companies.[68] It is not possible to prove statistically whether this is the case one way or another. But thinking about the exploratory phase in the process of commercialising scientific research suggests part of the answer. As discussed in Chapter 2, whilst exploratory R&D needs to be carried out in a business, rather than university, environment, projects are often too long term and uncertain for the private sector to fund. So there is a strong argument to be made that the decline in government funded R&D has provided less exploratory R&D for companies to build on during the commercial phase of technology development, perhaps even increasing UK firms' tendency to innovate by making acquisitions abroad.

A second important policy question concerns the type of R&D that is funded by Government and the instruments used. In particular is UK government R&D funding effective at supporting longer term, higher risk exploratory development in companies, particularly in innovative SMEs.

This second question has not been adequately tackled in relation to the UK economy. To do so, it is necessary to carry out a forensic analysis of Government R&D expenditure in much more detail than is possible using aggregate data.

Government R&D expenditure can be broadly divided into three categories:

(i) Direct funding of university research through the Research Councils and Higher Education Funding Councils

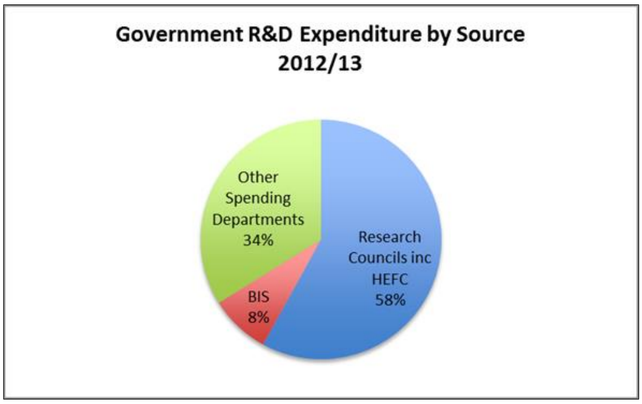
(ii) R&D expenditure by Government Departments like the MOD, and DEFRA, and aimed at meeting their own needs

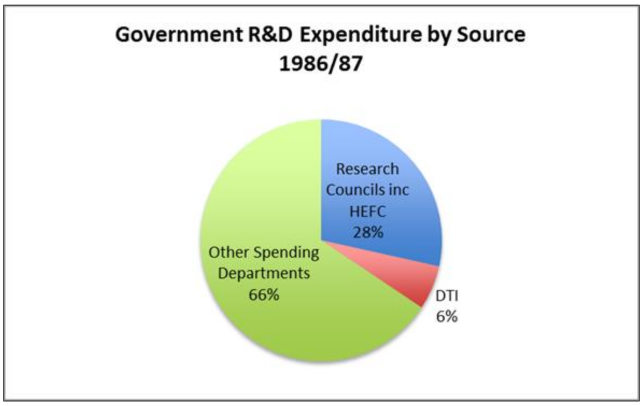
[68] Another possible explanation is that the decline in business R&D could be just a reflection of changes in industrial structure, our presumed competitive advantage in finance and services, or a result of stock markets that increasingly encourage short-termism by companies, and favour M&A over organic growth. Research at the Centre for Business Research suggests that the UK's low business R&D intensity is not just the reflection of its industrial structure. See *The UK R&D Landscape,* Alan Hughes and Andrea Mina, CIHE Enhancing Value Task Force, 2012 Centre for Business Research, University of Cambridge.

(iii) Funding from The Treasury and Department of Business Innovation and Skills (BIS) to subsidise R&D in companies

The changes in the breakdown of direct expenditure on R&D over the last quarter of a century are shown in Exhibit 11.

Exhibit 11: Long Term Changes in the Sources of Government R&D Expenditure





Since 1986 Research Council R&D expenditure[69] has increased from 28 per cent of total Government R&D spending to 46 per cent in 2002/3 and 58 per cent in 2012/13. This is nearly all used within the university system, the exception being where novel capital equipment is commissioned from suppliers. The £4.5m UK Biobank storage facility is an example.

BIS R&D represented 8 per cent of the total in 2011/12, compared with 6 per cent 25 years ago after a decline in the intervening years.

Other spending departments, like the MOD Department of Transport and Department of Energy and Climate Change, which might, prime facie, be expected to be an important source of innovation contracts for business, have collectively reduced their R&D spending from two thirds of the total in 1986/7 to half in 2001/2 and a third in 2011/12. This is despite the significant increase in Department of Health/NHS R&D.

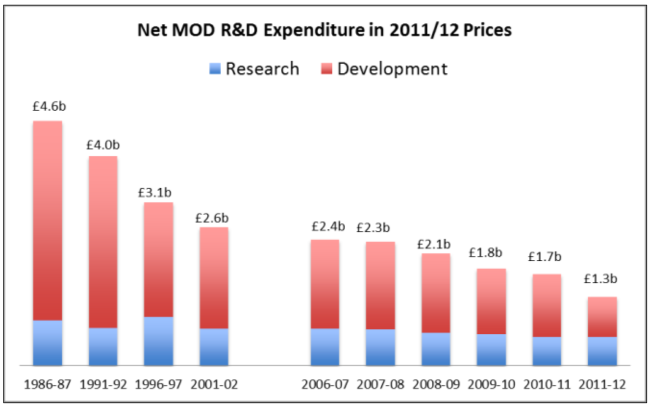
Further scrutiny shows that even these depressing figures are probably overstated. Much reported Government R&D expenditure is not strictly R&D at all, but policy and procurement advice (e.g. DFID, DEFRA and MOD). NHS R&D is almost entirely spent on research, with virtually none on funding the development of new technologies and products in companies.

An examination of the largest reported R&D spenders is revealing.

Research and Development at the MOD

Figures published by the Office of National Statistics show MOD R&D expenditure falling by over 70 per cent in real terms over the last twenty-five years. Expenditure is now running at around a quarter of levels in the 1980s.

Exhibit 12: Net MOD R&D Expenditure in 2011/12 Prices



However, even the published figures have for many years significantly overstated the true levels of R&D. Like all government agencies, the MOD uses the internationally recognised Frascati definitions of R&D, but much of the R&D actually reported either does not comply with these definitions or is of a kind that does not lead to innovative products or technologies.

[69] Including HEFCE funding

According to a review of defence R&D in 2007:

"*Expenditure reported as R&D often included items such as business processes, legal and commercial advice and document archiving, which are necessary for equipment acquisition, but are not technical. Such work should not… be classed as R&D.*

The Study also highlighted definitional issues in the research programme. These concerned the existence of contracts for Defence Science and Technology Lab support to help the Directors of Equipment Capability to identify capability gaps and research requirements and for "Knowledge Integration". The Team…queried whether they could be categorised as "research" in the traditional sense that they did not generate new knowledge or technology.

