# Lessons from the History of UK Science Policy

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# Foreword

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To support these efforts, the Academy's public policy team in collaboration with the Department for Business, Energy and Industrial Strategy, has undertaken a new programme of work on policy histories. The policy histories series develop historical analyses for individual policy areas. These analyses are used to provide:

- a structured, rigorous and objective account of the history of a given policy area and the significance of key milestones in context,
- an informed basis for analysis and insights from the timelines as well as dialogue and discussion about what history can tell us about the future.

There are two components to the programme of work for each policy history:

- An *historical analysis* which involves desk research to develop a chronological and contextual overview, of a policy area, and commissioning and facilitating of historically grounded analytical perspectives on that chronology from historians and policy experts in each area. Together the chronology helps to set the background and the analytical perspectives help interpret the chronology, set it in context, and provide views on what we can learn from the past.
- An *evening seminar*, which pick up on themes from the historical analysis and stimulate dialogue and discussion about what we can learn from history.

The views expressed in these contributions are those of the authors and do not represent the views of the British Academy or the Department for Business, Energy and Industrial Strategy.

1 *The British Academy Strategic Plan 2018-2022,* The British Academy, 2018. Available at: https://www.thebritishacademy.ac.uk/publications/the-british-academy-strategic-plan-2018-2022

# Executive Summary

The objective of this Policy History report is to reflect upon historical analyses of the developments in British science policy over the last 100 years, in order to identify insights, trends, and implications for policymakers today. In particular, the report asks what lessons this might have for our understanding of the relationship between science policy and industrial strategy, which has become increasingly significant with the UK government's publication of its Industrial Strategy in 2017.[2]

The report is composed of five analytical papers on the history of UK science policy, each contributed by a leading expert in the field. The first piece serves as an introductory overview of the implications the four subsequent historical pieces have for science, technology and innovation policymaking now. These reflections are particularly pertinent in light of contemporary developments such as the unification of the UK's research councils under UKRI, the creation of the Newton Fund and Global Challenges Research Fund, Britain's Industrial Strategy, Brexit, regional economic differences across the UK, and Britain's growing services economy.

Following the introduction are four historical analyses that together identify and examine significant shifts in UK science policy from 1915 until today, providing explanations for these shifts, and highlighting their consequences. The appendix of the report includes a chronology of significant milestones in UK science policy, as well as supplementary graphs and figures that provide visual depictions of some of the trends pointed out by the contributors.

Three clear questions emerge from the contributions collected together here, and the analyses suggest some answers which offer lessons for policy makers today, particularly regarding the relationship of science policy with industrial strategy. This summary also draws from discussions held at a seminar held at The British Academy with civil servants and the expert contributors. It ends with a list of eight more specific lessons that can be drawn from history for policymakers today. The three questions are:

1. What is science policy?
2. How can effective science policies be formulated?
3. What do science policies seek to achieve?

### What is science policy?

*Science policy is not a single, comprehensive programme*

Definitions of science policy have themselves involved assumptions about what counts as scientific research, what kinds of scientific research should be government funded, and where that research takes place. Flanagan identifies how, in the past four decades, research council-funded R&D has been seen as a "swiss army knife", expected to solve many of the problems of our economy and society. David Edgerton notes that before the 1980s *most government funding for research came from departments, not research councils,* and highlights the problems associated with equating science policy with research council policy.

An implication of Edgerton's analysis is that *we should view science policy as happening across the network of British government, industry, non-profits, higher education and research councils* (see Figures 2 to 6). It involves thinking about the role that scientific research, development, and innovation (and not just 'flagship' innovations) can play alongside the different needs and goals that exist across these sectors (for example, meeting the changing needs of businesses, responding to demands in education, or integrating with other social or environmental policies in government).

2 HM Government, 'UK Industrial Strategy: Building a Britain fit for the future', Industrial Strategy White Paper, 2017. URL: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf

It also requires careful consideration of Britain's relationship to the international landscape of science and innovation (see Figures 8 to 10). For example, elsewhere contributor Kieron Flanagan has discussed the problems of 'closed system fallacy' thinking about British science policy,[3] a point also highlighted within Edgerton's piece here. Flanagan, Agar and Edgerton all observe that *for the past few decades, science and innovation policy has essentially been a substitute for industrial policy, not a complement to it, whereas today research is once again seen as a key part of industrial strategy.* This is a promising development, but challenges remain, as Flanagan details.

The history of science policy is also not just a history of innovations – it is *a history of 'manpower.'* Sabine Clarke highlights how this was a formative aspect of science policy within the activities of the Department of Scientific and Industrial Research (DSIR) from 1914 to 1965. The DSIR aimed to train individuals so that they were equipped to undertake in-depth studies of materials and processes, giving British firms greater control over their work and the ability to improve products and manufacturing. By training scientists and focusing on the most general and fundamental problems in science, Clarke shows that the DSIR claimed a space for government science policy that was delineated from those more specific technical and scientific activities that were the responsibility of the individual company. Notably, the DSIR did not think of 'fundamental research' as a type of 'pure' or 'curiosity-driven' research solely conducted as part of the pursuit of knowledge, as the term might be used today. Instead, 'fundamental research' was the investigation of general problems that affected a whole sector of industry.

## How can effective science policies be formulated?

*Openness, access to decision making processes, inclusivity and interconnectedness should be central principles*

Since science policy is not a universal programme, understanding the various problems that science policies address for different stakeholders is vital, as is openness regarding the mechanisms by which policies are formed. Claire Craig highlights the *importance of mechanisms for brokerage and 'glue' in the system*. These mechanisms are forms of connective tissue through which various institutional bodies can articulate evidence, problems, needs, goals and ideas about the future to one another. These connective tissues are vitally important because, as Jon Agar notes in his contribution, science policies have historically been "pursued in different silos, by different departments, for different purposes". Therefore, a central challenge for government is to bring these policies into dialogue in such a way that policymakers can democratically manage shared ideals and potential tensions that might exist between them.

Given the various interests at play around them**,** science policies benefit from being formulated in a climate of *access and openness,* a point particularly highlighted by Jon Agar and Claire Craig's papers. *Science policies tend to represent those groups who have access to government* and can voice their perspective to government on the issue (those 'at the table'), and those groups who can see and interact with how decisions are being made. Clarke explains that, in its formative years, the UK Department of Scientific and Industrial Research (DSIR) focused specifically on funding what it termed 'fundamental research', which referred to general research that was oriented toward meeting public goals and industrial needs. She notes that this objective emerged from the DSIR's need to articulate its goals as meeting the interests of both British industry and British scientists, in order to gain support. *For the DSIR, the objective of 'fundamental research' corresponded to a strategy that involved balancing the concerns and ambitions of these groups.*

3 Contributor Kieron Flanagan has referred to this as the 'closed system fallacy'. See Kieron Flanagan, 'Does the UK need to spend more on basic research?', *The Guardian*, 27 Feb 2013. URL: https://www.theguardian.com/science/political-science/2013/feb/27/uk-spend-basic-research; Kieron Flanagan, 'Myths and misconceptions in the UK science policy debate', *The Guardian*, 23 Sep 2014. URL: https://www.theguardian.com/science/political-science/2014/sep/23/myths-and-misconceptions-in-the-uk-science-policy-debate.

Craig offers some suggestions as to how to build an infrastructure within government that could account for different framings of science policy problems, specifically noting the value of roles such as the Government Chief Scientific Adviser (GCSA) in providing 'glue' across these framings and enabling mechanisms for evidence synthesis. *Agar also lists features of an ideal GCSA*. In-house governmental science advisers and active research expertise within government have been particularly valuable because of the systems for knowledge brokerage that they enable. Equally pertinent are instances where scientific knowledge feeds back into policy goals. Craig identifies how methods of scientific inquiry (such as systems modelling) are themselves types of brokerage as they can help to convene groups with different expertise around important policy issues (such as manufacturing, climate change, managing the spread of disease, etc.). Identifying the assumptions, uncertainties and limitations of a method require diverse forms of expertise. In this way**,** *methods operate as platforms where policy clients can engage with scientific experts, and broker between their different framings of issues*.

**What do science policies seek to achieve?**
*Collectively science policies can be components of an industrial strategy, but the capacity to look forward to implement this strategy in a dynamic social, political and economic context must be actively cultivated*

Science policy is about the articulation of problems. The framings of these problems differ across institutions, departments and groups. *However, the role of policymaking is also to bring framings together – through mechanisms of brokerage, for example – as part of a collective strategy.* Flanagan and Keenan have noted elsewhere: "Identifying the ultimate goals of national research policy is important because without any consensus about what they should be, it becomes impossible to answer the key question: how much science should we do as a nation, and how much do we need to do?"[4]

Edgerton, for example, shows how *different science policies have corresponded to different political and economic aims of government,* specifically looking at those that have supported a liberal and global approach; those adopted to support an imperial economy, and those adopted to support a national economy. In the late 1980s, he argues that policy reverted back to a liberal approach, and that research policy became a substitute for an industrial policy. He also notes how, throughout these shifts, research policy for military defence has remained important.

Jon Agar encourages policymakers to *understand and improve the systems that enable groups to articulate their problems in ways that invite the successful attention of science.* He highlights lessons from science policies in the 1970s, 1980s and 1990s, including the impact of the 1971 Rothschild report, which articulated science policy in the language of the market (research performed by and for government departments – particularly applied research – was to be conducted on a 'customer-contractor' basis), on the relationship between science and government in the decades following its publication. The report appreciated the importance for research to address needs and problems and aimed to make research more efficient. However, Agar notes that its extension of the 'customer-contractor' principle later also led to a severe lack of dialogue between science and government about the very issues that they needed to work together on. The capacity to articulate problems to science is important but must therefore be supplemented by ways of brokering between framings.

This is highlighted by a shift in science policy that occurred under Thatcher's government in 1987, which Agar explores. The science policy strategy (advocated by George Guise of the Number 10 Policy Unit) enthusiastically funded 'curiosity-driven research' (aka 'pure science') while cutting support for 'near market' research (see Figures 11 to 14 for differences that remain today regarding source of funding for 'basic' and 'applied' research). In short, this presumed that industry would fund research with 'application', which allowed government to fund 'pure' science that would

4 Kieron Flanagan and Michael Keenan (1998), 'Trends in UK science policy' in P Cunningham (ed), *Science and Technology in the United Kingdom* (Cartermill).

supposedly lead to economic growth. Agar notes that many of the science policy committees at the time had advised against this shift, and he suggests that science policy since 1987 has been in part a slow crawl back from the decisions under the Thatcher government to an industrial strategy. The lesson here is that policymakers should take stock of what the variety of science policies in the UK achieve collectively, and do so through transparent and accessible systems of brokerage. Moreover, *science policies should not themselves be a substitute for industrial strategy; instead they can form some of its component parts by functioning alongside policies in other areas.*

## Lessons from history

*Finding the right science policies for the UK*

The national and global landscapes have changed significantly since the events in these histories: for instance, since the creation of the DSIR in 1916, the Rothschild report, or since Thatcher's abandonment of 'near-market' research. As Flanagan points out in his introduction, the UK's 80% services-based economy, the social and economic contours of the UK's regional landscape, the recent reorganisation of the research councils under UKRI, and the changes in the UK workforce that will come with Brexit, are all pressures and needs that demand consideration in the formulation of science policies today, and they take on a different character to the challenges of the past. The history of science policy nevertheless offers valuable lessons and trends for policymakers today. Eight lessons, drawn from the analyses here and from discussions at the seminar, are listed below:

- **Science policymakers must consider how science policies align with policy goals in other areas.** Science policy does not operate in a vacuum. It is related to other realms of policy such as economic policy, higher education policy, energy policy, agricultural policy and broader industrial policy. It is not restricted to research councils; research activities situated within or in close relationship to industry make up a sizeable portion of British R&D. Science policies should take this complex landscape into account. This also points to the fact that science policy cannot be an industrial strategy on its own. It should be situated within broader policy aims in other areas.
- **Training people can build absorptive capacity.**[5] Science policies can play an important role in training people in research activities – practices, processes, and methods. As Sabine Clarke points out in her paper, such training is a vital way of bringing science and industry into a closer relationship. This training enables people and organisations to identify new scientific developments and innovations (that often may be external to them), integrate these into their work, and benefit from these developments by using that knowledge to meet their own needs and goals. In other words, it increases 'absorptive capacity'. Kieron Flanagan's paper also discusses this in more detail.
- **Absorptive capacity can help Britain benefit from a global R&D landscape.** Crucially, building absorptive capacity enables Britain to benefit from its relationship to the global landscape of R&D. David Edgerton and Kieron Flanagan's papers both prompt consideration that the UK may only be best placed to pursue innovation at home in certain areas and, by contrast, may benefit from developing processes or innovations from abroad (or importing skills/products) in other areas. Britain has historically been very good at adopting other nations' innovations and must continue to invest in its own 'absorptive capacity' to benefit from them. Science policy should therefore not only foster innovations at home but also foster skills that enable external innovations to be identified, adapted, and utilised within Britain.

5 As defined by Cohen & Levinthal, absorptive capacity can be understood as the ability of an organisation "recognise the value of new, external information, assimilate it, and apply it to commercial ends", see Cohen, Wesley, M. & Levinthal, Daniel A. (1990), "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly* 35(1): 128-152.

A strong science base is key to the UK's ability to benefit from global developments in science and technology.

- **Policies can have significant long-term effects that are hard to reverse.** Jon Agar points out how, in the postwar period until the 1990s, R&D in the UK was mainly financed by government but performed by industry (and half was military in orientation), but from the 1990s to the present R&D in Britain has been mostly funded and performed in the private sector. In the 1960s, the proportion of GDP spent on R&D, public and private, peaked at around 2.3%. This dropped throughout the 1980s and 1990s to 1.8% by 1999, driven by reductions in both government and company spending. David Edgerton notes that from the late 1980s, research council spending was cut much less (in some cases this increased) relative to departmental research spending cuts. This also marked a shift away from publicly funded support for 'near-market' R&D – 'basic' ('curiosity-driven') research was to be funded by government through the research councils, whereas 'near-market' ('applied') research was to be funded by industry.
  The important lesson here is that the impacts of these changes still manifest today. In 2016, for example, research councils had 61% of their budgets allocated to 'basic' research (see Figure 11), though it is also likely that much of the 'applied' research funded by the UK research councils is closer to 'basic' research than to the technological development prioritised by other nations. Civil department R&D, on the other hand, was allocated largely toward 'applied' research and 'experimental development' (see Figure 12). R&D in business (Figure 14) is overwhelmingly orientated toward 'applied' research and 'experimental development'. The UK R&D landscape now continues to shift - as Kieron Flanagan points out, today research is once again seen as a key part of industrial strategy, whereas for the past few decades, as described by Edgerton and Agar, science and innovation policy has essentially been a substitute for industrial policy.
- **Brokerage and ways of convening enable the identification of valuable science policies.** Claire Craig's paper highlights the need for, and value of, ways of bringing the right people together to identify, frame, and work on solutions to science questions in a collaborative way. She notes that methods are one way of doing so because they create means for 'brokerage', enabling policymakers and experts/designers to engage with one another regarding the assumptions and limitations of a given method, for example. Formal structures such as the IPCC, or informal movement of exchanges of people through travel and migration, are other ways to create these infrastructures for brokerage. A related point that emerged in the seminar discussion was that, with these structures, there also needs to be a capacity for problems to be articulated from below (for example, smaller business and wider society, and not just the large companies in Figure 10, must be given ways of effectively convening with other R&D players).
- **Transparency and access to decision-making help to avoid mistakes.** Jon Agar discusses the impact of a switch in science policy in 1987, when there was a pivot of government funding towards the science base (branded 'curiosity-driven research') alongside a cutting of government-funded 'near-market' support. He suggests that this switch essentially ended an active, interventionist, science-based, publicly-funded industrial strategy. Greater openness and access to decision-making processes would have helped avoid this mistake.

- **Internal expertise can help to facilitate brokerage.** A point that emerged from the seminar discussion was that internal scientific expertise in government can be valuable in that it provides a 'connective tissue' between different framings of science policy issues. Similarly, encouraging scientists and science policymakers to train in the history of science during their education, would provide them with a better understanding of how their expertise has been situated within policy, and has related to societal demands, needs, and influences outside (and within) the scientific institution.
- **Policymakers need infrastructures that can overcome institutional memory.** Another point that emerged from the seminar was that lack of institutional memory in government poses a significant challenge for a policy area that demands an infrastructure of 'connective tissue'. These issues suggest that there need to be infrastructures in place that can manage knowledge about science policy as it travels and moves in and out of government. Thinking about this knowledge as also being embodied in individuals (who are changing posts or departments regularly), this points to the importance of convening across silos/departments/institutions as well as within.

# Contents

# Introduction – Why now is an important time to consider history

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**Central Points**

- There has never been a single UK science policy – for instance, R&D done by other government departments in support of their own missions and goals has historically been important and remains so today, albeit much reduced.
- For much of the past four decades science and innovation policy has been a substitute for industrial policy, with research council-funded R&D being seen as a swiss army knife – expected to solve all the problems of our economy and society.
- This discovery-and-commercialisation oriented model is built on a 'closed system' fallacy, in which discovery and exploitation are expected to happen in the same place – yet science and technological innovation are distributed, internationalised activities.
- In any case, the major social and economic impacts of innovations are only realised through their adoption, hence the supply of people with advanced R&D skills has been and should be at least as important a goal for science policy as the production and transfer of knowledge.
- The renewed interest in industrial policy and the contribution of science policy to local and regional economic development is promising, but a one-dimensional notion of 'excellence' still dominates thinking about UK science policy. Yet the contributors to this volume show very clearly that funding 'excellent' research was never the only driver of UK science policy, nor usually the major one.

Does the UK need to increase public and private spending on research and development to keep pace with established and new competitor nations around the world? Are we 'good' at 'discovery' but 'bad' at 'exploitation'? How should we choose what research to support with public funding - and which researchers? And who should decide what topics they work on? Such questions and preoccupations are never far from the heart of science policy discussions, yet there is surprisingly little institutional memory within government as to how they have been tackled in previous periods – or of their broader policy contexts.

As contributors to this volume show, the history discussed by policymakers and analysts alike has tended to focus overwhelmingly on the evolution of arrangements for the support of investigator-driven 'basic' research. They also show that the UK has long been wracked with concerns about falling behind, about failure to nurture and exploit the creativity of our great scientists and inventors. In this we are certainly not alone – many countries seem to have their own version of the 'good at discovery, bad at exploitation' meme, with their own frequently cited analogous examples to the great British discoveries and inventions lost to competitor nations such as the CT Scanner.[6]

These worries reflect a belief that discovery and exploitation should normally happen in the same place, and in a straightforwardly direct (dare I say linear?) fashion from 'discovery' to 'exploitation'.

6 See for instance this Twitter thread on the subject from former ministerial advisor Stian Westlake: https://twitter.com/stianwestlake/status/1010109520704688128.

Yet both research and technological innovation are globalised enterprises. And the training of highly-skilled researchers has typically been as important a goal of science policy as the production of knowledge per se, as Sabine Clarke shows in this volume. In any case many, perhaps most, innovations don't stem directly out of single scientific discoveries. And we don't really know to what extent research done elsewhere in the world is leading to economic and social impacts in the UK because, well, no one has really been interested in looking for that evidence (though, as David Edgerton notes in his contribution, many innovations adopted in the UK were very likely developed elsewhere).