The Review Team found that the MOD's current Resource and Accounting Codes afford little visibility of where and how R&D resources are being spent." [70]

An internal MOD report concluded in 2009 that the erroneous inclusion of pre-production engineering work had led to MOD development expenditure being overstated by up to 40 per cent, or £1.1 billion a year, in 2001/2 and 2002/3 and an average of 20 per cent between 2003/4 and 2005/6 [71] These adjustments are incorporated in the revised data on which Exhibit 12 is based, but there is no guarantee that similar overstatements have not continued.

This particular problem arises partly because the MOD has tended to attribute a nominal R&D element to turnkey contracts with platform and system suppliers, sometimes on a percentage basis. For example, in 2006, roughly 10 per cent of MOD R&D was attributed to the *Joint Combat Aircraft* project, most of it spent in the US[72]. Senior MOD officials accept that some of this may have been for *production engineering* rather than R&D.[73] In the two years 2008-9 and 2009-10 some 23 per cent of reported MOD R&D spending went abroad, though it has since fallen to about 8 per cent.

As another illustration of the opacity of the MOD's R&D programme, its reported R&D spend with SMEs was reduced from £458m a year in 2005 to £99m in 2009. Both are unsubstantiated figures.[74]

More important than individual discrepancies perhaps is the overall impact on the role that the MOD plays in developing new technology. This has long been much smaller than generally believed; an MOD analysis in 2005 showed that only 42 per cent of reported R&D spending was directed towards *innovative science and technology solutions and technology development*, with the rest concerned with *development of competence and expertise, planning decision making and front the line* and *other work*.[75]

Despite this the same report claimed that *"with the exception of (the) Department of Trade and Industry ….. the MOD's financial commitment to technological development for equipment is unique compared to other departments who utilise science and technology mainly for policy making and assessment".*

But the reality is that what the MOD has called R&D has been increasingly focused on operational research, research to test and select off-the-shelf equipment for procurement and background research and advice. It also has to undertake projects to demonstrate a sufficient level of domestic technological capability for the US to agree to UK purchases of the latest US equipment.[76]

Reprioritisations forced by budget cuts since 2010 have resulted in the role of MOD R&D being even more heavily focused on support and advice, with virtually no effort to fund the development of longer term technologies. Even the term R&D has been replaced with the much broader concept of *investment in science and technology*.[77]

As a result, the MOD is now incapable of playing a meaningful role in the UK's national innovation system, without an additional ring-fenced budget and a mandate to do so.

[70] *Maximising Defence Capability Through R&D; A Review of Defence Research and Development*, MOD, October 2007.

[71] *Determining the Frascati Compliance of MOD Research and Development Expenditure,* K.C.Stone &N.J. Bennett, DASA Defence Statistics Bulletin No 8.

[72] *Maximising Defence Capability Through R&D*, op.cit. and authors discussions with MOD officials.

[73] Discussions with MOD officials

[74] Figures provided by MOD to DTI

[75] *Maximising Benefit from Defence Research: A Review of defence research and technology for alignment, quality and exploitation*, MOD 2006.

[76] Author's discussions with MOD officials.

[77] *National Security Through Technology: Technology, Equipment and Support for UK Defence and Security*, MOD February 2012

R&D at the Department of Health

In contrast with the MOD, reported R&D expenditure by the Department of Health (including the NHS) has increased steadily in real terms over the last 16 year of a century, up from £575m in 1995/6, when figures were first collected, to £904m in 2012. The NHS is responsible for over 95 per cent of this spending through the National Institute of Health Research (NIHR).

Before 2004 NHS R&D budgets were fragmented and poorly coordinated. Since then Dame Sally Davies has created in NIHR one of the world's best regarded clinical research organisations. It funds a highly distributed set of research and training activities in hospitals and academic research centres across all parts of the UK except Scotland. Nearly its entire budget is devoted to clinical research – testing new approaches to diagnosis, clinical practice, the efficacy of drugs in different indications, surgical techniques and other modes of treatment and patient care.

In keeping with the Governments Strategy for UK Life Sciences, making it easier for industry to undertake clinical trials in partnership with the NHS and providing research assets, like patient databases, has been the main way it which the NIHR has sought to support economic growth. Roughly £150m a year is also being invested in *translational research* in academic Biomedical Research Centres.

The primary objective of the NIHR is of course to use research to help to deliver better and more cost-effective healthcare in the UK. The clinical and translational projects it undertakes with industry are at least as likely to be with foreign companies as with UK ones.

In 2012/13 only £12.5m of the NIHR's £960m budget was specifically devoted to the development of new technology, through its Invention for Industry (i4i) programme, though this is being increased to £20m in 2014/15. i4i funds projects *"to enable prototypes to be commercially developed for introduction and adoption in the NHS".* Many projects emanate from clinicians and researchers who are the main recipients of funding. When projects move to commercialisation, this is mainly through licensing.

The NHS SBIR programme is not financed out of the NIHR budget.

So whilst the NIHR's objectives are laudable, and its achievements as an organisation since it was created in 2006 are considerable, it is essentially a *research* organisation with a strong academic ethos. Only a tiny proportion of its budget goes to funding exploratory development within companies.

This is in stark contrast with the nearest US equivalent, the US National Institutes of Health, whose activities broadly correspond to the NIHR and MRC combined, plus some BBSRC programmes. In principle the whole of the NIH's budget is open to companies. The impact of this difference is illustrated by the experience of Dr Helen Lee, Director of the Diagnostics Development Unit at the University of Cambridge Department of Haematology. Dr Lee's distinguished career includes managing a large R&D group at Abbot and founding a biotech company in Palo Alto. She then selected Cambridge as the best place to establish an academic research group in blood diagnostics in 1996. However, she chose to set up a company to exploit the results of her Cambridge research in California, partly to benefit from US SBIR awards. Between 2002 and 2010, her company, Diagnostics for the Real World, received $6.7m in SBIR awards and total R&D funding of at least $16.6m from the US National Institutes of Health.

R&D at the Department for International Development

DFID's reported R&D expenditure has grown from £57m in 1986 to £236m in 2011/12. In recent years the Division responsible has been renamed the Research and Evidence Division, reflecting its primary responsibility to *"make DFID more systematic in using evidence as a basis for how best to reduce global poverty, and provide high quality relevant evidence to others".*[78] It aims to do this by *"commissioning research on key questions in development, robust evaluations of DFID's programmes, high quality statistics, active engagement with policy makers and strengthening DFID's professional cadres".*

Most of DFID's Research and Evidence expenditure does not qualify as R&D under the Frascati definition, and the Office of National Statistics seems to have failed to take note of comments to this effect from senior DFID officials.[79]

[78] *DFID Operational Plan 2011-2015*; DFID Research and Evidence Division, Updated June 2012.
[79] Author's discussions with senior officials.

DFID's main mechanism for supporting technology development is through a series of Product Development Partnerships with international not-for-profit organisations. The latest available Annual Report shows that just 14 per cent of its Research and Evidence budget was spent in this way.[80] Current programmes include the Drugs for Neglected Diseases Initiative (DNDi), Medicines for Malaria Research (MMV) and seven other programmes. The total DFID commitment is £138m over five years.[81] Only one of these organisations, the Innovative Vector Control Consortium, is based in the UK.