The major social and economic impacts of innovations are only realised through their adoption, so an economy's ability to absorb and adapt technologies developed elsewhere is therefore going to be at least as important as its ability to develop novel ones. Yet for many decades improving 'translation' and 'commercialisation' have been the major focus of attention of UK policy-makers. Such is the power of a carefully-wielded anecdote.

But the fearful anecdote is just one way that history finds its way into UK science and innovation policy debates. As Edgerton notes there is also the 'landmark report', a statement that sets policy on a new course. In this view, the history of UK science and innovation policy is a succession of policy statements which reflect shifting rationales and understandings and which sometimes lay down fundamental 'principles' that may still be relevant today. It is perhaps understandable that STI policy analysts pore over formal policy statements with care – but less so that they sometimes mistake the official rationale for the real reason that something has been done. The process even happens in reverse - policy scholars have sometimes dreamt up a neat theoretical rationale to explain a particular policy well after the fact. The retrofitting in the 1950s of formal 'market failure' justifications to pre-existing policies from research funding through to intellectual property rights is one example, whilst the overlaying of much the same policies with entirely new rationales around 'innovation systems' thinking from the 1980s onwards is another.

Some of this is inevitable – persuasive stories are part of how coalitions are built behind particular policy options. And yet the real, messy, confusing, obscure history of UK public policy in relation to science, technology and innovation, as explored by the contributors to this volume, does matter. Today, once more, research is seen as a key part of industrial strategy, whereas for the past few decades, as both Edgerton and Agar show, science and innovation policy has essentially been a substitute for industrial policy. Meanwhile, the creation of UKRI as a single funder explicitly intended to act more strategically than its predecessor bodies recalls past debates about how far social and economic priorities should shape public funded research agendas, and how this should be done in practice. Even the new emphasis on R&D in overseas development assistance, with the creation of the Newton Fund and Global Challenges Research Fund recall the importance of the international reach of UK science policy through the research activities of the Colonial Office, discussed by Sabine Clarke in more detail elsewhere.[7]

Scientific advice to and research in support of government action has been an important theme for UK science policy, and a key driver of departmental R&D activities. As Craig and Agar note, the UK has had a long tradition of the scientific advisor, typically a seconded leading scientist rather than a career civil servant and seen as an independent figure who can 'speak truth to power'. In the aftermath of BSE and FMD crises in the 1980s and 1990s Government overhauled the structures and processes through which it seeks, receives and uses independent scientific advice, and these structures and processes are now actively overseen with a view to ensuring rigour and quality in the face of uncertainty.

Government thinking about the future has also increasingly reflected the challenge of uncertainty, with the continued use of forecasting and models being supplemented with approaches such as horizon-scanning and foresight, as noted by Agar and Craig. The original UK Technology Foresight

7 Sabine Clarke, "A technocratic imperial state? The colonial office and scientific research, 1940-1960", *Twentieth Century British History* 18 (2007), p. 453-480.

Programme was very much established as an expert- and stakeholder-led process of setting research priorities, but in the face of a mismatch between the granularity of the priorities set and the kinds of signals a research system needs (and perhaps in the face of some resistance the research system to priority-setting of this kind) the programme progressively evolved into a more conventional forward-looking activity.

Despite the creation of UKRI, there remains no single seat of science policy in the UK, just as Clarke and Edgerton show that the DSIR was not the only game in town in the period after the First World War. UKRI may be a funding behemoth but other government departments accounted for almost £5bn of SET spending in 2016[8] (out of £10.5bn or so, excluding our notional contribution to EU R&D programmes). A long-standing preoccupation of UK science policy has been how best to 'coordinate' across this landscape of departments and agencies.

However, departmental commissioned and in-house R&D is a shadow of its former importance and continues to suffer under austerity. As Edgerton notes, this leaves the UK looking quite unlike many comparator countries in terms of the balance between public funding for scientist-led versus problem-driven research. Research council-funded science has had to become the swiss army knife of UK science policy, expected to solve any and all problems.

Yet more of the same is not likely to be enough in the context of industrial strategy goals and the 2.4% target for R&D/GDP.[9] A lot has changed since the last time UK R&D intensity was much above 2%. There is the loss of nationalised industries and public sector research establishments, the growing importance of foreign-owned R&D investment relative to UK-owned investment, the collapse in productivity of the big pharma R&D model, the rise of 'new' actors in private R&D, not only start-ups but also R&D services firms (some of which actually have a long history as Industrial Research Associations as recounted by Sabine Clarke in this volume). Most importantly, manufacturing industry, the sector where R&D is most significant as source of innovation, has continued to decline relative to services. The UK is today an 80% services economy yet there is little to no discussion of what services innovation policies might look like.

Meanwhile the policy landscape has also changed, not just the pulling back from applied and 'mission-oriented' departmental R&D and from ambitious general programmes of technological development, as described by Agar and Edgerton in this volume,[10] but also the much more recent emergence of tax incentives as a major feature of UK innovation policy. According to HM Treasury the UK offered almost £17bn of tax relief against private R&D spending between 2000 and 2016.[11] In truth R&D tax incentives can at best only be a blunt tool of STI policy, giving policymakers no scope to influence the quality and direction of the R&D supported. It would be more honest to admit that they are first and foremost an instrument of international tax competition.

The rise of the R&D tax credit highlights a fundamental paradox of UK STI policy. As R&D intensity has declined, policymakers have severely criticised British industry for under-investing in R&D. Yet they have continued to turn to that same industry for guidance about how best to spend public money on research. If industry is making such poor choices about investing its own money in research, why should we trust it to do better with public money? Isn't it the role of government in such circumstances to confidently set the agenda on behalf of our society?

A further paradox of recent UK STI policy is the growing interest in 'place', set against the continuation of policies designed explicitly to concentrate funding in a few places. Though private grumbles have often been expressed, this progressive geographical concentration of funds has

8 This sum includes more routine S&T related services as well as R&D. Source: ONS Govt SET Statistics for 2016.

9 History sometimes repeats itself very rapidly - the New Labour government set its own 2.5% R&D/GDP target, as a response to the EU's more ambitious Barcelona Objective of moving the Union to 3%. Neither target was achieved.

10 A trend only recently and very tentatively reversed with the creation of Innovate UK and the network of Catapult Centres.

11 'UK businesses receive £2.9 billion boost to invest in Research and Development', Gov.uk, 14 September 2017, https://www.gov.uk/government/news/uk-businesses-receive-29-billion-boost-to-invest-in-research-and-development

not generally been a matter for public debate, especially as some degree of concentration is seen as the inevitable outcome of peer review decisions. But a controversial decision in the late 90s to build a 'fourth generation' synchrotron source at Harwell in Oxfordshire rather than at the existing facility at Daresbury in Cheshire, and a more recent one to build a mega-institute for biomedical research, the Crick, in central London, have drawn attention to the issue outside of narrow science policy circles. Regional actors outside of the Golden Triangle have increasingly raised concerns about the geographical distribution of science infrastructure, with first the former English Regional Development Agencies and more recently a number of the new Local Enterprise Partnerships including science infrastructure in their economic development strategies. (There is, incidentally, an important historical study waiting to be done of the original decision to build a national synchrotron in Daresbury and the later one to build its replacement at Harwell.)

We've since seen some one-off major investments in the North,[12] and more recently a wave of English 'regional science and innovation audits', but to what ultimate end? It would be a major shift in philosophy to move away from the policy of deliberate concentration of public funding exemplified by the progressively tighter funding formula that uses Research Excellence Framework scores (formerly Research Assessment Exercise and originally the more honestly-titled Research Selectivity Exercise) to concentrate English university block research funding.

Even in times of Brexit, industrial strategy and modest devolution, it is hard to see this changing – the mantra of 'excellence' is too powerful a weapon in the hands of those who benefit most from it. But the contributors to this volume show very clearly that excellence was never the only driver of UK science policy, nor even was it usually the major driver.

Whilst there has been much continuity in areas of UK science policy, and whilst we undoubtedly do see some problems and responses recur, perhaps this is the most important contribution history can make to thinking about science, technology and innovation policy today - demonstrating that things can be different in the future by showing how they were different in the past. Science policy debates have often been constrained by pop histories and mythologies, and narrowed by fearful anecdotes and linear, closed system thinking about how innovation happens. Whilst science policymakers and analysts alike have fretted over 'translation' and 'commercialisation' over the past three or four decades, our economy and society have changed profoundly. Brexit implies further change. The very real challenges the UK faces in 'realising its potential'[13] over the next few years surely demand a new reassessment of where we have been and where we are going.

12 Such as the Royce Institute for Materials, with its main 'hub' in Manchester and 'spokes' in Sheffield, Leeds and Liverpool – and further spokes at Cambridge, Oxford and Imperial College. To be clear, the Crick has no spokes.

13 To take the title of the 1993 STI White Paper.

# What can be learned from government industrial development and research policy in the United Kingdom, 1914-1965

Dr Sabine Clarke
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**Central Points**

- The Department of Scientific and Industrial Research wished to bring science and industry in Britain into a closer relationship. One key way it did this was to train increased numbers of scientists in research methods.
- The creation of the DSIR was controversial at the time, and hostility to its creation shaped the ways it described its work.
- We should avoid reading into the past our contemporary understandings of what key terms such as 'fundamental research' mean. When the DSIR said it prioritised 'fundamental research', it was not referring to 'pure science'.
- The term 'fundamental research' was often used to refer to the study of widespread, general phenomena rather than more specific issues. The DSIR did not claim that fundamental research was the necessary first step in producing innovation.
- We need to understand the political utility of key terms in science policy. The DSIR used the idea of 'fundamental research' as part of a rationale for greater state involvement in the work of British industry. In this rationale, government could fund 'fundamental research' as this was the investigation of general problems that affected a whole sector of industry. The resolution of more specific manufacturing problems should be dealt with by individual firms. This arrangement allowed the DSIR to avoid the accusation that its work might favour one firm over another.

Government policy focussed on promoting science for industrial development between 1914 and 1965 was focussed on the funding and promotion of research as one of a range of scientific and technical activities that fall under the rubric of science. The prioritisation of research, often 'fundamental research', was an attempt to promote the in-depth exploration of industrial materials and processes. Additionally, it represented a solution to the issue of finding a politically acceptable mode of state intervention in the industrial sphere. The promotion of fundamental research should be seen as both an attempt to ensure that long term and in-depth investigation of basic scientific principles was not neglected, and also as a political strategy.

Understanding that terms such as 'fundamental research' could have different meanings in the early twentieth century to those they now carry is important if we are to avoid making assumptions about the sorts of activities that were prioritised by policymakers in the past. We should also recognise that actors knew the difference between the public claims of annual reports, and policy documents, and the reality of science in practice. The purpose of public discourse concerned with the nature of government science could be the need to legitimise new institutions or government action, or support the autonomy and professional standing of scientists, rather than accurately describe the work of the laboratory.

## The Department of Scientific and Industrial Research

The Department of Scientific and Industrial Research was created with the stated aim of bringing science and industry in Britain into a closer relationship. It had its origins in discussions at the Board of Education about the need to increase the funding of scientific research in British universities. The outbreak of war gave plans to create a new government department to organise Britain's scientific resources greater urgency as Britain faced a shortage of some key military materials that had previously been provided by German firms, and the result was the creation of the DSIR in 1916. The war therefore provided an opportunity to create new state machinery to fund and organise scientific research.[14]

The DSIR achieved its aim of bringing scientific research and industry closer together in a number of ways, none of which were predominantly focussed on fostering innovation. One area of work of the DSIR was the provision of grants to scientists in British universities. The DSIR believed its role as a body that organised science for the benefit of the country meant it had a duty to consider the provision of scientific manpower. The belief was that if industry was to gain greater benefit from British science, then government needed to ensure an adequate supply of people trained in research methods.

The DSIR supported university projects in a range of fields including physics, chemistry, biology, metallurgy and engineering. The priority when it came to allocating funds was less the support of work that had a direct bearing on industrial problems, and more the desire to identify the most capable individuals and help develop their skills as researchers. This aspect of the work of the DSIR illustrates clearly the way in which the department distinguished between 'science' in a general sense, and 'research'. The DSIR was not aiming to promote science in British universities but was focussed more specifically on promoting the activity of 'research'. The objective was to train individuals so they were equipped to undertake in-depth and fundamental studies of materials and processes.[15] This research would offer British firms the opportunity to exert greater control over their work; to improve their products and methods of manufacturing.

Apart from ensuring a supply of scientists trained in research methods, the DSIR also wished to encourage firms to invest in research themselves. The DSIR believed that industrialists could be quite ignorant of what constituted "research", complaining of the "loose use of industrialists and company promoters of the word 'research' to describe experiment by trial and error."[16] A need to educate industrial managers to see that an easily resolvable technical manufacturing problem was not actually 'research' as the DSIR defined it, led to the creation of the Research Association scheme in which firms that worked in a particular sector clubbed together to fund research to their mutual benefit. Some of the first associations included the British Iron Manufacturers Research Association, the British Photographic Research Association, and the British Research Association for the Woollen and Worsted Industry. In order to encourage the formation of these research associations, the British government created the Million Fund through which it contributed a pound for every pound paid to fund scientific work by industry, up to a limit of £1 million. By the time the Million Fund had been depleted in 1932, there were twenty research associations, and most of these were given further funds by the state. Many of these associations acquired their own laboratories, as well as funding work done at universities and colleges.

14 Board of Education, "Scheme for the Organisation and Development of Scientific and Industrial Research," Cd. 8005 (1915), British parliamentary paper (HMSO, London). The advisory council formed in May 1915 consisted of Sir George Beilby (industrial chemist and chairman of the Royal Technical College, Glasgow), Raphael Meldola (industrial chemist and head of Finsbury Technical College), Richard Threlfall (industrial chemist), William Duddell (consulting engineer), J. A. McClellan (chair of experimental physics at University College, Dublin), Bertram Hopkinson (engineer and professor of applied mechanics at University of Cambridge), and the mathematician and physicist, Lord Rayleigh. See Ian Varcoe, "Scientists, Government and Organised Research in Great Britain, 1914–1916: The Early History of the DSIR," Minerva, 1970, 8: 192–216, p. 207.

15 *DSIR 3rd Annual Report*, Cd. 9144 (1917–1918); *DSIR 4th Annual Report,* Cmd. 320 (1918–1919). On the difficulty of trying to categorise scientific work see DSIR 17/81, 10/4/18, p. 73, National Archives, London.

16 DSIR 17/5, 11/4/16, National Archives, London; and *DSIR 2nd Annual Report*, Cd. 8718 (1916–1917), p. 14.

The third function of the DSIR was oversight of a number of national laboratories and research boards such as the National Physical Laboratory and the Food Investigation Board. These were organisations that were said to deal with problems that were of such widespread significance that it was not reasonable to expect a particular business or sector to fund research in this area, and therefore government should assume responsibility. The NPL for example, had the job of determining accurate physical and electrical standards and this was an appropriate function for a laboratory funded by government as it was work of national importance, underpinning all other industrial and academic endeavours.[17]

## A Pervasive but Problematic View of the DSIR

Historians have often presented the DSIR as the first major commitment by the British government to the state funding of science, and seen it as significant for inaugurating the original research council system that subsequently included the Agricultural Research Council and the Medical Research Council. Of particular interest to many is the fact that the DSIR was constituted as a government department but was governed by an advisory council of scientists and a staff of civil servants drawn from the Board of Education. The DSIR had no Minister, but reported to Parliament through the Lord President of the Privy Council. The MRC and ARC were not constituted as government departments in exactly the same way but were headed by a council of scientists and also reported to the Lord President. The claim that is often made is that this arrangement worked to give the research councils a special position in which they were in receipt of state funds but were not subject to state control. In other words, this arrangement is judged as important for affording a great deal of autonomy to scientists when it came to making decisions about funding scientific research in Britain. Linked to this is the notion that the research councils pursued programmes of 'pure science', or 'fundamental research', in which the nature of the work that was undertaken was largely determined by the interests of the researcher. 'Pure science' was said to be research that was done without thought of practical matters, but the knowledge it generated was an important source of new applications.

There are a number of problems with this interpretation of the work of the DSIR and to some extent the ARC and MRC as well. In its public reports, the DSIR emphasised the need for expanded programmes of 'fundamental research' in British universities, in industry and at institutions such as the NPL. There has been a tendency by historians to assume that when actors in the past used the term 'fundamental research' it meant largely the same thing as pure science, namely work concerned with the acquisition of scientific knowledge, without thought of application.[18]

## A More Contextual View of the DSIR

The DSIR in fact distinguished between fundamental research and pure science in its reports, stating that unlike pure science, fundamental research had a practical aim. It also defined 'fundamental research' in other ways, so that the term had a range of meanings in the reports of the department. Grasping the meanings of 'fundamental research' as used by the DSIR is important if we are to understand the relationship between scientific research and the development of British industry that was promoted in the early and mid-twentieth century. Paying close attention to the use of the term 'fundamental research' also reveals the rhetorical intent that often lay behind the use of the term; it was more than a description of a particular mode of scientific activity. An exploration of

17 *DSIR 5th Annual Report*, Cmd. 905 (1919–1920), pp. 18 and 24.

18 Ronald Kline, "Construing 'Technology' as 'Applied Science': Public Rhetoric of Scientists and Engineers in the United States, 1880–1945," Isis, 1995, 86:194–221, pp. 216 and 217; Benoˆıt Godin, "Measuring Science: Is There 'Basic Research' Without Statistics?" *Social Science Information*, 2003, 42:57–90; and Jane Calvert, "What's Special about Basic Research?" *Science, Technology and Human Values*, 2006, 31:199–220; Timothy DeJager, "Pure Science and Practical Interests: the Origins of the Agricultural Research Council, 1930–1937," *Minerva*, 1993, 31:129–140. For the information from the MRC files, see FD 2/1, and FD 2/5, National Archives, London.

the political utility of the term is important in revealing the wider negotiations that accompanied the establishment of a new sphere of state action. It allows us to see how science policy is not merely informed by reference to abstract and rational models involving the fixed and unchanging categories of 'pure' and 'applied science'.

One key issue that influenced the way in which the DSIR chose to present its work was the response to its creation from some British scientists and industrialists. The DSIR was the subject of a hostile campaign by a group of eminent scientists that was played out in books, articles and the pages of *Nature*. This lobby mobilised a rhetoric intended to ensure that scientists in Britain retained control of the research agenda in the face of what was perceived as increasing control of research by the state. The fact that the DSIR was a body administered by civil servants prompted the claim that scientific research was passing out of the hands of scientists into the hands of bureaucrats and industrialists, and this would lead to the dominance of applied problems.[19] Such concerns prompted Richard Gregory, the editor of Nature, to launch a strident defense of the ideal of pure science as the central activity that advanced scientific knowledge and the origin of all useful invention.[20]

In the case of industrial managers, there were reports that this group saw little need for a new department that promoted science for industry. Despite claims that the outbreak of war demonstrated the need for British firms to become as scientific as those in Germany, it seems that many British firms did not feel they were in crisis. As the chair of the Advisory Council of the DSIR, William McCormick, expressed it, "so long as an industry is prosperous it is very apt to take short views and feel little enthusiasm for systematic research".[21] In addition, some firms expressed their suspicion of government attempts to encourage them to form associations among themselves, believing that cooperation in the funding of research would diminish the advantage held by individual companies.