Much of DFID's research expenditure is quite rightly spent outside the UK. In 2010 *"core funding to international and regional research organisations"* was responsible for 28% of the total research and evidence budget.

R&D at the Department for Environment, Food and Rural Affairs

The official Science Engineering and Technology statistics show DEFRA's R&D expenditure falling in real terms from £336m in 2006-7 to £161m in 2011/12.

Like DFID, DEFRA no longer refers to an R&D programme, but to an *Evidence Investment Strategy.* Detailed financial information on the structure of the overall programme is difficult to obtain and projects are managed through 27 other agencies and partners. The most recent DEFRA report contains no financial breakdown, though it does indicate a modest level of co-funding with the TSB and industry on projects to increase the uptake of research into farming.[82]

However an earlier document classified only around 55 per cent of the Research and Evidence budget as R&D. This R&D expenditure is itself a third lower than DEFRA R&D reported in the official Office of National Statistics data.[83] So once again, not only is DEFRA's R&D expenditure focused on academic research rather than on technology development, it is also over–reported in the national R&D statistics.

R&D in Other Departments

The Department of Transport, Home Office and Department of Energy and Climate Change, each spent around £30-40m on R&D in 2011-12. Discussions with senior officials reveal that these expenditures tend to be spread across many different groups and agencies with weak coordination centrally. There is uncertainty about what is included and whether reported R&D is consistent with the Frascati definition. Very little of these budgets is spent with industry.

R&D Support by the Treasury and the Department of Business Innovation and Skills

We have therefore a combination of trends, which together show a major long-term reduction in the amount of genuine R&D in UK companies that is funded through Government contracts. Reported R&D is down from 45 per cent of Government R&D spending in 1986/7 to 18 per cent in 2011/12. In addition, there has been a steady shift in emphasis in government departments away from R&D to develop new technologies and products, and towards academic research and support for procurement decisions. And a tendency for reported R&D expenditure to be overstated means that the negative impact on industry is even more severe than the numbers suggest.

Before drawing out the implications for procurement based programmes like SBRI, it is important to look at the three other main Government policies designed to encourage innovation by funding R&D in companies.

R&D Tax Credits

The most costly of these is R&D tax credits. In 2012/13 the R&D tax credit programme cost the Treasury £1.4 billion, four or five times as much as much as the value of TSB grants and SBRI contracts to businesses over the same period.[84] The cost is set to increase further as a result of even more generous rules. The scheme therefore needs to be examined in some detail.

Before the introduction of R&D tax credits in 2000, collaborative R&D grants were the main mechanism

[80] DFID Research 2009-10; Providing Evidence that Enables Poverty Reduction, DFID 2010.
[81] DFID press release 22 August 2013
[82] *Making the Most of Our Evidence: A Strategy for DEFRA and its Network,* DEFRA, June 2014.
[83] *DEFRA's Evidence Investment Strategy*: 2010 -2013, DEFRA, 2010.

[84] HMRC *Research and Development Tax Credits Statistics* and *Technology Strategy Board Annual Report 2012-13*

used to support business R&D. However most went to large companies and universities. The R&D tax credit was introduced to try to redress the balance and was initially restricted to SMEs. After industry lobbying, a large company scheme was introduced two years later and the categories of expenditure covered and levels of support have been steadily expanded and increased since.

R&D tax credits are seen as having some important advantages. From the point of view of firms, they are fairly predictable and do not require any increase in R&D expenditure or change in the mix of projects. R&D tax credits are also easy to apply for and most accounting firms have specialist teams to do the paperwork and advise on how to maximise claims.

For the Treasury R&D tax credits have the benefit of not requiring choice, so there can be no criticism of *backing winners*. Administration is relatively straightforward through HMRC's normal corporate tax processes.

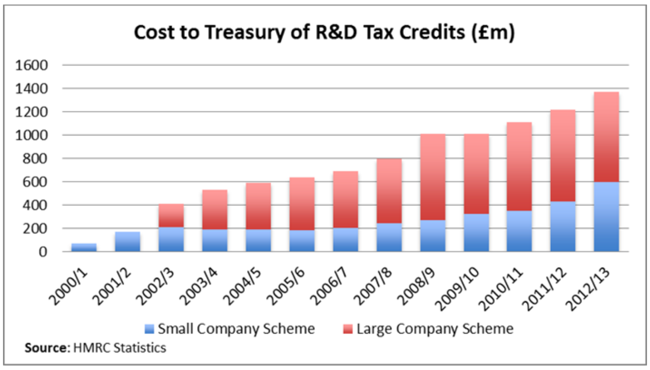
Many countries operate some form of tax credits. Within Europe, they are particularly important in France, the Netherlands, Belgium and Ireland. But Britain's enthusiasm for R&D tax credits is not shared by many of the nations we regard as innovation role models. [85] R&D tax credits are not offered by Germany, Sweden, Finland or Switzerland. And in the US, R&D tax credits are linked mainly to growth in companies' R&D spending. [86] As a result they represent only 2.0 per cent of total industry R&D expenditure, as opposed to around 7.5 per cent in the UK .[87]

Many econometric studies have tried to estimate the impact of R&D tax incentives. However doing so is notoriously difficult. A recent review by NESTA reported estimated price elasticities from 11 different studies with mean values ranging from 0.15 to 1.6 and estimates in the increase in R&D spending in the range from £0.3 to £3.0 per pound of foregone tax revenue.[88] It notes that the most recent study, on the Netherlands scheme, indicates that while the short-term multiplier on R&D spending is 3.24 for small firms and 1.21 for large firms, the long-term multiplier is 1.21 and 0.42. From this they conclude that the costs of the programme outweigh the benefits.[89]

There are a number of other reasons to believe that R&D tax credits represent bad value for money, most importantly because they do not require any change in behaviour. There is no differentiation between high-risk, long-term R&D, and the kind of routine R&D that any established company must undertake to keep existing lines of business competitive. So R&D tax credits are best regarded as a *subsidy to companies that do R&D* rather than a stimulus to do more.

The steady increase in the cost of UK R&D tax credits is shown in Exhibit 13.

Exhibit 13: Growth in Cost of R&D Tax Credits Since Introduced



This increase is partly due to extensions and changes to make the scheme rules more generous. It also reflects the increase in the proportion of UK business R&D for which R&D tax credits are claimed, up from 45 per cent in 2003, when large companies first became eligible to 70 per cent by 2009.[90]

What cannot be established is the extent to which an increase in claims is the result of misuse. As we have seen, R&D is notoriously difficult to define, even within government, and HMRC is simply not equipped to distinguish between a claim for genuine

[85] See, *R&D Tax Credits* in *OECD Science, Technology and Industry Scoreboard 2013*, *Innovation for Growth*, OECD 2014

[86] *2013 Global Survey of R&D Tax Incentives*, Deloitte, March 2013

[87] Author's calculations based on data from *National Science and Engineering Indicators, US National Science Foundation*, *2014*, *Science and Engineering Indicators, UK Office of National Statistics, 2013* and *Research and Development Tax Credits Statistics*, HMRC, 2014

[88] *The Impact and Effectiveness of Fiscal Incentives for R&D*; Christian Kōhler, Philippe Laredo and Christian Rammer, NESTA Working Paper no 12/01, January 2012

[89] *How Effective are Level-Based R&D Tax Credits, Evidence from the Netherlands*. Lokshin, B and P. Mohnen, Applied Economics 44(12) 1527-1538, 2012.