## Understanding fundamental research

*Fundamental research as pure science with a practical aim*

The success of the work of the DSIR depended upon the cooperation of industrial managers and scientists at British universities, as well as the approval of the public and Parliament. A need to gain the endorsement of the rather different audiences that existed for the work of the DSIR can be seen to have shaped the ways in which the department defined the nature of fundamental research and the relationship it promoted between state-funded research and the development of British industry.

When it discussed the work of university scientists the DSIR claimed that research in the university was a form of pure science but qualified this by suggesting that this work could be inspired by the need to resolve practical problems in industry – it was pure science, with a practical aim, and this activity was best described as fundamental research. A good example of this type of work was that undertaken in the laboratories of industrial research associations, where scientists were said to examine the most in-depth, underlying, or indeed, fundamental issues that would contribute to scientific theory and lead to advances in knowledge. This work was said to be both scientifically important and practically useful, and the starting point for this fundamental research was the need to address a practical issue.[22]

The DSIR can be seen in the pages of its reports responding to the concern raised by some scientists by defining fundamental research as a species of pure science, but one that had a practical motivation. Fundamental research was described as comprehensive, in-depth, and time-consuming,

19 Andrew J. Hull, "Passwords to Power: A Public Rationale for Expert Influence on Central Government Policy-Making: British Scientists and Economists, c. 1900–1925" (Ph.D. diss., Univ. of Glasgow, 1994), pp. 107–115 and 82–83.
20 Richard A. Gregory, *Discovery or The Spirit and Service of Science* (London: MacMillan, 1916), p. 235.
21 DSIR 17/5, 11/4/16, National Archives, London; and *DSIR 2nd Annual Report*, Cd. 8718 (1916–1917), p. 14.
22 *DSIR 1st Annual Report*, Cd. 8336 (1915–1916); and DSIR 2nd Annual Report, Cd. 8718 (1916 –1917).

and the industrial manager was warned not to demand quick answers.[23] The suggestion that researchers must be given ample time and space in order to pursue their investigations seems gauged to reassure scientists engaged in industrial research that they would be awarded freedom and autonomy in their work. At the same time however, the department could not suggest that it would fund research that would satisfy the curiosity of the individual scientist, first and foremost. It was unlikely that British manufacturers and the public would be easily convinced that these kinds of scientific projects could benefit industry.

In stating that its objective was the encouragement of more fundamental research, rather than pure science, the DSIR was able to claim that the activities prosecuted under its aegis were done with practical goals in mind, and not merely to satisfy the whim of scientific researchers. The need to reassure industrial managers that the science they supported financially was primarily aimed at bringing benefits to the firm is shown by a comment made in 1925. In a discussion of ceramics research undertaken on behalf of the British Refractories Research Association, it was stated that better explanation of this work in lay terms should be distributed to firms comprising the research association "to convince members that they are not subsidising a corps of scientific dreamers".[24]

### *Fundamental research as general research*

When it came to promoting the idea of research to industrialists who were contemplating the creation of a research association, the DSIR invoked a different set of meanings for the term 'fundamental research'. If definitions of fundamental research in the reports of the DSIR indicated that this work was done with a practical goal in mind, in ways that prevalent definitions of pure science did not, then we might ask what relationship the DSIR thought should develop between fundamental research and problem solving. Applied science was said to be nothing but the application of knowledge gained through pure science, and therefore pure science was the essential prerequisite for problem solving. In contrast, fundamental research was said by the DSIR to be a method for understanding widespread underlying phenomena in contrast to the solution of narrow and discrete problems. The relationship between fundamental research and other types of investigation presented most often by the DSIR was one in which fundamental research established knowledge about the materials and processes common to a group of firms, leaving individual companies to deal with problems that were specific to that particular business. Fundamental research was work that established universal theories or laws that remained constant from company to company within a particular sector of industry; it was general research. By proclaiming that the work of the DSIR was to encourage general fundamental work in industrial research, the DSIR could avoid the suggestion that public grants favoured the interests of one individual firm over another:

"Research undertaken exclusively for the benefit of one among a number of competing firms either by a public institution or at the cost of the State is indeed always likely to give rise to difficulties. Universities and public Research Institutes are maintained by endowments and public funds for the common good, and any arrangement which gives exclusive rights or benefits to a single firm as against others in the same industry is not easy to reconcile with the public advantage."[25]

Characterising fundamental research as either broad, general, or as background research, was important if the policy of the DSIR was to be compatible with liberal political economy.

In addition to the cooperative research done by the research associations, the DSIR claimed a further category of research in which it should take an interest. This work was described as "sufficiently fundamental to affect a range of interests wider than a single trade" while also having a "direct bearing on the health, well-being, or the safety of the whole population". Described as the most

23 *DSIR 1st Annual Report*, Cd. 8336 (1915–1916), p. 29.
24 DSIR 10/6, "Report of the committee appointed to inspect the British Refractories Research Association," National Archives, London.
25 *DSIR 1st Annual Report*, Cd. 8336 (1915–1916), p. 31.

fundamental of all the research sponsored by the DSIR, the work included food preservation research, fuel research, research into building materials, operating the Geological Survey and Museum, and the work of the National Physical Laboratory.[26] There was a clear sense in which this work was classified as 'fundamental' because it examined some of the basic necessities of all domestic and industrial life such as food, coal, and precise electrical and physical standards. It was research that was of the widest possible use and because so many national activities depended on these things, it was important. Again, the very fundamental quality of this work, which made it both extremely important and of such a scale that it was beyond the scope of an individual company's responsibility, provided a rationale for state intervention and support. The general nature of fundamental research meant that it could be done at the expense of the taxpayer. This fundamental research was work that was so general that plenty of room was left for the individual firm to investigate particular implications. In the case of fuel research, which involved a survey of the characteristics of the nation's coals, the following was stated in 1919: "The investigations of the Fuel Research Board, however successful they might be, will only establish fundamental data and broad generalisations as a basis for particular applications. And these applications must be worked out by the industries themselves."

### *Fundamental research as a public representation of scientific goals*

The term fundamental research therefore had a range of meanings, none of which were equivalent to pure science. While fundamental research was often described as in-depth and concerned with established fundamental knowledge about the composition of materials or the chemistry of manufacturing processes, it was defined as research that was inspired by a practical need. It would be wrong therefore to see this moment in British history as somehow representing a golden age of pure science where scientists receiving public funds were free to pursue their research in any way they saw fit.

Beyond this, we can see that the DSIR used its annual reports to negotiate and legitimise its position as a new government entity that aimed to organise science in Britain so it had a closer relationship with industry. There were a number of obstacles in the way of this ambition. The DSIR needed to reassure scientists that their work would not be directed by government officials and industrialists solely towards the resolution of practical problems. There was also a need to convince British firms that investment in research would be worth their while and bring tangible benefit. Finally and importantly there was a need to avoid the accusation that the work of the DSIR favoured the interests of one firm over another, or did nothing but line the pockets of businessmen.

These issues informed the ways in which the DSIR presented its work in its public statements and shaped the definitions of the term 'fundamental research'. In private, the department acknowledged that the emphasis it placed on fundamental research in its reports did not mean that it would insist that Research Associations limit themselves to this activity. In a letter to a cotton manufacturer in 1918, one official stated that the government had "no intention of limiting the work of the Associations to 'pure' or 'fundamental' or 'direct' research because in practice it was "impossible to draw the line".[27] This comment confirmed that the term "fundamental research" was used more for its rhetorical value than for any real attempt at classification of scientific work. Categories of 'pure science' or 'fundamental research' were of little importance in determining the allocation of funds by the DSIR but they were very important in its public representation of goals during its early years.

26 DSIR 2nd Annual Report, Cd. 8718 (1916 –1917), p. 17; DSIR 5th Annual Report, Cmd. 905 (1919 –1920), p. 18; DSIR 5th Annual Report, Cmd. 905 (1919–1920); and DSIR 7th Annual Report, Cmd. 173 (1921–1922), p. 12. The DSIR took over the National Physical Laboratory (NPL) from the Royal Society in 1918. The NPL's work was initially concerned with the elucidation of physical standards, and research into optical glass, metallurgy, aeronautics, and radio. As well as devising its own research programs, during the 1920s and 1930s the NPL carried out work through the coordinating boards on behalf of industry, the DSIR's research boards, and other government departments (very often including service departments such as the Admiralty).

27 *DSIR 16th Annual Report*, Cmd. 3989 (1930–1931), p. 14; and DSIR 17/81, letter from Heath to Mr. Abbott, 10/4/18, National Archives, London.

## Conclusion

The DSIR aimed to increase the supply of scientists in Britain that were equipped with research skills, to encourage industry to invest in research and to directly support research in areas considered to be of benefit to the nation such as food and fuel. The various definitions of fundamental research that can be discerned in the reports of the DSIR can be read as a justification for the new, and bigger, role of the state in the industrial life of Britain that was represented by the creation of this department. By training scientists and focusing on the most general and fundamental problems in science, the DSIR was claiming a space for government science in which this was delineated from technical and scientific activities that were rightly the responsibility of the individual company. Public funds could be spent on supporting British industry, but it required careful distinctions between the role of the state and the remit of the firm and the use of the term fundamental research was key to negotiating this.

# Science policy since the 1960s

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**Central Points**

- In the postwar period until the 1990s, R&D in the UK was mainly financed by government but performed by industry, and half was military in orientation. Even during the Cold War, the preponderance of defence research was seen as problematic. Only rarely was the balance of civil and defence research considered together, but this did not amount to a unified science policy. In the UK 'science policy' was not seen in terms of a single, comprehensive programme.
- The categories used to describe, and increasingly measure, science not only matter but are also not neutral. The linear model was a widespread way of thinking about the justification for funding science, despite its inadequacy.
- Not enough effort has been made to understand and improve the ways that problems are articulated in ways that invite the successful attention of science.
- The capacity of government to look forward has to be actively cultivated. It was only when the capacity for future trend analysis was expanded that anthropogenic climate change first became a topic for government deliberation.
- There was an important switch in science policy in 1987: the pivot of government funding towards the science base (now branded 'curiosity-driven research') and a cutting of government-funded 'near-market' support. This switch essentially ended an active, interventionist, science-based, publicly-funded industrial strategy. Greater openness and greater access to decision-making processes would have helped avoid this mistake.
- A set of ideal characteristics of a Government Chief Scientific Adviser can be listed. Science advisers need to be in as close – face-to-face – proximity to politicians as possible if evidence-based advice is to shape policy.
- The snapshot picture from the 1990s to the present is that R&D in Britain is mostly funded by, and mostly performed in, the private sector. Following BSE, public trust in scientists remained a subject of anxious debate (despite little quantitative evidence for a significant decline compared to other professions). Nevertheless, the insulation of the expert advisory system and the disasters of public communication encouraged the movement, already underway, away from public understanding of science towards public dialogue around emerging and controversial science-based issues. The scholarly work of social scientists and of policy practitioners who reflect on their experience in dialogue with scholars provide useful analysis.

I am a historian of science and technology, with research interests in the relationship between science and government. My most recent project has been a study of central government documents, recently released at the National Archives, concerning science and science policy during the Thatcher administration.[28] In the following I draw out some lessons from the study of the history of science policy in the 1970s, 1980s and 1990s.

28 Jon Agar, *Science Policy under Thatcher*, London: UCL Press, June 2019.

## Background

First, let's follow the money. In 1939, the United Kingdom spent £20m (around £1b in today's pounds) on research, of which half was defence research. Expenditure increased during the Second World War and was sustained during the Cold War. The logic here was that nuclear weapons presented an existential threat, and the slow processes of research and development had to be conducted in advance of conflict. In effect science was permanently mobilised. Between the 1930s and the 1960s, expenditure by government increased to £412m (1964-1965), the relative contribution of industry increased to one third of the total, while defence R&D continued to run at half of the national effort. Public funds would also partly be directed towards private industry. *Overall, then, in the postwar period until the 1990s, R&D in Britain was mainly financed by government but performed by industry, and half was military in orientation*. After the end of the Cold War, defence R&D declined as a proportion of overall R&D. By 2008, for example, UK gross domestic expenditure on R&D stood at just over £25b, shy of 2% of GDP, and 90% was civil. Even so the proportion of defence spending on research was still relatively high (as it was in France and the United States) compared to, say, Germany, Japan and Italy. The predominance of military R&D was, in international comparison, a stubborn, and as we shall see sometimes unwelcome, 'victor' effect. Furthermore, the contribution of industry-financed R&D, especially foreign companies funding science conducted in the UK, has increased. The snapshot picture *from the 1990s to the present, therefore, would be that R&D in Britain is mostly funded by, and mostly performed in, the private sector.*

Second, *the categories used to describe, and increasingly measure, science not only matter but are also not neutral*. Each category carries a baggage of assumptions, and when the category is used these assumptions should not go unquestioned. Historians have tracked the changing meanings of terms such as 'basic research', 'applied science', and 'innovation'. Up until the 1980s, science policy indicators largely concerned inputs, typically monetary investment or measures of human resources.[29] 'Research and development' (which only began to be measured systematically, for example by the OECD, according to international standards from the 1960s) and 'scientific manpower', are cases in point. From the 1980s, output indicators – numbers of patents, technological balance of payments, levels of high technology trade - became more prominent. This turn reflected *an increased attention to maximising the economic return from investment in science.* However, as the language of 'inputs', 'outputs, 'basic' and 'applied' suggests, these categories were assumed to connect to each other in a predominantly linear way.

## Lessons from the 1970s
*The linear model did exist*

In 1972, the UK, alongside Denmark and the Republic of Ireland, were negotiating to join the European Communities, and Sir Brian Flowers, physicist, chair of the Science Research Council, and a seasoned operator of the machinery of government for science, was sent to observe the scene. The European Commission had set out, with a fresh and distinct excitement, its belief that "the coordination and fostering ... of scientific research and technological development should be one of the first priorities for the enlarged European Community". Here's how Flowers, the diplomat, reported back to HMG:

> *"The meeting assembled for dinner at the Hilton Hotel the previous evening. My neighbours expressed great interest in the British attitude towards science and technology policy and I failed to get them off the subject. I took our usual line that in first approximation there was no such thing as science policy in general, but only policies for national objectives; but that in second approximation the task of matching vertical and horizontal objectives was sufficiently difficult and important to be called a policy.*

29 Benoît Godin, *Measurement and Statistics on Science and Technology*, London: Routledge, 2005, p. 120.

> *I found that quite a number of people still think in terms of an overall science policy, and believe in the linear model: research → technology → industrial innovation → profits.”*[30]

Flowers’ response illustrates several important ways in which science policy was framed. First, he was right to say that *in the UK ‘science policy’ was not seen in terms of a single, comprehensive programme.* Instead, policies were pursued in different silos, by different departments, for different purposes. Only as a second order phenomenon, say when one objective clashed with another, were more general science policy matters broached. Second, Flowers had not only clearly heard many of his fellow Europeans conceiving the relationship between research, technology and profitable innovation as a linear causal chain – and calls it the ‘linear model’ – but he was also familiar enough with this framing of science policy from home. While it has been criticised for decades, and indeed has always been a straw man argument, in other words something that only misguided others are said to hold, *the linear model was still nevertheless a widespread way of thinking about the justification for funding science. Funding research would lead ultimately to economic growth*.

Furthermore, a third general observation about how science policy was pictured can be made. The European Commission’s position paper not only argued that funding research was the route to profitable innovation, it also stressed that science and technology were important for solving society’s problems: they should contribute to the “security and well-being of society, conserve or improve the environment, and provide remedies for the undesirable fall-out from technical advance”.[31] Yet, in a way quite typical of discussions of general science policy, the incoherence introduced by talking both of addressing social needs and the linear model of innovation, remained unresolved. Historical research shows that much of twentieth century science was related to broad areas of problem solving, notably the conduct of war, maintaining a healthy and well-fed population, building technological systems, and civil administration.[32] Even apparently ‘pure science’ was often related to such problem-solving. Indeed categories such as ‘pure science’ were largely devised to protect the status and time of scientists who would be otherwise overwhelmed by problem-solving demands. If there is a general constructive criticism I would offer of science-policymaking, since the 1960s to the present, it is that *not enough effort has been made to understand and improve the ways that problems are articulated in ways that invite the successful attention of science.* One exception was the most controversial intervention into UK science policy of the 1970s: the Rothschild report.

## *Why Rothschild mattered*

Lord (Victor) Rothschild had been recruited from Shell to join Edward Heath’s new ‘think tank’ charged with shaking up Whitehall, the Central Policy Review Staff. Trained at Cambridge in biophysics, and with experience as chair of Agricultural Research Council, in 1971 Rothschild proposed a framework for organising aspects of science policy. He proposed that research for government departments should be organised on a ‘customer-contractor’ principle: the “customer says what he wants; the contractor does it (if he can); and the customer pays”.[33] The customer here was a government department, the contractor would be a laboratory or institute where research was done. Rothschild proposed that chunks of applied research money would be moved from the research councils’ budgets (specifically the Medical Research Council, Agricultural Research Council and the Natural Environment Research Council) to those of the corresponding customer departments.

Rothschild had kicked a hornets’ nest. The Royal Society saw it as an attack on the autonomy of science (often its institutional concern), while others saw the transfer of funds from the research councils to government departments, that is to ministerial control, as a breach of the so-called Haldane Principle.

30 TNA FCO 55/909. Brian Flowers, ‘European policy for science and technology. Notes by BEF who attended by personal invitation a meeting called by the Commission of the European Communities on 2 March 1972’, undated (1972).

31 TNA FO 55/909. Commission of the European Communities, ‘Elements of a common policy for scientific research and technological development’, February 1972.

32 Jon Agar, *Science in the Twentieth Century and Beyond*, Cambridge: Polity, 2012. The term I use to label these areas is ‘working worlds’.

33 *A Framework for Government Research and Development* (Rothschild Report), London: HMSO, 1971.

Some commentators have downplayed the significance of Rothschild. They point out that it was only aimed at a minor category of science (research to support government departments), that the new arrangements for health, agriculture and environment were only those already in place for the much larger sector of defence, or that the reductions in research council funds have long since been more than restored.

However, *Rothschild really did matter for UK science policy, not because of the heat of the initial controversy but because it was a guiding light for future thinking and also for its substantial indirect effects*. First, the language of the market was unmissable, a "business approach to a business matter" said Rothschild, and suggested to later policy-makers a direction of travel towards privatisation. Margaret Thatcher, the minister responsible for science under Heath, had initially been briefed by her department, supported by the Royal Society, to keep the status quo and oppose Rothschild. She emerged from the crucial meeting with Heath and Rothschild at 10 Downing Street on 20 April 1971 agreeing to the "fundamental change".[34] It is a concrete and early policy case where Thatcher became convinced, against establishment views, that markets delivered solutions. In 1979, in her first meeting on science policy with the Cabinet Secretary, John Hunt, Thatcher agreed that Rothschild should continue to be the guide for departmental science policy. Later in the 1980s the privatisation of government research laboratories was described within Number 10 as taking "the contractor/customer principle to its logical conclusion".[35] Second, as Miles Parker has argued, in his analysis of the consequences of Rothschild from the 1970s to the 2000s, the most "important and lasting adverse effect" was "on the ways in which Government interacted with the science community and consequently on the ability of government to access expert advice for policy-making".[36] Specifically, Parker contends that by "making this a commercial transaction, government scientists took on a lot of contract management work at the expense of analysis and advice, while the research community became more focussed on contractual delivery than dialogue with users". In other words the directly intended advantages of Rothschild – the user of research being encouraged to state its needs and problems explicitly, and increased accountability delivering efficiency and savings – were outweighed by indirect disadvantages: government scientists too busy managing contracts to provide essential high-quality advice and researchers with narrowed concerns.