[90] *R&D Tax Credit Reform- AN Economic Study for EEF Limited and The Society of Motor Manufacturers and Traders Ltd*, PWC, November 2011.

R&D and one where the level of novelty and risk required for a project to be eligible has been exaggerated or the times spent on it overstated.

The extent to which R&D tax credits are in practice taken into account in corporate decision-making is also a matter of some question. Research published by HMRC found that businesses felt the availability of R&D tax credits had little effect on decisions to undertake specific R&D projects, partly because of the gap between R&D and the finance function. Very few respondents could quote the tax credit percentage rates; most said their accountants would deal with it.[91]

In the case of large companies, the effective cost of R&D is only reduced by about 7-8 per cent. The difficulty that companies face in determining the benefits of R&D, mean that this is not a significant change in the relative cost-benefit ratio of R&D as opposed to other investments to develop the business. So it seems unlikely, therefore, that each £1 of tax credits received will increase R&D expenditure by more than £1. And given the way allocation decisions are made in companies it seems more likely that the additional cash will be spread amongst a range of headings, including marketing, acquisitions and dividend payments. This is particularly the case for foreign owned companies and UK corporations operating a financially driven, conglomerate style of management. In such cases, tax matters are handled at corporate level, and divorced from annual budget allocation decisions at subsidiary level.

A seven or eight per cent saving on R&D costs is also unlikely to be sufficient to swing a multinational's decisions on where to locate R&D facilities, as the decision by Pfizer in 2011 to close its Sandwich R&D facility illustrates. Other factors are likely to be far more important.

In any event the UK already has a highly competitive corporate tax regime. It is estimated that by switching its tax domicile from the US to the UK through its proposed acquisition of Astra Zeneca three years later, Pfizer's effective tax rate would have been reduced from 27.4% to 21.3% of profits, saving it $1.2 billion annually.[92] Interestingly, at the time of the closure of Sandwich, the Association of the British Pharmaceutical Industry argued the opposite.[93]

In the case of SME's R&D tax credits are more generous, averaging 23% of R&D costs. However, again the impact is questionable. For those companies that are profitable, and able to offset the credit against profits, the average claim is currently worth around £35k per company and there has been a steady increase in the number of firms claiming, more than doubling in the last five years.[94] For SMEs taking payable credits in cash, either because they are loss making start-ups or because they have insufficient profits to claim back the credit, the average claim is much larger, at about £240k. The number of companies claiming is almost the same as it was 12 years ago, though it almost halved following the financial crisis.

The cash that comes from R&D tax credits is certainly welcomed by investors in these sorts of companies, particularly angel investor syndicates and seed capital funds where the amounts invested in a company a year are typically between £100k and perhaps £2 million. The key question is whether R&D tax credits represent the most cost-effective way of supporting R&D in these kinds of businesses, especially given the dead weight of subsidising R&D elsewhere that would have been carried out anyway.

For most small companies, R&D tax credits are simply not large enough to make a significant difference to their ability to innovate. Two hypothetical examples illustrate the maths. The first is a start-up with, say, three founders and £100k of investment from their own resources. Like many entrepreneurial start-ups, the founders have also taken a substantial pay cut in the first year of operation. R&D tax credits on this investment would generate at most around £23k, even if all the company's cash was spent on eligible R&D: better than nothing, but far short of the £1m generally needed to make real progress with any major new innovation, and far less than SBRI can provide. Many start-ups don't even have this level of investment.

[91] *An Evaluation of Research and Development Tax Credits*, HMRC Research Report 107, December 2010

[92] *Pfizers Massive Tax Play for Astra Zeneca*, Cyrus Sanati, Fortune Magazine April 29th 2014

[93] ABPI argued that the UK does not have a globally competitive corporate tax regime. It stated that in 2008 the effective global tax rates were 29% for UK pharma, 20.2% for US pharma and 17.8% for EU pharma. See *Written Evidence to House of Commons Committee on Science and Technology Examination of Pfizers Decision to Close its Research and Development Committee at Sandwich*, 2 March 2011.

[94] *Research and Development Tax Credits Statistics*, HMRC

The second example is a profitable technology-based SME employing 50 people that has grown to £5m in revenues without external investment and now wishes to develop a new product with greater market potential, but higher risk. Such a business is unlikely to spend more than £0.5m on R&D a year, and most of this would inevitably be spent on incremental R&D to refresh existing products. Even if all its R&D was eligible for tax credits the amount received would not be more than £115k a year. This is a quarter of what a Phase 2 SBRI contract could provide annually, making it difficult to progress the development of the new technology and products involved at a fast enough pace to stay ahead of competitors.

Some comments made by Andrew Wyckoff, head of the Directorate for Science, Technology and Industry at the OECD are instructive:

Most firms engaging in R&D are multinationals that can use cross-border tax planning strategies that result in tax relief that may exceed what was originally intended. This in turn may cause an unlevel playing field vis-à-vis purely domestic firms that do not benefit from these same tax planning strategies. This may also disadvantage source of net job growth and tend to be the origin of radical new innovations that spur growth…

…Recent OECD analysis shows that well-designed direct support measures – contracts, grants and awards for mission-oriented R&D – may be more effective in stimulating R&D than previously thought, particularly for young firms that lack upfront funds. Direct support that is non-automatic and based on competitive, objective and transparent criteria can stimulate innovation.

Andrew Wyckoff, OECD[95]

The Patent Box

The Patent Box is a second Treasury driven innovation policy, introduced in 2013. This will halve the rate of corporation tax on income derived from patents filed from the UK. It is expected eventually to cost the Treasury over a billion pounds a year in lost tax revenues.

Anything that can halve corporation tax represents a significant incentive for multinational companies, but one which could have more impact on tax planning than the location of R&D. One independent assessment argues that, *"…a Patent Box is poorly targeted at the types of activity where government intervention is justified and provides only limited incentives for firms to conduct additional research in the UK…..it would be possible to hold patent income in the UK without co-locating any of the associated real activity".* [96] In the pharma sector where innovation is increasingly driven by buying small biotechs with valuable IP, there would appear to be no incentive to maintain an R&D team after an acquisition has been completed.

Whether the estimated £1 billion a year cost of the patent box scheme will result in a greater increase in R&D seems highly questionable, but at present it is too early to tell.

Department of Business Innovation and Skills Programmes

Reported non-Research Council expenditure on R&D by the Department of Skills has been the subject of frequent changes and revisions in recent years, and Department officials themselves find it difficult to keep track.