## *The capacity of government to look forward*

The environment became a major political issue in the 1970s, and it did so alongside a gathering interest in futurological methods. The Club of Rome's *Limits to Growth*, which used computer modelling techniques developed at MIT to predict economic turbulence, even collapse, within decades was circulating in policy networks in 1971. It was derided in Whitehall: Solly Zuckerman, formally retired as chief scientific advisor but an influential voice up to the 1980s, called it "nonsense words"; Peter Walker, Environment minister, called it "extreme, apocalyptic and naïve". However, while the application was considered sloppy, the methods – computer simulation, long future time-scales – fascinated policy advisers. Heath asked his chief scientific adviser, Alan Cottrell, to investigate, and Cottrell proposed that the capacity of government be increased to broaden analysis of population, economic growth and ecology, in 'width and depth' but most crucially in government's capacity to look forward in time. An Official Committee on Future World Trends was set up in 1972, as part of the Cabinet apparatus. Future World Trends became a forum for revealing and discussing topics such as supplies of food and raw materials, energy, population and pollution over spans of many decades, up to a century in the future. *It was in this capacity for future trend analysis that anthropogenic climate change first became a topic for government deliberation*.[37]

34 TNA PREM 15/408. Robert Armstrong, 'Note for the record', 21 April 1971. See: Jon Agar, 'Thatcher, scientist', *Notes and Records of the Royal Society* (2011) 65, pp. 215-232.

35 TNA PREM 19/2252. Guise to Thatcher, 10 March 1987.

36 Miles Parker, 'The Rothschild report (1971) and the purpose of government-funded R&D—a personal account', *Palgrave Communications* (2016) 2, Article number 16053.

37 Jon Agar, '"Future forecast—changeable and probably getting worse": the UK government's early response to anthropogenic climate change', *Twentieth Century British History* (2015) 26 (4), pp. 602-628.

Anthropogenic climate change was first raised between departmental experts in 1974, and the Met Office (then sceptical) produced the first Whitehall discussion papers on the subject, for Future World Trends, in 1975. By 1979, well before Thatcher's 1988 Royal Society speech, usually taken to be the start of serious government attention to climate change, HMG had prepared a report on the subject. The lesson of this surprisingly early recognition of perhaps the major issue of our age is that *the capacity of government to look forward has to be actively cultivated.* To some extent this has happened, with the Foresight panels, and other mechanisms, introduced in the 1990s.
However, the fate of climate change as a political issue – its political moment of potential action, the completion of the 1979 report, contingently coincided with the abrupt changes in direction of the new Conservative administration and was lost – also reminds us that *science-related policy issues are often trumped by higher priorities!*

### Lessons from the 1980s

Science policy in the 1980s in the UK can be divided into two periods. The first, up until 1987, was marked by rising tensions caused by cuts in public spending, criticism of the level of resources absorbed by both defence R&D and European 'Big Science' projects, and dissatisfaction with large-scale programmes supporting applied research in new technologies as part of an inherited industrial strategy. The second, from 1987, was the result of a new science policy, which ushered in cuts in government-funded 'near-market' research (thereby ending a key component of an industrial strategy), and, the other side of the same coin, an embrace of 'curiosity-driven research'. The key players - in order of influence - were the Prime Minister, the political analysts of the Number 10 Policy Unit, central departments (defence, trade – then DTI, environment, education, Treasury) and their ministers, chief scientific advisers, the heads of the research councils, industrialists (via the Advisory Council for Applied Research and Development, ACARD), and, lastly, the academies and academics.

#### *Too much defence research?*

The major public spending cuts affecting science, especially in universities, were introduced in the March 1981 budget. While in the following years research council funding was ring-fenced, the other side of the 'dual-support' system, funding via the University Grants Committee that underpinned facilities, academic wages and infrastructure, was reduced. In September 1983, Keith Joseph, minister for education and science, supported by David Phillips, leader of the research councils, and the Royal Society, wrote to Thatcher on the necessity of "maintaining the strength of the science base".[38] Robin Nicholson, Thatcher's second, most politically-attuned chief scientific adviser, told her bluntly that "the excellence of our science base is starting to be eroded through insufficient funding".[39] (Notice the rhetorical work being done by categories here: 'base' was not basic as in simple, it was 'base' as in 'take away the base and the edifice will fall'.)

The initial appeal for more funds failed. Thatcher's response, to quote Nicholson, was: "I believe in science and technology but they cannot be set up on a pedestal with a private pipette to the Treasury (her phrase)."[40] Instead, the internal debate became one about the balance of civil and defence research spending. Joseph, at education, pushed to transfer funds. Heseltine, at defence, pushed back. Heseltine here was being a good departmental minister, defending turf and resources. However, what is notable is that the prevailing analysis, including those from Thatcher and the Number 10 Policy Unit, was that, as the Unit's then head, Ferdinand Mount, put it: *"Our whole economy is distorted by the present preponderance of research on defence".*[41] And this was during one of the peaks of the Cold War. One lesson here is that *occasionally the balance of civil and defence*

38 TNA PREM 19/1369. Joseph to Thatcher, 15 September 1983.
39 TNA PREM 19/1369. Nicholson to Thatcher, 13 October 1983.
40 TNA ED 273/111. Nicholson to Hancock, 24 October 1983.
41 TNA PREM 19/1369. Mount to Thatcher, 18 October 1983.

*research were considered together, but this did not amount to a unified science policy.* Nothing much had changed since Flowers' 'first approximation' of no science policy from 1972. Indeed, in this immediate case, nothing was resolved.

## *Big Science problems*

One of the main trends of twentieth-century science has been the increasing scale and expense, at the top end, of science. Ground-breaking nuclear physics experiments that were typically lab-table-top scale in the 1910s filled large buildings by the 1950s. In September 1983, the mathematician John Kingman (father of the current chair of UKRI), reviewing the choices between cutting defence R&D, civil research grants or central facilities, raised the possibility of axing the Spallation Neutron Source (now ISIS), just completed at Harwell. He did not mention CERN. Yet when the issue came to a meeting of ministers the following month, Thatcher reportedly said:

> *"The Science Vote and the Research Councils have been protected for 10 years but have done nothing to manage their cash limits. There has been no real shift towards useful science and money is still lavished on grand but useless projects such as CERN. At the same time other nations have benefitted from our science because our University scientists are too toffee-nosed to get involved in applications. We can no longer afford to do science for prestige, it must be science for economic benefit."*[42]

The expense of keeping at the forefront of fundamental physics was such that, by the 1980s, the UK could not afford a top-of-the-range national facility, and international collaboration, such as the European laboratory CERN, was essential. Yet international Big Science was vulnerable: costs were beyond national control, and increased commitments were at the expense of national spending under a capped budget (this problem continued, and would be somewhat contained by the establishment much later of a separate Science and Technology Facilities Council in 2007). Furthermore, Thatcher disliked CERN in particular as prestige-driven science, a centre for 'useless' science devoid of application, and for being defended by the French because, she underlined, it was "largely on French soil".[43] In public, the line was that unless CERN made efficiency savings, the UK would withdraw. In private, it was clear that the issue was about more than sound management of budgets. Other prejudices were at work. International, especially *European Big Science, while it strained government resources, had a complex politics in which were mixed issues of nationalism and expectations of commercial return from science.*

## *How we lost an industrial strategy*

Thatcher's government inherited numerous schemes that supported, directly or indirectly, 'near-market' research, and further proposals were made and adopted in the early 1980s. *Collectively they contributed a substantial part of an industrial strategy.* Examples included the Microelectronics Industry Support Programme (£70m over five years), the National Enterprise Board's support of the transputer firm Inmos, much defence research, and the Alvey programme (£350m, between 1982 and 1987, for next generation computing). Furthermore, patents derived from publicly-funded research were held and exploited through the National Research Development Corporation, an entity that dated from the Attlee years. Such use of public funds displeased Thatcher and many – but not all, Michael Heseltine being an exception – of her ministers and political advisers.

Action did not come quickly. *Only when multiple tensions came to a head were they addressed by a single switch in policy.* These tensions, in addition to hostility to publicly-funded industrial R&D programmes,

42 TNA ED 273/111. Thatcher's words, speaking on 19 October 1983, and quoted in Nicholson to Hancock, 24 October 1983.
43 TNA PREM 19/1369. Thatcher, handwritten comment on telegram, Paris to FCO, 20 January 1984.

included accusations that academic researchers lacked entrepreneurial zeal, failing to secure patents (especially in the case of monoclonal antibodies), and that industry was risk-averse. Contingency also played a part: Heseltine's resignation in 1986 removed a powerful, countervailing voice from Cabinet.

1987 was the year in which Thatcher's 'policy for science' changed. Indeed, it should justly be called the first Thatcherite science policy. Three things happened. First, led by her chief scientific adviser, John Fairclough, the machinery of 'policy for science' was reformed and centralised, enabling stronger control. Second, the Advisory Board for the Research Councils published *A Strategy for the Science Base*, which called for a three-tiered structure with a few research intensive universities distinguished from mere teaching centres, and a more mission-oriented approach. It was also evidence-based, drawing on a deepened, quantitative grip on science indicators. While the given justification for the *Strategy*, the efficient and restrained use of public funds, might seem to square with the aims of Thatcher's manifesto, the truly Thatcherite science policy was actually devised in opposition. Specifically, the third event of 1987 was the ascendancy of the science policy advice of George Guise, of the Number 10 Policy Unit, over that of the chief scientific adviser (as well as the ABRC and ACARD). Guise agreed with the Cambridge molecular biologist Max Perutz's furious attack on the *Strategy for the Science Base* when he said it stifled innovation by seeking to micro-manage the independent researcher. Guise fed Thatcher with story after story – this was policymaking by anecdotal history of science – to argue that maximum economic benefit came, in the long run, from freely-conducted, undirected pure science, while industry underinvested in research because public-funding of 'near-market' research had crowded it out. *Therefore, Guise argued, government should enthusiastically fund pure science (now branded 'curiosity-driven research') and cut 'near-market' support, essentially ending an active, interventionist, science-based, publicly-funded industrial strategy.* Science policy from the 1990s to the 2010s, from renewed investment in the 'translation' of applicable research to the announcement of a new industrial strategy, is partly a slow crawl back from decisions taken in 1987.

Such a move deserves the epithet 'Thatcherite' because it was grounded on the values of championing the entrepreneurial individual researcher, cutting public funding, encouraging privatisation (not least of the defence laboratories), and leaving private industry to better judge its own investments, confident that in the cut and thrust of the market it would invest in research. The 1987 shift in policy was not formally announced, but its language and values can be heard in Thatcher's flagship science speech at the Royal Society in September 1988, read in the Department of Trade and Industry's white paper of January 1988, deduced indirectly from the sharply reduced hostility to CERN at the centre of government, but only uncovered in detail through painstaking historical research on primary sources recently released at the National Archives. What is also remarkable about the shift is that it happened against the instincts, advice and evidence of the highest committees of science policy advice.

## *Did it matter that Thatcher had been a scientist?*

Should more politicians have a scientific training? Would it improve science's cause if they did? Why is it, asks, for example, Mark Henderson, Head of Communications at the Wellcome Trust, that politicians do not grasp that increased public funding for science would more than repay its costs in economic benefits? Why do politicians misunderstand, misuse or disrespect empirical evidence? Why can they not learn from scientific values and methods? "The answer lies chiefly in the wider failings of the political classes' understanding and experience of science", he states, adding that "only one of the 650 MPs in the UK's House of Commons was a scientist in his previous career … There is a lack of familiarity with the practice of science, of what it needs to succeed, which blinds politicians to the consequences that their funding decisions will have".[44] Variants of this argument have been offered by the science lobby for over a hundred years.

44 Mark Henderson, *The Geek Manifesto: Why Science Matters,* London: Bantam Press, 2012, p. 147.

Thatcher not only received an Oxford degree in chemistry, but had working experience as an industrial chemist in two companies between 1947 and 1951. She used science as part of her image in her early political career – electioneering photographs posed her in white lab coat. As Secretary of State for Education and Science under Heath, her experience as a working industrial scientist provided a different view of science – perhaps a more typical one – than the one promoted to her by the Royal Society (and indeed her department) during the Rothschild discussions. As Prime Minister, she asked for seminars on the latest science, held at Chequers. During the acid rain controversy, she demanded, and received, lists of atmospheric chemical reactions, while the Norwegian leader Gro Harlem Brundtland connected to her, saying "we scientists must stick together and set an example to other people". *Sometimes a politician's scientific background mattered, in terms of image, knowledge or diplomacy.* But the value of a past career in the sciences can fade. The 1987 science policy switch was a decision that could only have been taken by a politician for whom the experience of being a working scientist was now decades distant. Whereas the 1971 Rothschild decision seemed to be one a scientist who had lived experience in the applied science of private industry might have naturally made, the 1987 'near-market' decision was that of an ideologue-politician now far removed from a working knowledge of science in business. *Scientists-turned-politicians are politicians first.* Also, ultimately, the expertise or an experience of an individual politician mattered less than the organised provision of expert advice.

## *What makes a good chief scientific adviser?*

The role, position and function of chief scientific advisers in government have changed over time. Nevertheless, *a set of ideal characteristics* can be extracted from the reflections of Solly Zuckerman, who played the top role in the 1960s:

1. Offer up sensible, reasoned, dispassionate advice.
2. Be independent of vested interests.
3. Keep in touch (in civil service and in science).
4. Answer requests for information. CSAs play this role in departments.
5. Anticipate information that will be needed, and therefore commission research if necessary.
6. Sometimes (!) manage staff.
7. Should not be excluded from key discussions.
8. Be personally trusted by Prime Minister.
9. Be personally trusted by Cabinet Secretary.[45]

The Thatcher era provides plenty of evidence of how these ideals worked, and did not work, in practice. Thatcher inherited a Chief Scientist, John Ashworth (1976-1981), part of the Central Policy Review Staff, and appointed Robin Nicholson (1981-1985), John Fairclough (1986-1990) and Bill Stewart (1990-1995) as Government Chief Scientific Advisers. Nicholson, in particular, was trusted by his Prime Minister (ideal 8). Fairclough, while not distrusted, did not have so close a relationship, and he barely met Thatcher during the key period when the new science policy was developed; he was "excluded, apart from written comments" for a crucial six months.[46] Given the importance of what was decided in 1987, the lesson here (extending ideal 7) is that *science advisers need to be in as close – face-to-face – proximity to politicians as possible if evidence-based advice is to shape policy.*

45 Attributes 1-7 are extracted from: Solly Zuckerman, 'Scientists, bureaucrats and ministers', speech to the Royal Institution, copy in TNA CAB 134/4854, STO(CS)(84)33, 24 October 1984. Attributes 8-9 are extracted from: TNA CAB 164/1642, Zuckerman to Robert Armstrong, 12 February 1981.

46 TNA PREM 19/2479. Guise to Thatcher, 15 November 1988.

## Lessons from the 1990s

Primary source documents from 1990s are only beginning to be made available to historians, so the specific insights from historians on science policy are lessened. Nevertheless, *the scholarly work of social scientists and of policy practitioners who reflect on their experience in dialogue with scholars provide useful analysis.*

### *BSE: science, politics and publics*

The first cases of 'mad cow disease' were incubating in the 1980s, but it was not until 1996, with the acknowledgement that the disease had been transmitted to humans, as variant CJD, that it became a full-blown controversy. Urgent scientific advice had been provided by the Southwood working party, set up in spring 1988, consisting of a zoologist, a pathologist and a neurologist: BSE had probably spread in animal feed, but it was "most unlikely" that BSE had implications for human health. With the European Community restricting beef exports and BSE cases continuing to rise, the minister for agriculture, John Gummer, appeared on television in 1990 eating a beef burger, saying "when you've got the clear support of scientists who deal with these matters, the clear support of the Department of Health, the clear action of the government, there is no need for the people to be worried."

The official, large-scale inquiry led by Lord Phillips concluded that government policies had been sensible and appropriate, and mistakes concerned communication with the public rather than in how risks were assessed. Sociologists of science policy have gone further. *Jasanoff identifies a distinct national style of science-based decision-making processes (the UK's being discreet and insular).*[47] BSE would, for Jasanoff, be just one example of a general UK pattern. Miles Parker, a practitioner-turned-scholar, notes that, post-BSE, the advice function of chief scientists was reemphasised, a reversal of Rothschild. Zwanenberg and Millstone argue that

> *"the UK government's response to the emergence of BSE failed not just because it did not enable the general public to understand and accept that policy-makers were being sensible, competent and reasonable. It failed, first, because it subordinated consumer protection and public health to an economic and political agenda. Second, it misrepresented the objectives of policy, and the nature of, and grounds for, policy decisions. Third, it sought to maintain those misrepresentations by acquiring, interpreting and representing scientific information and advice in ways that were unscientific and anti-scientific."*[48]

Gummer's ill-advised burger speech would be a plain example of the latter.

The consequences of the BSE crisis were manifold. MAFF ended, merged with Environment, spawning DEFRA. Phillips' findings on advice and advisers were codified by the chief scientific adviser, Robert May, into a form that still circulates as central guidance. *Public trust in scientists remained a subject of anxious debate (despite little quantitative evidence for a significant decline compared to other professions).* Nevertheless, the insulation of the expert advisory system and the disasters of public communication encouraged *the movement, already underway, away from public understanding of science towards public dialogue around emerging and controversial science-based issues.*

47 TNA PREM 19/2479. Guise to Thatcher, 15 November 1988.
48 Sheila Jasanoff, 'Civilisation and madness: the great BSE scare of 1996', *Public Understanding of Science* (1997) 6, pp. 221–232.

### Lessons from lessons from history

History, fundamentally, is a method. With access to primary sources, the views, interests and actions of a diverse set of actors can be reconstructed and lessons learned. Previously hidden aspects come into focus. What we saw at the time is not always what we subsequently find out. In particular, the protagonists, motivations and arguments behind the key shift in science policy in 1987 were not visible, sometimes not even to others within government. *Greater openness, greater access to decision-making processes, would have helped avoid mistakes.*

# What has British science policy really been?

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**Central Points**

- We need to beware of bad history – much is indeed bunk.
- Research policies have been undertaken by multiple agencies and their scope and ambition have changed radically over time.
- Research policies need to be understood in the context of national defence, industrial, economic, and agricultural and other policies.
- In the past, research policies have been seen as a substitute for radical policies that governments did not favour.
- Today perhaps the most important lesson is not to indulge in delusions of grandeur about the quality and significance of British science. Its weight in the world has changed drastically, as has that of British business, and this needs to be understood for the development of an effective policy.

Much discussion of the relationship between history and policy assumes that policymakers are not already exposed to history. In the case of research policy, history is already central to the policy discourse. The problem is that it is largely the wrong sort of history. The quality of the historical and policy discourse around science policy is notably lower than for say economic or defence policy. There is no standard set of historical and policy debates in 'science policy' comparable to those in other policy areas (e.g. Keynesianism versus monetarism) to stimulate discussion. A second problem is that while defence, or health, or economic, policy have reasonably robust common sense meanings, what 'science policy' refers to is not stable, and this matters a good deal. A third specific problem is that, in contrast to defence and economic policy, science policy too often assumes that the UK is an island unto itself, that what applies to the whole world applies to the UK, that the UK is a little world in miniature, a serious error in this area.

Any proper application of history to policy has to be based on an accurate rendering of what actually happened in the past, as well as of what the policy objectives were. This is a tall order for science policy as these questions are only recently being systematically explored, and much of the older literature suffers from systematic flaws which make it unhelpful for policymakers. In this paper I first outline some of the key problems with the older literature,[49] and then tell a brief story of research policy drawing on the work of historians who have transformed our understanding over the last twenty years or so.[50]

By 'science policy', professionals mean policy for scientific research, not all science: it is not about policy for scientific knowledge as a whole (which would include education). They mean policy

49 The best of the old – research council focussed histories are Hilary Rose and Steven Rose, Science and Society (London: Allen Lane, The Penguin Press, 1969); Philip Gummett, *Scientists in Whitehall* (Manchester: Manchester University Press, 1980); Peter Alter, *The reluctant patron: science and the state in Britain, 1850-1920* (Oxford: Berg, 1987); and Tom Wilkie, *British Science and Politics since 1945* (Oxford: Basil Blackwell, 1991).

50 The essence of the change is in recognising the importance of 1) private business and 2) military and departmental research of the state. See, for the encapsulation of the new picture with lots of statistics, David Edgerton, *Science, Technology and the British Industrial 'Decline'* ca. 1870-1970 (Cambridge: CUP/Economic History Society, 1996).

for research, but not all research. In practice, 'science policy' is policy for research funded by government agencies that are concerned with civil work of an academic character that is largely taking place in universities. It is the policy of 'research councils'. Now this might be a perfectly reasonable approach, but problems arise when research council research is identified with all government research, or all research, which happens regularly in the policy and the older historical literature. It is particularly inappropriate looking backwards, because things were very different then. The whole was not the same as the minor part the histories focus on. To put it more generally – the most important agents of research policy have not had 'science' or 'research' in their titles.

Historically most government funded research was funded by mainline departments, not research councils. The greatest state laboratories, the greatest research programmes – whether in aeronautics, or electronics, or nuclear power, or food, had (with few exceptions) belonged to ministries whose names are now obscure. If you want to know about the history of research policy, you need to know about the policies of these ministries. However, histories of 'science policy', which were written from the 1960s, focussed on the research supported by research councils, often as if no other government research existed. It was often suggested, for example, that the Department of Scientific and Industrial Research (DSIR), the first research council, pioneered the funding of research by the British state (during the First World War). But research was funded long before this (and gave us radio, for example), and during the war the DSIR was a very minor research player. Indeed there are many other similar category errors routinely made in histories of 'science policy'.

A key historical example which has been central to science policy discourse recently is the 'Haldane Principle' of 1918. It has been assumed that there was a single science policy governed by a single principle, though one never clearly defined, along the lines that scientists determined science policy. In fact, there was no such 1918 Haldane principle, nor could Lord Haldane ever have defined *one* principle for science policy. He understood very clearly that most research was done by departments, but he wanted *some* research to be done in a semi-independent way by what we now call research councils. He had his model in the DSIR, and he followed this precedent in recommending a similar structure for the Medical Research Council (MRC), a structure that was later adopted for other research councils. Haldane gave an intelligent set of reasons for having research councils alongside departmental research, envisioning each doing different sorts of things under different kinds of control. The 'Haldane principle' of 1918 of the policy discourse was an invention of the 1960s and reflected a poor understanding of actual research policies and practices even then.[51]

The 'Haldane Principle' isn't the only fanciful history of science policy that policymakers argue with. In discussions of science policy one will hear that science in Britain is on tap, not on top; that there has long been a deep division between 'two cultures'; that the civil service has been dominated by classicists, perhaps even historians; that apart from the world wars and Harold Wilson's White Heat of the Technological Revolution, science was ignored; that Britain has been good at inventing but bad at developing; that politics is short term so government has not been able to make the long term commitment innovation needed. We also know that British universities were until recently ivory towers dominated by arts faculties. All this history explained why, except in emergencies, the nation systematically and disastrously failed to invest enough in R&D, and why the R&D that was undertaken was misdirected, mismanaged, wasted. In the more specialised literature, we learn that in the past the directors of science policy were deluded folk who believed in something called the linear model of innovation. This needs to be understood as left-overs from the claims of self-interested parties who have sought to promote science, and their science, by using stories of failure, indifference to science, and all the rest. Indeed, a useful rule of thumb is that expenditures, influence, and impact correlate positively with the strength of the arguments that claim they are low. Thus, complaints about lack of R&D funding peaked at the moment in British history when R&D funding was at its highest as a proportion of GDP (the early 1960s).[52]

51 See my talk to the Institute of Government conference on Haldane - https://www.instituteforgovernment.org.uk/events/haldane-report-next-100-years and my 'The 'Haldane Principle' and other invented traditions in science policy', *History and Policy* 88 (2009).

52 For a description of the declinist literature, and a comprehensive rebuttal, see David Edgerton, Science, *Technology and the British Industrial 'Decline' ca. 1870-1970* (Cambridge: CUP/Economic History Society, 1996).

Another set of historical discourse directly informs the present and is also very present in science policy discussion. This is the one that tells us confidently, authoritatively even, that we are living through a revolution comparable to past revolutions. Experts in innovation policy used to talk of these revolutions as long waves of technical innovation, and they often still do, though this language is now less common. The talk today is of our being in a 'fourth industrial revolution', preceded of course by other revolutions dating back to the first in the late eighteenth century. We find that each of these great transformations was brought about by one, two, or three key technologies, which between them changed everything. These claims are not based on serious historical research, but rather propagandistic histories that are part of a claim for more public money.

## From 1900 to 1939

What kind of research policies did the United Kingdom pursue before the Great War? The United Kingdom was the greatest free trading power on earth – it imported half its food, and many manufactured materials as well as raw materials. Some wanted to protect national agriculture and national industry, and to grant preferences to other parts of the British empire. It was not to happen for years, but these political pressures had to be responded to. Economic liberalism did not imply indifference to research. Indeed, research was promoted as an alternative to protection. This is what David Lloyd George did, through what was called the Development Commission, whose remit was to do something for agriculture. It pumped money into agricultural research and would continue to do so until its functions were taken over by other government agencies in the interwar years. Research as an alternative to an active policy would be a recurring theme.

On the military and naval side, the state promoted new devices like nobody else – the Navy had co-invented the radio, and the army had a research station developing aviation along scientific lines (under the leadership of Haldane, no less). It pursued a distinctive liberal militarism, which had new machines at its heart, different from Prussian militarism. When it came to the great mass of British industry, the state was not especially concerned – its economic liberalism meant it was not really worried about what was made or developed in the UK. It was not concerned that cars or dyes were predominantly imported; it was neither pleased nor displeased when businesses in the UK adopted techniques of overseas origin.

What happened during the Great War is what one would expect. First, the armed services ramped up their research and development, growing their existing facilities (for example, Farnborough and the Woolwich Research Department) and creating new ones (for example, Porton Down). Secondly, there was new need to produce and research materials previously imported from a blocked off continental Europe. The state intervened to create new industries and firms – most notably a new British synthetic dye industry, but not only that. A new industrial policy went along with a new research policy. And it all succeeded – the UK ended the war with extraordinary military industrial capacity and new civilian industries too. What did the DSIR have to do with this (recalling that the standard story is that the DSIR was the agency created once the government had realised how disastrous its neglect of science had been)? The answer is nearly nothing at all. The DSIR was there for the postwar era, to support research in universities, in government laboratories, and in what became the industrial research associations.

What then of the interwar years? What were the research policies of the British state? The context here was broadly a return to liberalism, with crucial exceptions, and then a move to protectionism and imperialism in the 1930s. The military continued with the development of new methods and continued to dominate state R&D spending. The service ministries all appointed directors of research, and they came up with lots of important new devices, such as radar, jet engines, and ASDIC (sonar), to meet the operational requirements of users. 'User control' was the central policy – what was later called the 'customer-contractor' principle. In 1939 it would have been hard to argue that there were any significant general deficiencies in the quality of British arms.

In civil research policies, one can see a number of strands: a continuing liberal strand, together with emergent national and imperial strands. The liberal strands can be seen in many of the policies of the DSIR. As Sabine Clarke has shown, the DSIR developed a very particular notion of 'fundamental research', which was consistent with its limited interventionist stance, while also developing university research.[53] For example, the industrial research associations existed for entire industries, not particular firms. The new Empire Marketing Board (EMB) funded research as an alternative to a thoroughgoing imperial protectionism, which government rejected until the 1930s (when the EMB was dissolved). One programme the EMB developed, working with the DSIR, was new refrigeration techniques to improve and increase imports of food from the empire. In the 1930s there was also a decisive attempt to shift to imperial food supply, for example through using new refrigeration techniques to bring beef from Australia. Imperial concerns were clearly there in the state-led development of civil aviation, which included an Imperial airship plan, and a huge flying boat programme of the 1930s – by the late 1930s there were regular flights (involving many stops) to Australia and South Africa. There were also important national dimensions. Infant industry safeguarding promoted private industrial research in the chemicals industry and the electrical industry. There was also a partial move to a national policy in the case of oil. The DSIR's largest research programme, oil-from-coal, was in the 1920s, and was a programme that nationalists loved. It was put into operation by Imperial Chemical Industries in the 1930s. It was not a British invention, but one of many examples of the UK importing and adapting technology, in this case from Germany. It should be clear by now that the DSIR was much more directly involved with development than research councils would later be.

## The Second World War

As one would expect, the research councils had a minor role in the Second World War. Research activity was directed, on a huge scale, by ministries supplying the armed services. These were the Ministry of Supply, created in 1939 from the War Office (Army) procurement divisions, the Ministry of Aircraft Production, created in 1940 by hiving off procurement and research from the Air Ministry, and the Admiralty (the navy ministry), which kept control of research and procurement. Their main efforts went into the development of old and new weapons. They were responsible for radar and radio, atomic bombs, aviation, including the new jet engines, and much more besides.[54] They were also responsible for the development of medicines, including penicillin. Academic scientists were drafted into the research laboratories of the military. The great R&D programmes were overseen by men and institutions unknown to most science policy discourse.

A notable wartime development was the internationalisation of certain programmes. The UK operated as part of an empire, with a coordinated imperial military research system. There were important links with France to 1940. Most importantly, there were links with the United States from 1940. These links led to not just research sharing, but joint development of some key innovations, notably the cavity magnetron, the jet engine, and, above all, the atomic bomb, which shifted entirely to the USA (and Canada). The US had taken the lead in proximity fuses and fire-control, in the largest, most powerful aero-engines, and in the largest aircraft too.

Were the policies pursued successful? It could certainly be argued that the interwar investment in new machines of war paid off in many important cases. Most of the new weapons, not least radar, jet engines, ASDIC and more, were in development by the military long before the war. Furthermore, technical development was pursued during the war on generally sensible lines, avoiding commitment to large rockets (which did the Nazis no good) or independent development of the atomic bomb. On the other hand, some famous developments proved much less significant than claimed, including the PLUTO pipeline, the Mulberry Harbours, and the Bouncing bomb.

53 Sabine Clarke, 'Pure science with a practical aim: The meanings of fundamental research in Britain, circa 1916–1950.' *Isis* 101 (2010): 285-311.

54 The story of the British jet engine has long been told (not least by Sir James Dyson) in an extraordinary declinist version bearing little relation to reality. For the astonishing real story of Britain and the jet, see Hermione Giffard, *Making Jet Engines in World War II: Britain, Germany, and the United States* (Chicago: University of Chicago Press, 2016).

The belief that research had been central to British success in the war gained ground. In later work, this was associated with some well-known scientists who were engaged in advice, not the development of weapons. An important argument from the scientific left (though not the right) was that wartime research showed that research could be planned for the national interest. This stimulated a debate on planning versus freedom in research (a debate that had started in the late 1930s), but this debate had virtually no impact on research policy, and was really an ideological struggle between left and right. There was, however, a wide-ranging consensus that more research would need to be done than before the war, for the military, and for industrial reconstruction.

## The age of techno-nationalism

The research policy of the British state after the Second World War can only be understood in the context of a new economic nationalism that was central to politics into at least the 1970s. The state developed the capacity to develop new things, and to put them into operation through its control of major industries and through its ability to control what was imported. One important general aim of research policy was to replace imports with home and imperial substitutes. An example is the development of processes to make sulphuric acid from local anhydride rather than imported sulphur. The most important import substitution programme, and the longest lasting, was in agriculture. The UK went from importing half its food to near self-sufficiency in the 1980s. A very large civil nuclear programme – the largest in the world – would substitute for imported oil. The national impulse was also there in weapons development. For example, the British state decided to develop a *national* atomic bomb, and it deployed such a bomb in the early 1960s. There was also an imperial aspect of some importance. As Sabine Clarke has shown, for example, the Colonial Research Council (which has never counted as a research council in the literature because it was departmental – dependent on the Colonial Office) spent more than the MRC or ARC in the 1940s.

Central to state research policy was the provision of new British equipment to British nationalised industries. Thus, the enormous mission-oriented programmes in aviation, atomic energy, the military, and in electronics. The key agencies involved were the wartime procurement ministries, which were merged in 1946. The Ministry of Supply directed the civil and military aircraft programmes, the civil and the nuclear atomic programmes, and the electronics programmes too. There was some dispersal of functions with the creation of the Ministry of Aviation (in 1959) and the United Kingdom Atomic Energy Authority (UKAEA) (in 1954) out of the Ministry of Supply. There was another agency that would become reasonably important, which came under the Board of Trade – the National Research Development Corporation. This was there to finance the exploitation of inventions made in the public sector (including universities) laboratories (and other laboratories too). It put money into such projects as the fuel cell (a favourite for policymakers in the 1960s) and the Hovercraft.

Meanwhile the research councils, while they remained relatively small, expanded. The DSIR, by far the largest, with interests in research in many fields, built up its own laboratories and created new and expanded Research Associations. The MRC and ARC were joined by Nature Conservancy in the 1940s.

The early 1960s saw very important administrative realignments that were debated in a context of declinism – the belief that the UK was not doing as well as it should have been, that it was failing, for national reasons. One crucial element was thought to be the lack of, and misdirection of, R&D. Another part of the context was the UK pulling out of large scale projects – large missiles in particular, but also large independent aircraft projects, where it discovered it could not compete with the USA. This was the context of Harold Wilson's famous declinist speech, which spoke of the 'White Heat' of the 'Scientific Revolution', which was the cliché of the time.[55] The scientific

55 Wilson did not speak here of the 'technological revolution' – 'scientific revolution' was the term of the era, used, for example, in the title of *The Two Cultures and the Scientific Revolution* by C.P.Snow. In the Soviet World the 'Scientific-Technical Revolution' became a term of art in the 1960s.

revolution he had in mind was uncannily similar to the present fourth industrial revolution rhetoric – it was focussed on electronics and automation and nuclear energy. Wilson particularly focussed on computers with judgement.

The details of the changes are complex, but in essence two things happened. The first was break-up of the first research council, the DSIR. The 'Haldane Principle' was invented in response to this.[56] What happened was that the bits that funded academic research became the Science Research Council, and alongside this the other research councils went to a new Ministry - the Ministry of Education *and Science*. But the bulk of the DSIR – the National Physical Laboratory, the Food research bodies, the old Fuel Research institutions, the Road Research and Building Research, and more – went to a new Ministry of Technology (MinTech), along with the UKAEA (which had come out of the Ministry of Supply). MinTech was a ministry of atomic energy research and development, as well as a ministry for a number of other major state laboratories, with responsibilities for some industries. It also got NRDC. The most important development was the takeover of the Ministry of Aviation in 1967, which made Mintech by far the largest state spender on R&D. Mintech was a comprehensive industry and research ministry – a Ministry for Business, Energy (it took over the Ministry of Power) and Industrial Strategy (which came from DEA), and on top of that (most) Defence Procurement. Furthermore, it had extraordinary more power and influence. It could decide the shape of British energy, major industrial programmes, and support whole industries.

Understanding the Harold Wilson - White Heat - Mintech story is crucial to understanding research policy of the era.[57] Central to policy was a reduction in defence R&D; the shift from large scale prestige projects to smaller more commercial ones; the creation of large national businesses capable of innovating seriously; the idea that the state should use the methods and expertise of the supply departments to promote British industry. It did all of these things to different degrees. Perhaps the most important development within Mintech and among the key government advisers was the increasing recognition that lack of R&D, even of the right sort, was not the issue. It was noted that national R&D spend did not correlate positively with national rates of growth (this is still the case, for good reasons, and should be known as the first law of research policy). Despite high R&D spending, the economy was not growing as fast as hoped – lack of R&D spend was not the problem. Attention shifted decisively to the questions of management and industrial efficiency more generally.

From the late 1960s, a great sense of disillusion with native British technology started to emerge, though on the political fringes. No British nuclear reactors had been sold since two from the first programme, and no new sales looked likely, despite vast expenditures partly justified on the grounds that they would sell. Concorde did not look as if it would be bought by anyone, and other big civil projects had poor sales. Arms sales too were concentrated, for special reasons, on Saudi Arabia.

The upshot was much more scrutiny of research plans. It now had to be established much more clearly that a research programme would really lead to outcomes the nation wanted. One way of ensuring this was creating more of a sense of the government as customer for research, and the research establishments as suppliers of research. Formalising this was a way of trying to get the key questions asked. This is how the Rothschild Report (1971)[58] needs to be understood – as the extension within government of what he called the customer-contractor principle, to bring research programmes under more control. And this happened.[59] Rothschild also argued that a fraction of the research of three research councils, the MRC, ARC, and NERC, should be deemed applied research and should come under the customer-contractor principle (it turned out to be a total of less than 20

56 David Edgerton, 'The 'Haldane Principle' and other invented traditions in science policy', *History and Policy* 88 (2009).

57 The following accounts of MinTech is derived from an ESRC-funded project I directed in the late 1980s – for which see my 'The 'White heat' revisited: the British government and technology in the 1960s', *Twentieth Century British History 7* (1996): 53-82 and for the wider context *Warfare State: Britain 1920-1970* (Cambridge: Cambridge University Press, 2005). See also work by Richard Coopey out of the project.

58 Lord Rothschild, *The Organisation and Management of Government R&D Included in A Framework for Government Research and Development November* 1971 Cmnd. 4814. The scope and aims of this report are widely misunderstood so consulting the original report and associated documents is essential.

59 *Framework for Government Research and Development* July 1972 Cmnd. 5046, the government response, makes clear that the bulk of government applied research already operated under customer- contractor principles.

percent of total research council spend). This led to a continuing unfounded story that Rothschild represented an abandoning of the (mythical) Haldane Principle and a radical change in British research policy. If it was a radical change it was not due to Rothschild, and it barely affected the research councils as whole, though was important for ARC.[60] If there was a change in the 1970s, it was a radicalisation of the direction of travel of the late 1960s. It can be seen in the more general alignment of research with department responsibilities. MinTech was broken up in 1970, with the defence side going first through aviation supply into the Ministry of Defence, in a new Procurement Executive. Many laboratories that had been under MinTech were shifted to more appropriate departments (e.g. Road Research to Transport, and food research to Agriculture and Food).