According to ONS statistics, BIS spent £695m on R&D in 2012. However, in an answer to a Parliamentary Question, the Minister indicated that spending was only £233m[97]. This was much closer to the TSB's spending in that year of £300m. The difference reflects BIS funding of the Royal Society and other national academies, expenditure on university facilities through the HEFCE Research Capital Investment Fund (RCIF) and Science Research Investment Fund (SRIF), aerospace launch investment support and UK Space Agency funding. [98] It is questionable whether this is all R&D within the Frascati definition and most of it is destined for academia rather than business.

The TSB, BIS's principal channel for funding business R&D, has had a significant increase in budget in recent years, with net grant expenditure up from £262m in 2011-12 to £526m in 2013-14. It received a

[95] *In Search of Elusive Growth: Making the Most of R&D Tax Incentives*, Andrew Wyckoff, OECD Insights, 14 October 2014

[96] *Corporate Taxes and Intellectual Property Simulating the Effect of Patent Boxes*, Rachel Griffith, Helen Miller and Martin O'Connell, Institute for Fiscal Studies Briefing Note 112, 2010.

[97] Parliamentary question by Mr Chuka Umunna MP to the Secretary of State for Business Innovation and Skills, 18 April 2012

[98] Correspondence with BIS officials

further £5m in cofunding from the Research Councils and £41m from other Government Departments and agencies. Of this total around £172m was spent on Catapults and industry networks, leaving £400m for direct funding of R&D projects.[99]

Most of this money goes on multi-partner collaborative R&D projects. These typically involve both universities and companies and until the TSB was formed roughly half the funding went to large corporations, with universities taking a further quarter. [100] Since then small businesses have increased their share of collaborative grants, but universities are still significant beneficiaries. Between 2006/7 and 20010/11 large companies received 45 per cent of collaborative grant funding and universities 20 per cent.[101] SMEs received 31 per cent. Collaborative R&D grants can cover 100% of university costs, and 50 per cent of company R&D costs, rising to 60 per cent for SMEs.

Linking companies with academic researchers in universities is a key thread running through nearly all TSB grants. Along with other not-for-profit research institutes, universities accounted for 15 per cent of TSB project grant expenditure in 2013/14.[102]

Grant for R&D is the TSB's main programme aimed at SMEs and does not require collaboration with another organisation. Expenditure on this programme was £42m in 2013-14. The three sub programmes cover up to 60 per cent of R&D costs up to £100k and up to 45 per cent for larger projects (35 per cent for non-SMEs). The maximum grant is £250k. As with R&D tax credits, grant values are too small to make a difference and only companies with substantial profits or venture capital backing can take advantage of them easily. Most innovative SMEs are simply not in this position.

So SBRI is not simply just another bright idea for spending government money. Rather it reaches critical parts of the innovation process that other policies cannot. By creating *a market for things that don't exist* which is linked to unmet customer needs, SBRI delivers genuine additionality and better value for money than the programmes through which the bulk of UK Government R&D support to business is currently channelled.

[99] *Technology Strategy Board Annual Report and Accounts* 2013-14

[100] See e.g. answers to Parliamentary Questions to Secretary of State for Trade and Industry by Mark Prisk MP, Hansard 19th February 2007

[101] See answers to Parliamentary Questions to Secretary of State for Business Innovation and Skills by Chuka Umunna MP 18th April 2012

[102] Analysis of Technology Strategy Board Annual Report and Accounts 2013-14

6. Conclusions and Policy Implications

Reality and National Self Interest in Innovation Policy

The decline in the UK's industrial base goes back many decades and the role of innovation in halting and reversing it has been re-emphasised ad nauseam by successive governments. R&D spending has been rightly seen as a key measure of the investment in innovation, and by this yardstick we fall a long way short of the competitors we most admire. As a share of GDP R&D has been doggedly stuck at about 1.8 per cent since 1997, a level all UK Governments have regarded as unsatisfactory. The latest data shows it falling closer to 1.7%.[103]

The need to rebalance the economy has assumed new urgency since the banking crisis of 2008. Science and technology businesses have a key part to play as they tend to be strongly export orientated and employ skilled and well-paid people.

But still the rhetoric of UK innovation policy places its emphasis on academic research, and Silicon Valley style venture capital, failing to reflect the reality of how innovation works in practice.

The benefits to society, from the government's investment in academic research, and the benefits to international financial investors, through venture capital backed start-ups, have all too often been implicitly equated with benefits to the British economy. This is partly unwitting repetition of the conventional wisdom, and partly the desire to support the arguments of particular interest groups. But the reality is different, especially in the UK, much of whose industry is weak in terms of its ability to absorb new science and technology, and whose economy is more open to overseas financial investors and foreign acquirers than any other advanced industrial nation.

Indeed, for major British scientific discoveries with long lead times to commercialisation, like graphene, it is almost inevitable that commercialisation will mainly take place elsewhere. With all the interest in graphene's properties, the UK can only contribute a small percentage of the world's total investment in downstream R&D. In the case of liquid crystal displays, in which the UK undertook pioneering research in the 1960's, leadership passed to RCA in the US and later to Sharp in Japan before commercialisation really took off some 20 years later. It was customer pull that achieved this, building on the technology push of the previous decades.

And whilst the media image of scientific innovation in the UK is that of a professor in a white coat describing how his discovery can lead to new medical treatments, it's portrayal of manufacturing and engineering is typically one of a machine shop using 30 year old equipment to bash out simple components. The engineering sector has for many years been betrayed as the Cinderella of British industry.

As the examples in Chapter 2 demonstrate, innovation is fundamentally about problem solving. Sometimes an entrepreneur has enough knowledge to define the problem himself. In the case of new consumer products and services, like Dyson's vacuum cleaners or Facebook, the founders could make a good stab at the functionality they wanted to deliver, as potential users. The same is often true of new scientific equipment developed by research scientists. The in-house developers of new technologies to support a company's core business can usually gain a similar quality of insight from their colleagues and sponsors.

Renishaw, founded in 1973 by David McMurtry and John Deer to commercialise the touch trigger probe that McMurtry had invented to support manufacturing when he worked at Rolls Royce, is an example. Today it employs 3300 people and is one of the UK's most successful specialist engineering companies. Arm has similar origins. It was spun out of Acorn Computers in 1990 to commercialise the RISC processor that the R&D team had developed to power Acorn's new Archimedes computer.

But most science and technology based products are sold to specialist users or system integrators within a

[103] ONS Statistical Bulletin; UK Gross Domestic Expenditure on Research and Development, 12 March 2014.

complex value chain. The innovative company seeking to develop products that meet their requirements can only do so if those requirements are carefully defined and prioritised by the individuals and companies that will buy and use them. And without a paid development contract there is little incentive for managers in a large organization to do this with the precision required. Indeed a single individual may only understand part of the picture himself.

So development contracts for customers play a key role in helping new companies define the products and applications they are most likely to be able to sell. This applies whether a company is based around the specialist skills and knowledge of its founders, or whether it already has a proprietary technology, or invention to commercialise. And it applies whether the time to market is short, like new software, or very long, like graphene and other new materials with multiple, but as yet unproven, possible applications.

A paid R&D contract concentrates the mind, both for customer and supplier. Breaking it into phases helps review expectations, capabilities, requirements and progress on both sides. And rather like a university examination, the hard deadlines involved in a contract encourage a supplier's scientists and engineers to work all hours to meet the target. Government grants rarely have this effect.

A country is only as innovative as its customers, those that can define problems and unmet needs, are open to new ideas and willing to pay for them to be turned into reality. So innovation policy must try to ensure that there as many such customers as possible, from both the public and private sectors. Stimulating demand is one of the keys to creating an effective *market for things that don't exist*.

Building Significant UK Companies and the Role of the Unbackable Entrepreneur

Besides being about problem solving, innovation is also about champions. And champions usually find it difficult to get heard in large organisations. Start-ups and small companies provide the perfect vehicle for the entrepreneurial champion to take forward his ideas. Some remain focused on the science and technology and need to be embedded in a broader management team. Venture capitalists are good at recruiting professional managers to build such teams, the aim usually being to create a product line for a larger corporation to acquire and distribute.

But the best entrepreneurs want to retain their independence and grow a substantial business. They often start young and learn fast. Bill Gates, of Microsoft, Steve Jobs of Apple, Sir John Dyson, Mike Lynch of Autonomy and Richard Branson are all such individuals. They were probably all unbackable when they started in business. Others start later in life, perhaps after having developed specialised expertise and technology with fellow team members in an established company or research institution. Often the initial market opportunities they see are too small to attract VC interest. And for many, the opportunity to start a business may come at a time in their life when the need to support a family and pay off a mortgage may make this impractical.

Making a Difference

Helping entrepreneurs without significant business experience or capital to develop and test out their ideas with real customers is vital if we are to create businesses with a commitment to continuing growth in the UK, rather than temporary R&D subsidiaries for companies headquartered overseas.

As we saw in Chapter 5, the established mechanisms to encourage R&D, BIS grants and Treasury R&D tax credits do little for such businesses. The amounts involved are insufficient to make a difference, and small firms lack the internal funds to provide match funding. SBRI contracts are much more useful, providing 100 per cent funding of up to £1M in Phase 2. This is typically enough to fund a project, if not a whole company, for two years, making it easier to recruit a permanent team and providing time to engage with further customers and, partners, and if necessary, investors. But they also do much more.

First, they ensure the engagement of a customer or specifier in setting requirements, and evaluating the resulting products against them as developments progress. This makes R&D more focused and reduces time to market. Second, by being deliverables based and split into phases, SBRI contracts inject a level of urgency. Third, they provide endorsement, at both R&D and finished product stage, for further customers, and for investors. And finally, by allowing suppliers to keep the rights to any intellectual property created, they make it possible for them to sell to others and create a product business. This is not always possible with private sector lead customers.

Benefits to Public Sector Customers

From the point of view of its customers, SBRI contracts harness new technology and creative individuals to develop solutions to intractable problems. And the phased approach helps to reduce risk and focus funding on the best projects. This approach is incidentally in stark contrast to the tendency of government agencies to let large, turnkey IT projects to established system houses….and the failures that have too often followed. It is interesting to consider whether such projects would benefit from the phased approach used in SBRI contracts to try different solutions to the more challenging elements of such projects. This might enable key risks and uncertainties to be dealt with before full-scale system development and deployment.

Building on Success

The managers of the US SBIR sometimes call it the *"biggest seed capital programme in the world"* and SBRI could play a similar role in the UK. In both countries, the approach is already funding exploratory developments that investors find difficult. It helps not just to bridge the *valley of death,* but also to reduce the size of the chasm. As we saw in Chapter 5, grants and R&D tax credits do not play this role to any significant extent.

Unlike venture capital investors, who concentrate on established centres of high technology enterprise, or successful entrepreneurs who reinvest some of their wealth as angel investors, the SBRI process is geographically agnostic. Companies in Penzance or Inverness have as good a chance of winning contracts as those in Oxford, Cambridge or Silicon Roundabout.

Chapter 4 showed that the UK SBRI programme is already a success, and both the Chancellor and the TSB are committed to expanding it. However, this will not happen without further measures to ensure that key government departments have the finance and organisational capabilities to do the job. Specific actions to achieve this are proposed in Chapter 7.
But the experience of SBRI so far also shows how the approach can be applied more widely.

The SBRI programme was deliberately designed as a simple, standardised process, as in the US. But the US SBIR was also set up with the aiming of getting SME's onto the first rung of the procurement ladder. Federal agencies also place much larger R&D contracts, either as an alternative to SBIR or to follow SBIR Phase 2s in what are nominally termed *Phase 3 SBIR* fundings. The total value of SBIR Phase 3s alone is probably in excess of the combined value of Phase 1's and Phase 2s.

The research reported in Chapter 5 shows that the next steps of the ladder are missing in the UK. Funding technology development for their own benefit is no longer something that UK government departments are engaged in to any significant or systematic degree. For the public sector to deliver its full contribution to economic development as a lead customer, its role in funding the technology development it needs must be re-established more widely, using not just SBRI, but also other public sector R&D programmes.

The way in which SBRI has been used in practice, for example in the TSB/DCLG Retrofit for the Future competition, DECC's energy storage competition and NC3R's animal testing replacement project, shows that a phased R&D procurement based approach could have many wider applications in government. Though all of these competitions strictly fell outside SBRI's remit, the departments and agencies involved found its phased competitive approach a valuable way of funding the development of things the public sector needed, things that did not currently exist.

There is also much to be gained from encouraging more private sector organisations to fund R&D contracts as lead customers, as this is a practice which is less prevalent in some sectors and companies than others. Again some specific proposals are made in Chapter 7.

7. Detailed Proposals for Putting Lead Customer R&D Contracts at the Centre of UK Innovation Policy

Increasing SBRI Commitments by Departments

The Chancellor of the Exchequer has already committed to expanding SBRI expenditure to £200m in 2014/15. And the Treasury has specified how much should be spent by six key departments. Less than half of this looks likely to be achieved. So the first priority is to ensure that departments set aside the funding to meet these commitments.

To achieve this, the Treasury should identify the amounts it wants each department to spend on SBRI in future spending settlements as a part of its growth programme. And it should make it clear to senior officials that that the SBRI component of departmental budgets is not transferable to other activities.

A three year scale up programme should now be put in place to take the total value of SBRI contracts awarded to £150m in 2015/16, £200m in 2015/16 and £250m in 2017/18. This is a sum broadly equivalent to the US SBIR programme given the relative sizes of the two economies

Each SBRI competition has a three year cycle, starting with needs definition and evaluating competitive proposals, followed by Phase 1 and Phase 2 contracts. The spending rate increases over this cycle. So the Treasury should also require Departments to put in place rolling three year SBRI programmes, rather than allowing annual budgeting to disable the SBRI process by requiring all SBRI awards made to be spent within the budget year, as experienced by the NHS SBRI team.