The general picture that emerged of the techno-nationalist programmes was a negative one. Failure was explained by a supposed overemphasis on defence and prestige projects, which Mintech in fact countered. But were there successes? At one level yes – the material infrastructure of the UK was transformed, from the post office, to agriculture, to the railways and mines.[61] The question is really whether national programmes were the most effective way to achieve these ends. But where there is no doubt is that something large was achieved.

There was some return to a stronger industrial – technological strategy under Labour in the 1970s, notably with the creation of the National Enterprise Board, and Inmos (a state-funded semiconductor firm). Indeed, it could be argued that the 1970s saw a flowering of inventive activity, leading to new micro-computers (Acorn and its descendants like ARM), for example, and the blockbuster pharmaceuticals that drove the growth of these firms into the 1990s.

## Liberalisation

However, the general drift of understanding from 1979 was that techno-nationalism had failed. From the early years of the Thatcher governments the shift in policy was clear. Although there was a wide-ranging and ambitious programme of research in computing (the Alvey programme), there was, especially from the late 1980s, a shift away from near-market research. The government retreated from what were called 'near-market' activities. That meant the radical cutting back, privatisation, and contractorisation of government laboratories. Departmental research and development was slashed along with the rationale for major state-led programmes. The entrepreneurial state (which did exist) was killed off. The research councils were not cut anything like as much.

The wider context saw radical changes. Getting rid of the imperative to buy British in itself had major consequences, made stronger by the privatisation of the nationalised industries. Where once infrastructural technologies had been innovated and manufactured in Britain, that over time ceased to be the case. That had huge consequences for nuclear energy, aviation, railway, telephone equipment and more. More generally, there was a fundamental shift away from a focus on R&D as the motor of growth to markets and entrepreneurs. The state had no business in business. At a time when foreign car makers were encouraged to come into Britain, a national industrial strategy would have made no sense.

The R&D:GDP ratio *fell* from the early 1960s. It continued to fall through the 1980s, falling under 2% of GDP in the early 1990s, where it has remained. Other countries now spend considerably more, whereas in to the late 1960s the UK stood out as the major European R&D player.

The result of the shrinking of departmental research and industrial research was that the research councils loomed larger and larger in the government's R&D spending. The result was that politicians

60 'The "Haldane Principle" has, evidently, little or no bearing on the conduct and management of Government R. & D. in the '70s' said Rothschild, p. 19. 'Haldane Principle' was in inverted commas because Rothschild was himself clear that there was no single Haldane Principle.

61 For this argument, see my *The Rise and Fall of the British Nation Lost: a Twentieth-Century History* (Allen Lane, 2018).

and others now looked to the research councils to produce inventions that would generate economic growth; and the research councils began to look to argue that they could do this. There was much talk of entrepreneurial universities, and spin-outs, and of course Silicon Valley. It now looked as if the UK had a uniquely strong 'science base' that needed to be exploited by more vigorous entrepreneurship. Industry may have declined, but not academic research, was the assumption; 'Realising our potential' was the name of the key white paper. The paradox was that continuing government support was based on the idea that only research far from the market should be supported, and that this research would lead to new products and processes.

That research policy has been a substitute for an active industrial policy may be illustrated by the case of graphene, discovered in Manchester and made a huge fuss of. The government set out to exploit this discovery with a £50m centre. But if the potential was as great as was made out, £50m was a paltry sum in a world where £50bn bought a short-distance railway. It is also a tiny fraction of what was spent on Concorde, for instance.

Since the 1990s, research policy has been a substitute for industrial policy, not a complement to it. A partial exception has been biosciences, where claims were made for unique British strength in both research and in the industry. However, it is worth noting that this sector has notoriously low research productivity. It is with justification that there is now talk of a 'biomedical bubble' in research.[62] And the record of success in biotechnology is not great.[63] Indeed what is lacking, remarkably so, is any serious assessment of the effectiveness of policy over the last thirty or forty years. Where are the businesses created by the exploitation of British inventions? Of course, finding the evidence would be difficult, but surely it is not impossible to find some major plausible examples?

## Bibliography

Peter Alter, *The reluctant patron: science and the state in Britain, 1850-1920* (Oxford: Berg, 1987)

Sabine Clarke, 'A technocratic imperial state? The colonial office and scientific research, 1940–1960', *Twentieth Century British History* 18.4 (2007): 453-480.

Sabine Clarke, 'Pure science with a practical aim: The meanings of fundamental research in Britain, circa 1916–1950." *Isis* 101 (2010): 285-311.

Sabine Clarke, 'The research council system and the politics of medical and agricultural research for the British Colonial Empire, 1940–52', *Medical history* 57.3 (2013): 338-358.

Sabine Clarke, *Science at the end of empire: Experts and the development of the British Caribbean, 1940-62* (Manchester, 2018) OPEN ACCESS

David Edgerton, 'Science and Technology in British Business History', *Business History* Vol. 29 (1987), pp. 84-103.

David Edgerton with Kirsty Hughes, 'The Poverty of Science: A Critical Analysis of Scientific and Industrial Policy Under Mrs Thatcher', *Public Administration*. 67 (Winter 1989), pp. 419-33.

David Edgerton, *England and the Aeroplane: Militarism, Modernity and Machines* (1991, Penguin, April 2013)

David Edgerton with Sally Horrocks, 'British Industrial Research and Development before 1945', *Economic History Review*, Vol. 47 (1994), pp. 213-38

David Edgerton, *Science, Technology and the British Industrial 'Decline' ca. 1870-1970* (Cambridge: CUP/Economic History Society, 1996).

62 Richard Jones and James Wilsdon, *The Biomedical Bubble: Why UK research and innovation needs a greater diversity of priorities, politics, places and people* (London: NESTA, 2018)

63 Geoffrey Owen and Michael Hopkins, *Science, the State, and the City: Britain's Struggle to Succeed in Biotechnology (Oxford, 2016) – see also my review in the Financial Times* 29 April 2016.

David Edgerton, ‘The ‘White heat’ revisited: the British government and technology in the 1960s’, *Twentieth Century British History* 7 (1996): 53-82

David Edgerton, *Warfare State: Britain 1920-1970* (Cambridge: Cambridge University Press, 2005).

David Edgerton, ‘The ‘Haldane Principle’ and other invented traditions in science policy’, *History and Policy* 88 (2009).

David Edgerton, *Britain’s War Machine: Weapons, Resources and Experts in the Second World War* (Allen Lane/Penguin, March 2011)

David Edgerton, *The Rise and Fall of the British Nation Lost: a Twentieth-Century History* (Allen Lane, June 2018)

David Edgerton with John Pickstone, ‘The United Kingdom’, for *Cambridge History of Science,* volume 8 *Modern Science in National, Transnational, and Global Context* (forthcoming)

Hermione Giffard, *Making Jet Engines in World War II: Britain, Germany, and the United States* (Chicago: University of Chicago Press, 2016).

Philip Gummett, *Scientists in Whitehall* (Manchester: Manchester University Press, 1980)

Sally M. Horrocks, ‘Industrial chemistry and its changing patrons at the University of Liverpool, 1926-1951’, *Technology and culture* 48.1 (2007): 43-66.

Sally M. Horrocks, ’The internationalization of science in a commercial context: research and development by overseas multinationals in Britain before the mid-1970s’, *The British Journal for the History of Science* 40 (2007): 227-250.

Richard Jones and James Wilsdon, *The Biomedical Bubble: Why UK research and innovation needs a greater diversity of priorities, politics, places and people* (London: NESTA, 2018)

Geoffrey Owen and Michael Hopkins**,** *Science, the State, and the City: Britain’s Struggle to Succeed in Biotechnology* (Oxford, 2016)

Paolo Palladino, “Science, Technology and the Economy: Plant Breeding in Great Britain, 1920-1970,” *Economic History Review*, 49 (1996), 137-53.

Hilary Rose and Steven Rose, *Science and Society* (London: Allen Lane, The Penguin Press, 1969)

Michael Sanderson, *The Universities and British Industry* (London: Routledge & Kegan Paul, 1972)

Keith Vernon, “Science for the Farmer? Agricultural Research in England, 1900-1936,” *Twentieth Century British History*, 8 (1997), 310-33.

Norman J. Vig, *Science and technology in British politics* (1968)

Tom Wilkie, *British Science and Politics since 1945* (Oxford: Basil Blackwell, 1991).

Abigail Woods, *A Manufactured Plague. The History of Foot and Mouth Disease in Britain* (London: Earthscan, 2004)

# Policy towards science and science in policy: questions and answers?

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**Central Points**

- The worlds of science and policy frame matters differently, so scientific thinking rarely aligns exactly with policy's needs. In order to accommodate this mismatch, as well as to benefit science itself, policy towards science must support plurality and diversity: of funding types and of people.
- Within the plural and distributed systems that then exist, policymakers must pay careful attention to the points of intervention such as brokerage, connection ('glue') and transmission. At the heart of designing effective interventions is the question of how to ensure that the potential solution-holders and potential question-owners find each other.
- For example, high quality evidence synthesis is an intervention that helps the policy-maker and publics make better sense of stakeholders' arguments, even when based on cherry-picked evidence. Such synthesis illuminates the different types of knowledge that are relevant to the policy question and assesses the uncertainties associated with each in an accessible way.
- Similarly, good models create robust evidence that improves the quality of debate. They also act as convening vehicles, connecting those who supply the data and the expertise, those who must inform and make decisions about the questions for which the model is being developed, and those who will be affected by the decisions.
- Science-based futures work, such as in the UK's longstanding Foresight programme, also helps link historic observational evidence with the plausible but uncertain outcomes of policy choices.
- Meanwhile areas of sustained policy and science focus, such as climate change, require bespoke interventions, such as the IPCC. These interventions enable continuous discussions about questions, answers and knowledge. They might rely on formal reporting structures, or more general support for the exchanges of observations and movement of experts.
- Continued investment in plural forms of science will help ensure future policymakers in all areas have more of the knowledge we do not yet know they will need. For example, the arc of science, public debate and local and global politics over climate change did not start from an originating policy question about the potential states of far future climates, but in large part reflected fundamental scientific curiosity about earth systems.

64 Claire was Chief Science Policy Officer at the Royal Society, and was formerly Director of the Government Office for Science and author of How does government listen to scientists? (2018)

## Introduction

The UK was one of the first countries to formalise the role of a Government Chief Scientific Advisor (GCSA), to help ensure science informed policy across government. This paper takes the roles GCSAs, science policymakers and others concerned with science in government, and uses them to examine wider questions about ways in which scientific knowledge and scientists have informed government decisions over time, drawing out implications for science policy more generally.

In doing this the paper makes two key arguments. First, it raises awareness of the different framings and challenges that science and policy face. This points to the need for science policy to support plurality and diversity, of funding types and of people. Second, it makes the case for policymakers to pay careful attention to the points of intervention such as brokerage, connection ('glue') and transmission, within the distributed and plural system.

## Different framings: why designing for plurality and brokerage is necessary

To answer complex policy questions, as to answer complex research questions, requires a plurality of approaches and a diverse community of researchers, along with a culture that welcomes difference, allows for the right kind of failure, and supports healthy debate and challenge. This plurality and diversity provides resilience to enable the breadth of potential insights to inform policy questions that have never before been asked, as well as to generate answers, in the form of newly identified risks and opportunities, that are not anticipated by politics at all.

The timeline of science policy milestones shows consistent patterns of plurality, but of different types, as the research councils form and reform, notions of applied and pure research change and the shape of the wider landscape, including the volume and priorities of government, business and civil society spend, also changes.

Meanwhile, at all points on the history timeline there will have been occasions on which a policy question was apparently fully framed, hard to change, and urgently demanding of at least partial solutions: ones capable of getting democratic support and of being implemented in practice. Chief Scientists were and are often at the heart of trying to meet this challenge, where the stock of accessible scientific knowledge at any point doesn't match the immediate policy question. In such situations decision-makers and their advisors often face the choice between a reasonably certain answer to a partial question and a very uncertain answer to a 'better' and more comprehensive question. Scientists may have the luxury of being able to define the system at stake for their purposes in a way they believe may be most tractable to science; while policy-makers have to fight very hard to frame the issues and define the relevant systems in a way that makes them tractable to policy, and sometimes simply cannot achieve it.[65]

Designing interventions that best connect the different framings, while taking account of the continuous evolution in policies towards research funding and governance as a whole, is a major challenge for policymakers. That challenge has had numerous different historic responses and, to pull out from experience some general principles that might apply to future designs, this paper first examines what is meant by different framings.

To start with the framings of science: scientific questions tend to reflect disciplinary structures. The system being studied may be defined by what can be modelled given the state of scientific knowledge and observational capability. Or it may be the result of long-standing patterns of investigation with a discipline or groups of disciplines used to working together. In the natural sciences in particular there is little reason for the system being studied to coincide with the policy

65 Cairney, P. (2016). *The politics of evidence-based policymaking*. Palgrave MacMillan

question.[66] In addition, scientific understanding of extremely complex systems often does not generate findings capable of straightforward political interpretation. For example, one of the challenges of climate change policy is the use of global average surface temperature as a key metric of the overall effects of carbon emissions on the climate system. This measure is simple enough to shape international debate and decision-making around reducing carbon emissions. But, because of its distance from individuals' experience of climate, manifested as remembered local weather, is not well designed to either engage publics with the risks of future climate states, or to inform decision-making, at least at the regional, national or local levels which are where most policy levers lie. The potential applications of findings based on economists' assumptions of perfect information and human rationality in some ways reflect the same fundamental challenges of linking scientific findings based on valuable abstractions, to well-founded public debate, which requires understanding, explanation and engagement with multiple potential futures.

For policy development and policy-makers, the system that defines what they take to matter for their decision-making may be set by several factors. It may be the history and the pathway of the debates, the pre-existing pattern of stakeholder interests, or the sequence of recent events and social amplification of selected aspects.[67] Their systems may be set by their departmental boundary, their access to the levers of influence, or a much wider political narrative - for example, concerns about Artificial Intelligence (AI) and automation being framed by impacts on jobs that are also part of a wider set of concerns about globalisation and inequality.[68] In the case of AI, public narratives of hope and fear, such as for ease and obsolescence, have pervasive forms as far back in history as Homer.[69] The policy framing may also be influenced by factors such as the tendency for narratives to focus on individual or concrete problems at the expense of the larger system.

An illustration of where the plurality of policy and scientific framings for a given issue has created challenges for science policy and policy more generally concerns the long-running disputes about whether selectively to cull badgers to help manage the risks from bovine TB. Successive GCSAs, departmental CSAs, Select Committees and others have grappled with the ways these disputes exemplify the reality of policy debates' tendency to be framed around charismatic entities and relatively concrete narratives and choices. The popular and policy framing leads to research and experimentation, in this case funded by a government department, directed at those questions. However, the longer-term and more complete solutions require, amongst other things, consideration of the much less tangible systemic issues of biosecurity in farms, agricultural business models and the management of populations of a wide range of wild and domestic animals.[70]

A further example of the differences in systems and framing between science and policy concerns the history of decisions on the drugs ecstasy and khat. In both cases a scientific advisory Council advised on the basis of the potential harms to humans from the drug. As the Home Secretary's formal response to the Council on khat set out, the systems taken into account in the final decision included very different ones, such as that of the effectiveness of co-operation between international police forces.[71]

In addition to needing to find ways to accommodate matters of framing and systems definition, science advice has relied consistently on the existence of science policies that supported diverse forms of research, including that which was conducted without expectation of at least some of the applications for which its findings were subsequently used. To take two recent examples; first, the introduction of significant measures to tackle modern slavery depended in part on estimates of the numbers of people affected in the UK that in turn drew on diverse forms of mathematics identified by the Home Office's Chief Scientific Advisor.[72]

66 Here and elsewhere this paper draws on Craig, C. (2018). *How does government listen to scientists?* Palgrave

67 Pidgeon, N. (2003). *The Social Amplification of Risk*. (N. Pidgeon, R. E. Kasperson, & P. Slovic, Eds.) Cambridge University Press.

68 The British Academy and the Royal Society (2018) *AI and the future of work* https://royalsociety.org

69 Royal Society (2018) *Portrayals and perceptions of AI and why they matter* https://royalsociety.org

70 Department of Environment, Food and Rural Affairs (2018) *A strategy for achieving bovine tuberculosis free status for England* https://www.gov.uk/government/publications/a-strategy-for-achieving-bovine-tuberculosis-free-status-for-england-2018-review

71 May, Rt. Hon. (2013, published July 9). *Letter to ACMD on control of khat*. https://www.gov.uk/publications/letter-to-acmd-on-control-of-khat

72 Bernard Silverman, B. (2018) *Modern slavery: The size of the problem.* TedX Whitehall https://www.youtube.com/watch?v=MDdCSAArIxU

Similarly, the need to look beyond the apparently obvious sources of knowledge was strikingly illustrated by the case of advice given during the Ebola epidemic of 2014. Here, the GCSA followed the established practice in civil emergencies of establishing a Scientific Advisory Group in Emergencies (known as SAGE, and discussed further in a later section) to advise the Ministerial COBR committee. The Group initially drew in expertise routine to such situations, such as epidemiology, but it rapidly became obvious that, to be effective, efforts to tackle the outbreak had to be informed by the expertise of anthropologists and social scientists. These researchers helped ensure that the full significance of burial and other important indigenous practices were properly recognised and integrated into the operations.[73]

The question of how to ensure that the potential solution-holders and potential question-owners find each other (and noting that the roles may be interchangeable at different times) is at the heart of designing effective interventions. Given this, what can be done to try and mediate and broker between the two systems of policy and policymakers on the one hand, and science and scientists on the other? This paper discusses three specific areas of brokerage and mechanisms (used by GCSAs, but also more widely relevant) that can be thought of as providing 'glue' in the system: mechanisms for evidence synthesis; the use of models; and futures work.

### Learning from different types of brokerage and 'glue' in the system: mechanisms for evidence synthesis

The British Academy's timeline points to the creation of a first Government Chief Scientific Advisor in 1964 although there had been departmental CSAs earlier, with a CSA covering agriculture and fisheries as far back as 1920. During that time a key function of CSAs has been to deliver accessible scientific knowledge, drawing together insights from different disciplines, to top decision-makers. This practice of evidence synthesis can happen in a matter of seconds in an expert's mind; in a matter of hours and days during a civil emergency; or over months or years in the case of reports by national academies, or the Foresight programme discussed below. At these longer timescales some areas of policy and science have long-standing and established mechanisms, such as the Cochrane medical reviews or the UN Intergovernmental Panel on Climate Change's (IPCC) comprehensive synthesis process, with suites of reports every five or so years.

In 2009 the then GCSA formalised a very immediate intervention in the government and science systems in the form of the SAGE which is convened to advise COBR. SAGE is a standing mechanism that adapts its disciplinary reach to different forms of emergency. It delivers what is in some ways the simplest form of evidence synthesis: accepting a policy or operational question as given, and doing the best possible job under constrained circumstances to bring existing forms of knowledge together to inform the decision. In practice this means taking knowledge embodied in people and organisations and working rapidly to synthesise relevant insights between them.

SAGE has operated in cases from the nuclear emergency at Fukushima or the Icelandic volcano which disrupted air traffic, to the much more slowly evolving emergency of the Chalara ash tree dieback disease.[74] It is striking how each manifestation grappled with the fundamentals of translating scientific knowledge into political reality; for example, what is reasonable certainty in the context of the question of human safety during events at Fukushima? But it is also striking how plurality delivered by the science system, coupled with the detailed design of interventions, matter. The Ebola illustration showed how anthropological, cultural and social sciences scholarship that some might have thought to be a long way from urgent operational need, nevertheless was the tipping point to operational success. However, high quality synthesis requires careful selection of the disciplines and sources of expertise, rigorous quality assurance and challenge mechanisms, and intellectual independence, coupled

73 House of Commons Science and Technology Committee. (2016). *Science in emergencies: UK lessons from Ebola*. London: The Stationery Office Limited. Retrieved from Publications, Parliament.

74 Records of SAGE are archived at https://www.gov.uk/government/groups/scientific-advisory-group-for-emergencies-sage

with close engagement with the intended audience.[75] At its best, it helps the policy-maker and publics navigate different types of evidence and make better sense of stakeholder arguments based on cherry-picked evidence. The programme of Oxford Martin School Restatements tackles subjects controversial in UK politics such as bovine TB, or the effect of neonicotinoids on pollinating insects. By setting out and assessing different types of evidence they help illuminate the different types of knowledge, and of uncertainty associated with each, relevant to the policy question. The Royal Society's judicial primers represent another example, targeted in this case at the courts and created in collaboration with bodies such as the Judicial College.[76]

Public reasoning would often benefit from the provision of carefully synthesised and easily accessible evidence and there are excellent examples, such as the Cochrane reviews, in health. Increasingly, too, researchers within a field need more systematically to access the knowledge available within it or within adjacent fields, in order to inform their future research, so elements of synthesis might be valuable for the research community too. But policy creates relatively few incentives to provide it. Academics are primarily rewarded for creating new knowledge within their disciplines and, in the absence of reliable access to synthesised evidence in most policy domains, policy-makers do not learn to ask for it.

### Learning from different types of brokerage and 'glue' in the system: science and for decision-making using models

The evolution of science and policy with respect to climate change discussed later in this paper illustrates some of the fundamental challenges of using observational evidence about the past to inform policy questions that are always concerned about the future. Models are a significant way of linking the two.[77] In broad terms, models are used for at least five purposes: prediction or forecasting, the explanation or exploration of future scenarios, understanding theory, illustrating or visualising a system, and analogy. They are always in some sense fictions, but they are fictions that simplify and abstract important properties of the actual object or system being modelled, to create insights or outputs useful for the purpose at hand.

In science, computational models form the basis of understanding of the largest systems, such as galaxies or the Earth, and the smallest, such as cells. In society, models help design and run cities, manufacture cars, streamline business systems and the operation of hospitals and generate cleaner production processes. In public policy, the past and future are often bridged by the use of computational models or simulators such as those of the climate based on the fundamental laws of physics, to empirical models of the economy, or of the spread of an infectious disease.

Here, models play a particularly important role because they not only create robust evidence, they also do it in a way that improves the quality of debate around that evidence. This is partly because they act as vehicles to convene groups: those who supply the data and the expertise, those who must inform and make decisions about the questions for which the model should be developed and to which it should be applied, those who make judgements about the assumptions that underpin the model, and those affected by the model's outcomes.

This convening function means stakeholders with different forms of expertise can develop, challenge or use the model. In 2013 the McPherson Review of the quality assurance of models in

75 Donnelly, C; Boyd, I; Campbell, P; Craig, C.; Vallance, P; Walport, M; Whitty, C J M; Woods, E; Wormald, C (2018). *Four principles to make evidence synthesis more useful for policy.* Nature, 558, 361-364

76 The Royal Society and the Royal Society of Edinburgh in conjunction with the Judicial College, the Judicial Institute, and the Judicial Studies Board for Northern Ireland. (2017). *Forensic DNA analysis*. The Royal Society.

77 Calder, M., Craig, C., et al (2018) *Computational modelling for decision-making: where, why, what, who and how.* Royal Society Open Science, 5(6):172096

use in the UK national government found over 500 models with a significant influence on policy.[78] They ranged from basic Excel spreadsheets constructed by in-house analysts to the models of global climate created by international teams and subject to extensive peer review through the IPCC. The Review, set up after the errors that led to a major economic and political failure in the Department for Transport's review of the West Coast rail franchise, highlighted several risks with the use of models. In particular, it can be very tempting and easy for a model created for one purpose to be stretched to apply to another to which it appears to fit but for which, in practice, it is less well suited and may even be misleading.

The basic lessons to ensure they are used wisely are: to ensure that the scientific basis is sound, the data are good, that the policy client is engaged with the modelling experts throughout, and that the assumptions behind and limitations of the model are well understood both by its designers and those who may act on its findings.

## Learning from different types of brokerage and 'glue' in the system: futures work

The UK, under successive GCSAs, has experimented with different types of brokerage applied across a wide range of topics. As one way of explicitly bridging past and future, GCSAs have deployed the UK's Foresight programme, where projects include elements both of evidence synthesis and of modelling. The programme has taken several forms but, since 2000, has consistently been about bringing a variety of forms of evidence to bear on a matter of significant policy interest, looking forward from 10 to 100 years depending on the nature of topic.

Projects under this programme have then used very different ways to work with stakeholders, on a variety of scales, to engage with what that evidence might mean for possible futures and what those insights about the long term future might mean for near term decisions. The largest projects, such as those on Global Food and Farming, engaged several hundreds of researchers directly, created reviews in over 50 disciplines, and not only created newly accessible evidence but also networks and transmission mechanisms in their areas. A recent project on the future of cities deliberately worked with individual UK cities on their own futures as well as considering the UK system of cities as a whole. It included scholarly analysis of the history of visions of future cities throughout the 20th century, as a way of exploring how those visions in turn did or did not influence outcomes.

Together, the projects informed policy in areas from physical infrastructure investment in the Future Flooding project (2004) to longer term implications of cognition enhancers in the project on Brain Science, Addiction and Drugs (2008) or of future constructs of identity (2014).[79]

## Climate change: a concluding illustration of the value of plurality and different brokerage mechanisms in science policy

Sometimes science creates knowledge that is unexpected and unasked. The arc of science, public debate and local and global politics over climate change did not start from an originating policy question about the potential states of far future climates. The scientific knowledge in large part reflected fundamental scientific curiosity about earth systems. The science drew on, and informed, deeply disciplinary-specific areas of science in physics, chemistry and mathematics, such as fluid dynamics and radiative transfer. It relied on investments in science that had begun in previous centuries, and for other purposes. For example, climate science drew on aspects of meteorology which were developed for weather forecasting with a wide range of direct applications in areas from agriculture and the military, to aviation and finance.

78 McPherson, N. (2013). *Review of quality assurance of government models.* HM Treasury. Retrieved April 14, 2018, from https://www.gov.uk/government/publications

79 Material relating to all Foresight projects is available through the UK Government website, gov.uk

Meanwhile, the past and future evolution of the science depended on consistent investment in observational infrastructure, and increasingly in supercomputing and data infrastructure, to support the demand for greater confidence and granularity in numerical weather and climate prediction. These consistent investments, not only in lines of research but in observational, supercomputing and data infrastructure that can then inform future lines of enquiry, are a further part of the plurality of science policy that supports long term resilience.[80]

At the same time, and as the science and debates have evolved since the mid 20th century, the policy and evidential landscapes have become more complex and distributed. The role of economics, social and behavioural sciences, arts and humanities has become clearer. The scientific and policy questions expanded to include not only notions of global risk, but how to adapt to different types of impact such as patterns of precipitation and of extreme weather as well as large scale trends in measures such as Arctic sea ice and sea surface heights, and then expanded also to consider more fully the ways those impacts interact with social, economic and natural systems. The social sciences, arts and humanities brought new ways both of engaging with what has happened so far and understanding and shaping possible futures.[81]

In many areas, as in climate science, what is at stake is not only the concern of national science policy, but also science's role in foreign policy and in international collaborations, some supported by governments and some not. These collaborations might be the exchanges of knowledge taking place through formal structures such as the IPCC, which includes government, business and civil society groups engaging with the science and scientists; exchanges of observations such as those shared by national meteorological offices under the conventions of the UN's World Meteorological Organisation; or through exchanges of people as they migrate and travel. Mechanisms such as these are proving deeply significant in brokering and shaping future science and the policy response to it.

As the 20th century's most significant long running set of debates about policy and science, climate change has evolved its own landscapes and brokerage structures to enable different forms of science to be brought together and to enable dialogue between parts of the global policy community.

### Conclusion: platforms for convening matter

A helpful account of the variety of types of brokerage that the plurality of science and policy systems have accommodated comes from a study by the Institute for Government that discussed six case studies of radical policy evolution in the UK, from the introduction of the ban on smoking in public places, to the introduction of the national minimum wage.[82] One of the case studies was the introduction of statutory carbon budgets in 2008. In that case, as in all the others, a success factor was the existence, sustained over years, of informal alliances of people in government, academia, business and the third sector, who consistently promoted and worked to move the issue forward. In adjacent fields, the Royal Commission on Environmental Pollution enabled similarly careful and sustained relationship building and brokerage between those working in science and policy during the years from 1970 to 2010.[83]

Very longstanding convening structures such as the IPCC exist in few other areas of science and policy. Those which do exist have a wide range of forms that makes them difficult to categorise and perhaps, therefore, harder for top level policy debates to consider effectively and systematically. For example, a very different model from that of the IPCC enables informal discussions about priorities and funding in health in the UK. Here, the Office for Strategic Coordination of Health

80 Royal Society (2015) *Observing the Earth* https://royalsociety.org

81 See, for example, Hulme, M. (2009). *Why We Disagree About Climate Change: Understanding Controversy, Inaction and Opportunity.* Cambridge University Press.

82 Rutter, J., Sims, S., & Marshall, E. (2012). *The "S" Factors: Lessons from IFG's policy success reunions.* Institute for Government. https://www.instituteforgovernment.org.uk

83 Owens, S. (2015). *Knowledge, Policy and Expertise.* Oxford University Press.

Research (OSCHR) formed in 2007 builds on the property unique to health science and policy, of having consistently received broadly similar scales of investment from a government department, research council and a charitable funder in the form of the Wellcome Trust. Defence and security have a further set of formal and informal structures, ranging from the Defence Scientific and Technical Laboratory and the Defence Academy, to links with specific universities and longstanding innovation and procurement arrangements.

However, outside defence and health, other areas of policy and science such as energy, justice or education[84], have much less of a history of sustained mechanisms for convening. The science policy timeline shows strikingly, for example, how policy and scientific concerns about agriculture were visible in the 20th century. The timeline could also be read as indicating that sustained research funding from a government department may contribute to the continuity of brokerage mechanisms that enable discussions across the policy and science systems that are most relevant to it. That in turn invites the question as to what areas of policy and science are the 21st century equivalents of the mid-20th century's concern with agriculture, and what will be the framings, pluralities and brokerage mechanisms we should be attune to now in order to address them.

Continued investment in plural forms of science, including 'curiosity driven' and fundamental research, will help ensure future policymakers in all areas have more of the knowledge we do not yet know they will need. In the present: platforms for convening matter and the mechanisms that provide the 'glue' in the system are important. For those areas like energy, justice or education that do not have such sustained and dedicated mechanisms, policymakers, scientists and scholars might do society a future favour by calling attention to them now, rather than looking back as historical lessons to learn from.

84 See for example discussion of science coordination mechanisms in https://publications.parliament.uk/pa/cm201719/cmselect/cm-pubacc/668/668.pdf and British Academy and The Royal Society (2018) *Harnessing educational research* https://royalsociety.org

# Figures

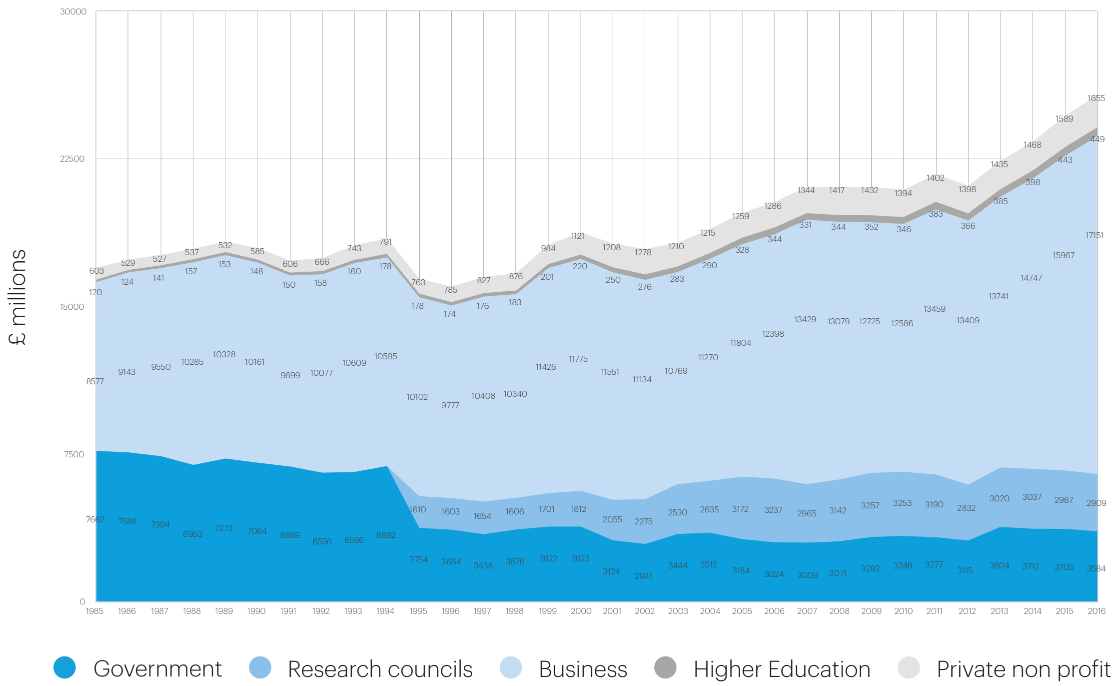
**Figure 1** **R&D Spending in the United Kingdom, 1964-1975**

| **Spending at historical prices** | **1964** | | **1969** | | **1975** | |
|---|---|---|---|---|---|---|
| | **(£) million** | **(%)** | **(£) million** | **(%)** | **(£) million** | **(%)** |
| **Performer** | | | | | | |
| Government | 212 | 28 | 263 | 25 | 566 | 26 |
| Universities and further education establishments | 47 | 6 | 80 | 8 | 179 | 8 |
| Industry | 489 | 64 | 680 | 65 | 1340 | 62 |
| Others | 20 | 3 | 22 | 2 | 66 | 3 |
| Total | 768 | 101 | 1045 | 100 | 2151 | 99 |
| **Funder** | | | | | | |
| Government | 412 | 54 | 529 | 51 | 1117 | 52 |
| Industry | 316 | 41 | 449 | 43 | 877 | 41 |
| Other | 40 | 5 | 67 | 6 | 157 | 7 |
| Total | 768 | 100 | 1045 | 100 | 2151 | 100 |

Source
*Central Statistical Office, Economic Trends (July 1979), London: HMSO, 1979 reproduced in Gummett, Scientists in Whitehall, Manchester: Manchester University Press, 1980, p.55.*

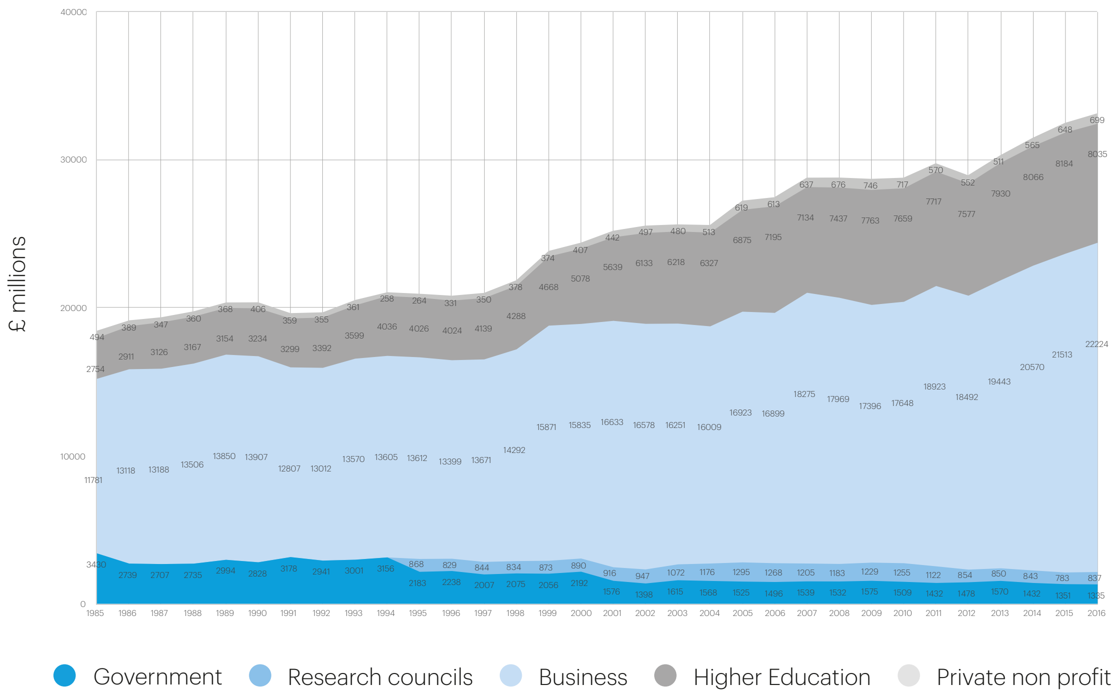
**To Note:** From the 1960s to the 1970s, UK R&D was mostly *funded* by government and *performed* in industry, though industry did still fund a considerable amount of R&D in this period (~40%). This had shifted significantly in the 1980s; see Figures 2 and 3.

**Figure 2** Breakdown of UK Gross Expenditure on R&D, by Sector of Funding, 1985-2016 (Constant Prices)




Source
*ONS (2019): Total GERD by Sector of Funding, 1981-2017*

**Figure 3** Breakdown of UK Gross Expenditure on R&D, by Sector of Performance, 1985-2016 (Constant Prices)




Source
*ONS (2019): Total GERD by Sector of Performance, 1981-2017*

**To Note:** While industry has continued to grow as the largest sector in which R&D is performed in the UK since the 1980s, it has also from the 1980s grown into the largest funder of R&D (now funding more than all other sectors combined). The performance of R&D in higher education has also been on the increase, particularly since 1998, while government performed R&D has dwindled.