Each department should be encouraged to fund a balanced portfolio of R&D projects, covering technologies and products that, if they are successful, it would consider buying itself, and those which are needed to meet its broader policy objectives.

SBRI projects should include both developments with short times to market and projects with longer timescales. In the latter case, the objective of Phases 1 and 2 is to help position the project so that the business involved can raise further funding, from either the public or private sectors.

The NHS SBRI management approach should be adopted as a model by each department running an SBRI programme.

Budgets for programme management should be broadly in line with NHS England experience at around six per cent of the annual value of contracts awarded.

A New Larger Innovation Contracts Programme

Alongside SBRI, the Treasury should set aside an additional fund, the *Larger Innovation Contracts* programme for larger demonstration projects, SBRI Phase 3s and other ad hoc lead customer R&D contracts.

The *Larger Innovation Contracts Fund* should be held as a central pot by TSB with individual departments bidding into it to fund innovation competitions. The value of contracts awarded under this programme should increase from £50m in 2015/16 to £250m in 2018/19.

Ministry of Defence

As discussed in Chapter 4, the MOD is not currently operating an SBRI programme in anything other than name. And there is an urgent need to increase Ministry of Defence funding for innovative defence technology development in industry generally. It will be important to involve people from across the industry with expertise at component, and subsystem level in specifying SBRI topics.

It is therefore proposed that a *Mini-DARPA* is created with a budget rising to £200m a year over 4 years. Half of this would be for SBRI and half for larger innovation contracts including SBRI Phase 3s.

The new organization should be separate from DSTL, which is an internal MOD R&D resource, and should borrow key features from the US DARPA model. This includes recruiting a Director and programme managers from outside the MOD on three plus two year contracts to ensure the regular renewal of expertise and ideas.

Research Councils

The Research Councils should re-introduce SBRI through a Research Tools programme. Its object should be to fund companies to develop and trial new instruments, process equipment, software and consumables aimed at the research market. Scientists from the UK's academic research community should be involved in defining competitions and acting as lead customers. The programme should also be used to help commercialise research tools originally developed by academics for their own use. The budget for this programme, spread across the Research Councils, should be increased to £30m per annum over a three year period.

Interdepartmental SBRI Programme for IT and Digital

A new interdepartmental SBRI programme should be created for information technology, digital and systems projects. Its aim would be to define and manage SBRI programmes for departments like the Department of Work and Pensions and HMRC, which are major users of IT, but for whom a full scale SBRI programme might not be appropriate. There are many many challenges that goes across the public sector, like security, *big data* opportunities, interoperability issues and dealing with legacy systems.

The budget should be held centrally, possibly by TSB, and individual departments would be encouraged to bid into it and to run their own competitions. The budget for this programme should be increased to £30m over 4 years.

Role of The Technology Strategy Board

The TSB should continue to promote and coordinate the SBRI programme across the public sector, to advise and assist Departments in running competitions, and to market them through its network. It should also produce an annual report on the programme, including detailed analyses of expenditure, contract sizes and types of organization receiving awards by departments and agencies.

A condition of any SBRI contract should be that basic information is made publicly available through a TSB database, as in the US. This should include the awarding department, company name and location, and a description of each project, together with the value and the date of the contract.

There continues to be a tendency for departments to claim projects under SBRI which do not meet the programme's rules, for example because competitions have been used primarily to fund university research rather than company R&D, or because of the size of contracts. The TSB should discourage this and separate out any such competitions in its annual report. Funding for such projects should instead come from the Research Councils or the programme for larger innovation contracts proposed above.

Eligibility and Role of Universities

As in the US, the aim of SBRI is to fund commercial businesses that plan to sell and support a product if the R&D is successful. It is not aimed at funding universities. However, academics seeking to start a business should not be required to establish a company prior to a Phase 1 contract being signed.

Again, as in the US, award winners should not be allowed to subcontract more than 35% of the value of a project to a university department with which one of the company's principle or a member of the project team have a position.

As at present, SBRI should be aimed at innovative start-ups and SMEs, together with new ventures established within larger companies to develop activities outside their core business

An "SBRI" for Private Sector Lead Customers

SBRI is concerned with contracts for lead customers in the public sector. A parallel programme should be established to encourage more private sector organisations to act as lead customers for new technologies developed by SMEs. This could be achieved within EU State Aid Regulations by adapting the TSB's collaborative R&D grant mechanism to fund bilateral partnerships between SME suppliers and large company customers.

SME support levels (i.e. the percentage of total project costs funded) should be at the increased levels introduced by the EU in 2014 as part of Horizon 2020, rather than the less generous levels normal for TSB programmes.

The new EU SME Instrument, which is inspired by the US SBIR and was introduced following proposals made by the author to the European Competitiveness Council, shows that substantial grant funding can now be made available to SMEs within State Aid Regulations. [104]

After piloting the private sector SBRI, the aim should be to increase funding to £100m a year.

Paying for the Changes

The additional cost of the measures proposed in this report rises to £600m in four years' time.

By starting to redress the deficit of public sector R&D spending with businesses these measures represent a vital investment in our future. It is an investment which would make a significant contribution to rebalancing the economy and increasing exports, thereby helping to pay for improvements to the NHS and other public services.

But at a time when all aspects of government expenditure are under pressure, it is necessary to examine the totality of government spending on R&D in companies dispassionately to see how it can be made more cost effective. This includes spending by BIS through The Technology Strategy Board, SBRI and the costs to the exchequer through R&D tax credits. It must be possible for the proposals made in this report to be paid for by savings elsewhere.

Chapter 5 showed clearly the weakness of the R&D tax credit system and argued that it was much less effective than lead customer programmes like SBRI. This is not just because of the additional acceleration and endorsement benefits that come from engaging with lead customers, but because SBRI not does not suffer to nearly the same extent from the *deadweight problem*; the danger of funding R&D projects that companies would undertake anyway. Instead, programmes like SBRI can be focused on deserving projects and companies for which funding is hard, or impossible, to raise.

To pay for the programmes proposed, the R&D tax credit should be restructured along the lines of its US equivalent, so that tax credits for larger companies are linked to growth in their R&D spending, rather than the absolute amount in any year. It is estimated that this would save around £600m per annum, enough to pay for all the report's proposals.

Large companies would, of course, benefit from the increase in opportunities to partner with innovative companies through *open innovation*, a strategy that has become increasingly important in recent decades. They would also be able to use SBRI and the *Larger Innovation Contracts* programme to help fund innovative new ventures and *step out* projects entailing high risks and long lead times.

These proposals should be implemented in such a way that overall Government support for R&D in business remains stable as the mix of policies change. As economic circumstances permit, government support for business R&D should be increased to close the gap between the UK and our main industrial competitors.

A Change in Philosophy

For decades UK innovation policy has been aimed at increasing the **supply** of R&D in order to address what economists call *market failure*. It has tried to achieve this by increasing research funding in universities and by subsidising business R&D through grants and R&D tax credits. But when it comes to the early stages of trying to create and commercialise very innovative technologies, when there is still no clear idea of a product, and no market exists, the concept of market failure is largely irrelevant.

Since 2001, when government began a massive increase in expenditure on these subsidies through R&D tax credits, net UK business R&D expenditure[105] as a percentage of GDP has actually fallen by around 14%.[106]

Clearly we need to adopt a different approach. Policies that create customer **demand** for innovation, as practiced extensively in the US, offer an important part of the answer.

[104] The SME Instrument provides Phase 1 lump sum funding up to €50k for a six month feasibility assessment. Phase 2 provides up to €2.5 million for R&D to cover demonstration, scale up and testing. It reimburses 70% of direct costs plus overheads calculated at 25% of direct costs. No collaboration is required. The budget is around €500m per annum over the seven year life of Horizon 2020 across the EU. See e.g. *Horizon 2020, Dedicated SME Instrument, Work Programme 2014-2015, European Commission.*

[105] Business R&D expenditure net of R&D tax credits

[106] Author's calculation based on *ONS Statistical Bulletin 22nd November 2013* and HMRC R&D Tax Credit Statistics

Appendix – The PolyPhotonix Story

PolyPhotonix was set up in 2008 on the back of a £3.2m Technology Strategy Board collaborative R&D project to manufacture organic light emitting diodes (OLEDs) for high volume applications, including automotive and lighting.

The company's founder, Richard Kirk, was an ex-artist who had already created a successful start-up making large area outdoor displays with many world first design installations.

PolyPhotonix's partners in the collaboration were a Japanese automotive components manufacturer, Sanko Gosei and the Centre for Process Innovation. Based in Sedgefield, the Centre was already established with £30m of government funding and PolyPhotonix is based within the building.

Finding the match funding for its part of the collaborative project was a particularly difficult challenge for PolyPhotonix given the financial climate at the time. But its location within CPI provided credibility and a lower perceived technical risk. Alongside regional loans and early revenue from consultancy and design projects, this helped it to raise enough to support its project commitments.

But within a year or two, Richard's discussions with major global electronics companies, together with progress on the company's own R&D programme, led him to conclude that a process for manufacturing thin film OLEDs in volume was still many years off. Consequently Richard decided to focus on applications that would still allow the company to exploit the novel and highly innovative nature of OLED technology, but which had less stringent performance characteristics than, for example, the automotive sector.

Medical applications looked particularly attractive and offered the team the added attraction of being able to make a difference to people's lives. Early research showed that there were a number of interesting opportunities including wound healing and photodynamic therapy for cancer patients. After much desk research and attending many different conferences, Richard met Professor Geoffrey Arden, a distinguished, neurophysiologist and ophthalmologist. Arden's early research had demonstrated the influence of light on the level of oxygen in the eye's retina and the impact that reduced oxygen levels during dark adaption had on its sensitivity. He had argued for some years for possible treatments of progressive sight loss resulting from diabetic retinopathy and macular degeneration based on the concept of directing low intensity light into the eyes.

Richard saw that OLEDs could provide a practical and precisely controllable way of delivering this kind of therapy. He secured a £300k grant from Northern Way, a collaboration of regional development agencies, to do some initial work at Liverpool and Northumbria Universities. As with the earlier TSB grant, this grant required matched funding and much of the money went to finance the work with university partners.

Over the following months an Advisory Board of leading UK ophthalmologists was created, including Professor Ian Grierson from Liverpool University who was also a Special Trustee of Moorfields Eye Hospital in London.

From this point onwards PolyPhotonix needed to pursue a two-track programme. The first track entailed continuing with its original core business of process development for the manufacture of OLEDs in high volumes; PolyPhotonix has continued to advance this technology, financed through a combination of TSB collaborative projects matched to its revenues. At the same time it established a parallel activity in medical technology to progress its increasing focus on bio-photonic applications, and the company has again been very successful in winning a number of peer reviewed grants to fund programmes and clinical trials in the UK with university partners.

In February 2011 NHS East launched an SBRI competition with the theme, *"Improving the Health of People with Long Term Conditions"*, and PolyPhotonix decided to submit an application for product development funding supported by Professor Grierson. Its focus was on halting eyesight deterioration in early onset patients suffering from macromolecular degeneration and diabetic retinopathy. Ninety per cent of type 1 and 67% of type 2 diabetic sufferers will develop some form of retinopathy within 10 years of diagnosis. The current treatment involves monthly injections directly into the eye and costs the NHS £10,000 per eye per year, or expensive and highly invasive laser surgery. Patient numbers and costs are escalating with the ageing population. The cost of PolyPhotonix' treatment is around one twelfth of intra-ocular injections, the existing treatment of choice by NHS clinicians.

A Phase 1 award of £100k was followed in 2013 by a Phase 2 award of £480K. This enabled the company to develop the mask and related electronics, and carry out patient acceptance and usability tests. Prototypes of the *Noctura 400* sleep mask were used to undertake a small-scale clinical study on patients with severe diabetes in the Czech Republic. The eyesight of each of the 40 patients involved had already deteriorated to the point where they were registered blind. The trial showed that after 6 months of using the Noctura treatment there were significant improvements in visual acuity and the progress of the disease in the majority of the patients was halted or reversed.

An independent healthcare assessment carried out as a part of the Phase 2 SBRI programme in April 2012 concluded that the economic case for Noctura was extremely strong. It recommended that an application be made to the National Institute for Clinical Excellence (NICE) for recommended use of Noctura within the NHS to be fast tracked, and a £1m Phase 3 SBRI award in 2014 enabled PolyPhotonix to begin the complex process of developing *a Patient Care Pathway Model* for NICE approval. 240 patients in 15 NHS hospitals are involved in this trial. The Noctura device is also in a phase 3 clinical trial with Moorfields eye hospital.

> *There is no contest that I would choose the mask over the laser treatment. It is easy to use and removes any traumatic experience that occurred when having my eyes lasered. I will wear the mask at night and would encourage anyone with diabetes and suffering from retinopathy to do the same.*
>
> *Noctura Using Patient*

PolyPhotonix continues to access CPI equipment and expertise to enable it to develop innovative manufacturing methods at pilot scale to enable it to fabricate OLED devices for clinical trials. It is intended that volume manufacturing and further R&D will take place in the UK, and PolyPhotonix is currently building a 25,000 sq. ft. UK HQ and R&D center.

The PolyPhotonix story shows the important relationship between specialist commercial suppliers of technological innovation, in this case CPI, together with PolyPhotonix and a lead customer organisation prepared to fund the highly speculative development of *a product which does not exist*, but which could meet a key need. Through SBRI, the NHS has been able to play that role.

Richard Kirk's earlier company, Elumin8 grew by undertaking contracts to design and supply display products for private sector customers. It became one of the largest printed electronic companies in Europe.

The much riskier start up proposition offered by PolyPhotonix was not fundable from private sector customer contracts, and neither was venture capital available.

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