**Figure 4** **The picture today**

| | Sector performing R&D (£ million) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Sector funding R&D** | **Government** | **Research Councils** | **Higher Education** | **Business Enterprise** | **Private Non-Profit** | **Total** | **Overseas** |
| Government | 1136 | 137 | 483 | 1730 | 98 | 3584 | 542 |
| Research Councils | 47 | 554 | 2107 | 5 | 197 | 2909 | 292 |
| Higher Education Funding Councils | | | 2207 | | | 2207 | |
| Higher Education | 2 | 17 | 299 | | 131 | 449 | |
| Business Enterprise | 15 | 25 | 350 | 16742 | 18 | 17151 | 6658 |
| Private Non-Profit | 13 | 42 | 1242 | 188 | 170 | 1655 | |
| Overseas | 122 | 60 | 1346 | 3560 | 85 | 5174 | |
| Total | 1335 | 837 | 8035 | 22224 | 699 | 33130 | 7492 |

Source
*ONS (2018) UK gross domestic expenditure on research and development, 2016; reproduced in Royal Society Report 'Investing in UK R&D' (May 2018). Note - figures are rounded. See also pie chart versions of this data (Figures 5 and 6). Overseas sources play a significant role in UK R&D today, funding 15% and performing 18%.*

**Figure 5** **Sectors Funding UK R&D in 2016**

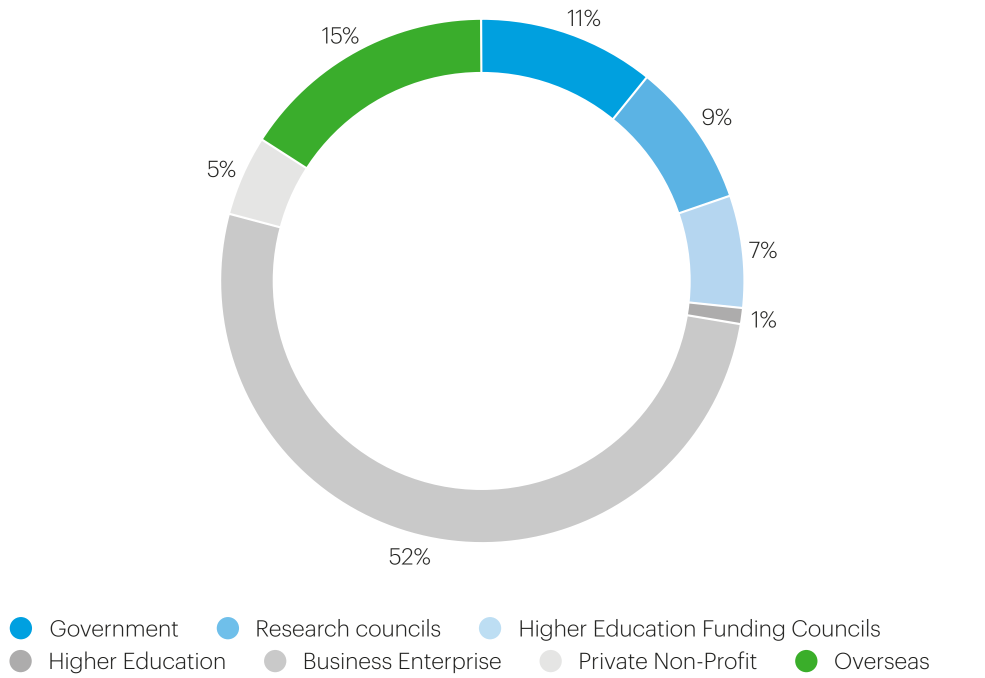



**Figure 6** **Sectors Performing UK R&D in 2016**

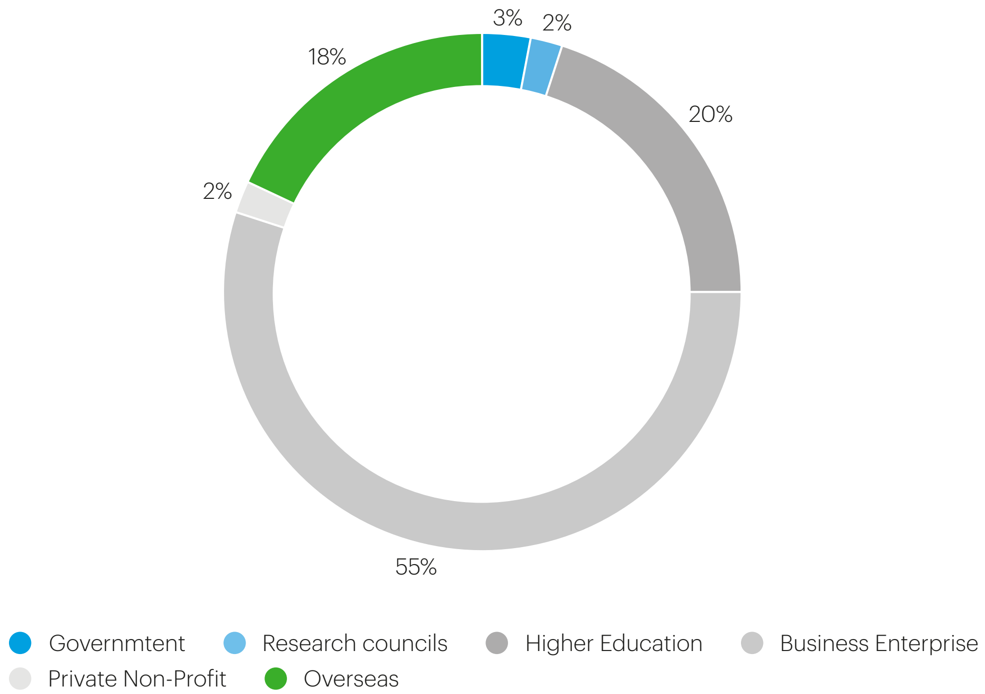
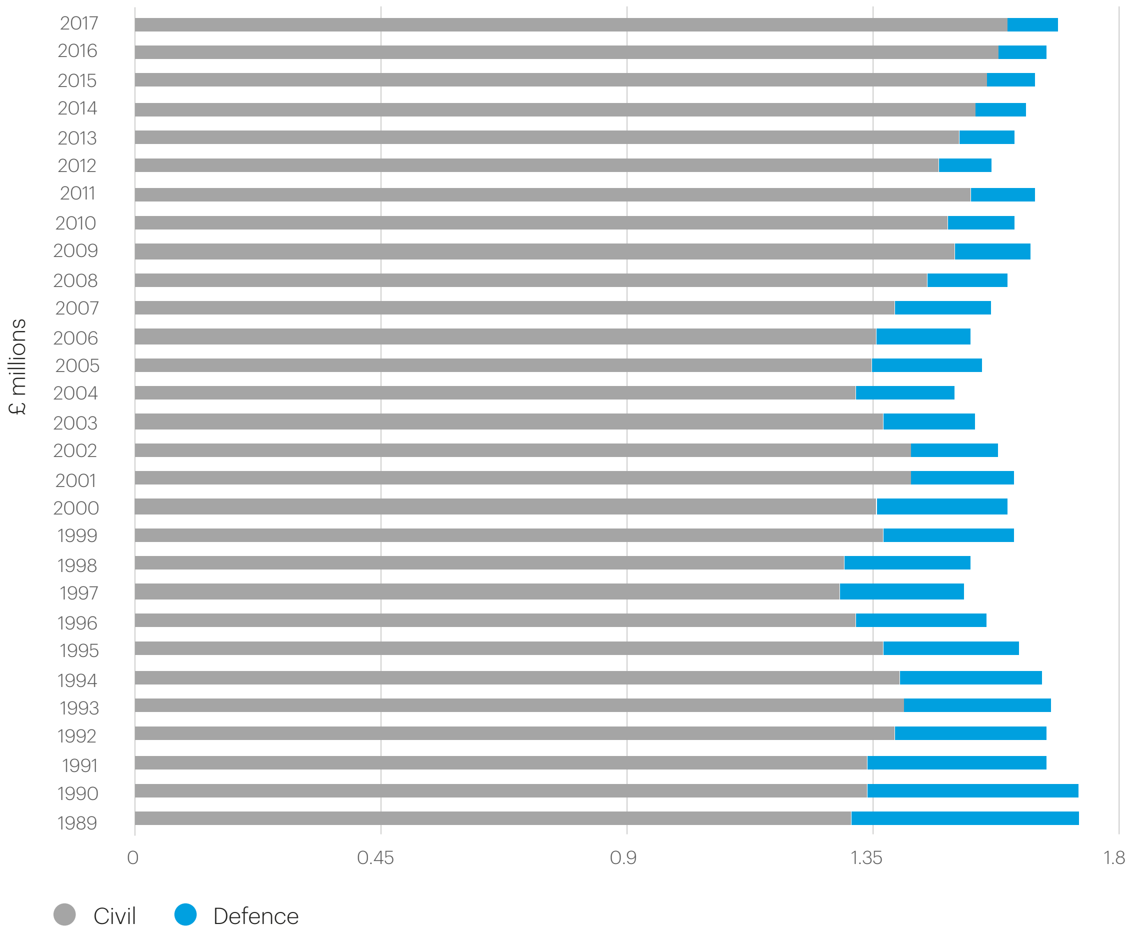


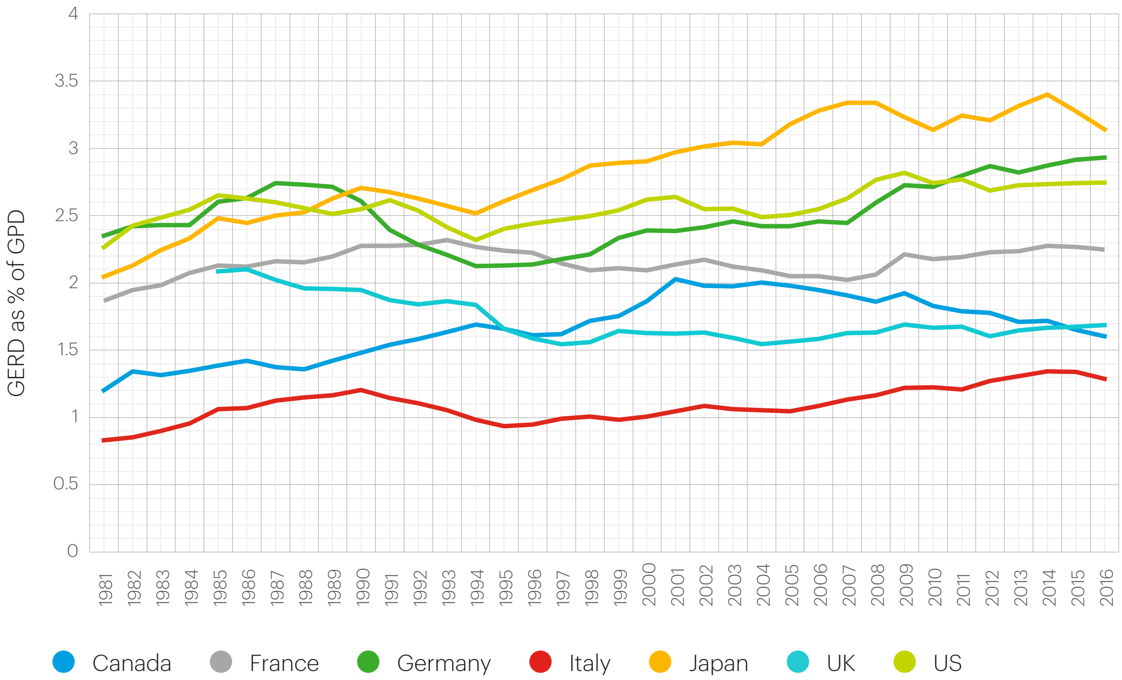
**Figure 7** **Gross expenditure on R&D as % of GDP - Civil and Defence**




Source
*ONS (2019): Gross expenditure on R&D(GERD) – Total civil as a percentage of GDP, 1989-2017; Gross expenditure on R&D(GERD) – Total defence as a percentage of GDP, 1989-2017*

**To Note:** The UK spend on defence R&D is today much lower than civil R&D spend and has decreased since 1989. The total spend on R&D as a % of GDP in the UK has remained between 1.5 and 1.7 since 1990.

**Figure 8** **Gross domestic expenditure on R&D in G7 countries as a % of GDP (1981-2016)**




Source
*OECD Science, Technology and R&D Statistics: Main Science and Technology Indicators, 2018, https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm*

**To Note:** The overall picture of UK spend on R&D as a % of GDP is a decrease since 1985 (particularly between 1985 and 1998). The spend has remained relatively level since 1998. The UK spend on R&D as a % of GDP is considerably lower than that of France (2.19%), the USA (2.79%), Germany (3.02%) and Japan (3.20%). The 2017 OECD average was 2.37% and the 2017 EU average was 1.96%.

**Figure 9** **Top 30 global companies by R&D expenditure (2017-18)**

| World Rank | Company | Country | Industry | R&D 2017/18 (€Mn) | R&D One-Year Growth (%) |
|---|---|---|---|---|---|
| 1 | Samsung | South Korea | Electronic & Electrical Equipment | 13436.7 | 11.5 |
| 2 | Alphabet | US | Software & Computer Services | 13387.8 | 18.4 |
| 3 | Volkswagen | Germany | Automobiles & Parts | 13135.0 | -3.9 |
| 4 | Microsoft | US | Software & Computer Services | 12278.8 | 13.0 |
| 5 | Huawei | China | Technology Hardware & Equipment | 11334.1 | 16.6 |
| 6 | Intel | US | Technology Hardware & Equipment | 10921.4 | 2.8 |
| 7 | Apple | US | Technology Hardware & Equipment | 9656.5 | 15.3 |
| 8 | Roche | Switzerland | Pharmaceuticals & Biotechnology | 8884.5 | 4.8 |
| 9 | Johnson & Johnson | US | Pharmaceuticals & Biotechnology | 8800.1 | 16.0 |
| 10 | Daimler | Germany | Automobiles & Parts | 8663.0 | 15.0 |
| 11 | Merck US | US | Pharmaceuticals & Biotechnology | 8474.1 | 48.7 |
| 12 | Toyota Motor | Japan | Automobiles & Parts | 7859.6 | 2.6 |
| 13 | Novartis | Switzerland | Pharmaceuticals & Biotechnology | 7330.9 | -2.3 |
| 14 | Ford Motor | US | Automobiles & Parts | 6670.6 | 9.6 |
| 15 | Facebook | US | Software & Computer Services | 6465.4 | 31.0 |
| 16 | Pfizer | US | Pharmaceuticals & Biotechnology | 6167.8 | -4.9 |
| 17 | Bmw | Germany | Automobiles & Parts | 6108.0 | 18.3 |
| 18 | General Motors | US | Automobiles & Parts | 6086.9 | -9.9 |
| 19 | Robert Bosch | Germany | Automobiles & Parts | 5934.0 | 0.4 |
| 20 | Siemens | Germany | Electronic & Electrical Equipment | 5538.0 | 9.5 |
| 21 | Sanofi | France | Pharmaceuticals & Biotechnology | 5450.0 | 5.7 |
| 22 | Honda Motor | Japan | Automobiles & Parts | 5396.8 | 10.7 |
| 23 | Bayer | Germany | Pharmaceuticals & Biotechnology | 5162.0 | 8.1 |
| 24 | Oracle | US | Software & Computer Services | 5078.8 | -1.1 |
| 25 | Cisco Systems | US | Technology Hardware & Equipment | 5052.1 | -3.8 |
| 26 | Bristol-Myers Squibb | US | Pharmaceuticals & Biotechnology | 4963.7 | 22.9 |
| 27 | Nokia | Finland | Technology Hardware & Equipment | 4916.0 | 0.2 |
| 28 | Qualcomm | US | Technology Hardware & Equipment | 4556.8 | 6.3 |
| 29 | Astrazeneca | UK | Pharmaceuticals & Biotechnology | 4512.6 | -4.2 |
| 30 | Glaxosmithkline | UK | Pharmaceuticals & Biotechnology | 4351.0 | 14.0 |

Source
*R&D Scoreboard, 2018, http://iri.jrc.ec.europa.eu/scoreboard18.html*

**To Note**: In the global context, US, Japanese and European companies are the most significant R&D investors. There are only two UK companies in the top 30 – and three UK companies in the top 100 (Shire is the third at no.98) – and all of these are in the pharmaceuticals industry. This highlights a trend that Edgerton points to: that the UK has historically been better at developing technologies from abroad than innovating them at home. Nationality is that of the Business HQ; R&D expenditure is global (not solely UK).

**Figure 10** **Top 25 UK companies by R&D expenditure (2017-18)**

| UK rank | EU rank | Company | Country | Industry | R&D 2017/18 (€mn) | R&D one-year growth (%) |
|---|---|---|---|---|---|---|
| 1 | 9 | Astrazeneca | UK | Pharmaceuticals & Biotechnology | 4512.6 | -4.2 |
| 2 | 10 | Glaxosmithkline | UK | Pharmaceuticals & Biotechnology | 4351.0 | 14.0 |
| 3 | 31 | Shire | UK | Pharmaceuticals & Biotechnology | 1430.9 | 22.1 |
| 4 | 35 | Rolls-Royce | UK | Aerospace & Defence | 1112.0 | 13.6 |
| 5 | 39 | Lloyds Banking | UK | Banks | 957.6 | 83.6 |
| 6 | 43 | Unilever | UK | Food Producers | 900.0 | -8.0 |
| 7 | 50 | Royal Dutch Shell | UK | Oil & Gas Producers | 768.8 | -9.1 |
| 8 | 55 | Barclays | UK | Banks | 745.8 | -30.7 |
| 9 | 57 | Aptiv | UK | Automobiles & Parts | 735.4 | -26.5 |
| 10 | 67 | BT | UK | Fixed Line Telecommunications | 573.4 | -1.7 |
| 11 | 74 | Arris | UK | Technology Hardware & Equipment | 449.5 | -7.8 |
| 12 | 76 | Royal Bank Of Scotland | UK | Banks | 432.6 | -20.0 |
| 13 | 90 | Relx Group | UK | Media | 342.5 | 8.6 |
| 14 | 95 | bp | UK | Oil & Gas Producers | 326.0 | -2.3 |
| 15 | 97 | Bae Systems | UK | Aerospace & Defence | 318.8 | 36.7 |
| 16 | 102 | GKN | UK | Automobiles & Parts | 301.9 | 5.5 |
| 17 | 115 | Sky | UK | Media | 262.5 | 14.2 |
| 18 | 116 | International Game Technology | UK | Travel & Leisure | 261.1 | -8.9 |
| 19 | 117 | Atlassian Corporation | UK | Software & Computer Services | 258.6 | 48.9 |
| 20 | 122 | Aston Martin UK | UK | Automobiles & Parts | 252.7 | 76.2 |
| 21 | 126 | Dialog Semiconductor | UK | Technology Hardware & Equipment | 243.3 | 16.7 |
| 22 | 131 | Vodafone Group Services | UK | Mobile Telecommunications | 232.0 | 480.0 |
| 23 | 140 | Weybourne Group | UK | Household Goods & Home Construction | 223.1 | 10.1 |
| 24 | 147 | Amdocs | UK | Software & Computer Services | 216.0 | 2.7 |
| 25 | 149 | Reckitt Benckiser | UK | Household Goods & Home Construction | 210.7 | 25.5 |

Source
*R&D Scoreboard, 2018, http://iri.jrc.ec.europa.eu/scoreboard18.html*

**To Note:** The R&D spend of the UK's two largest pharmaceutical companies (AstraZeneca and GlaxoSmithKline) comes to approximately 78% of the remaining 25 companies' R&D spend combined. These larger companies clearly have the capacity to articulate problems in such a way that merits the attention of science; a challenge for policymakers is to aid smaller businesses in having the capacity to articulate their problems to science. While R&D has the capacity to improve industrial processes and methods, these challenges first need to be articulated by industry.

Again, R&D expenditure here is that which is spent by the companies anywhere in the world. This list does not show who the largest industrial spenders on R&D are in the UK (and many are not British).

**Figure 11** **UK Government Net Expenditure on Research Council R&D by Frascati Type of Research Activity, 2016**

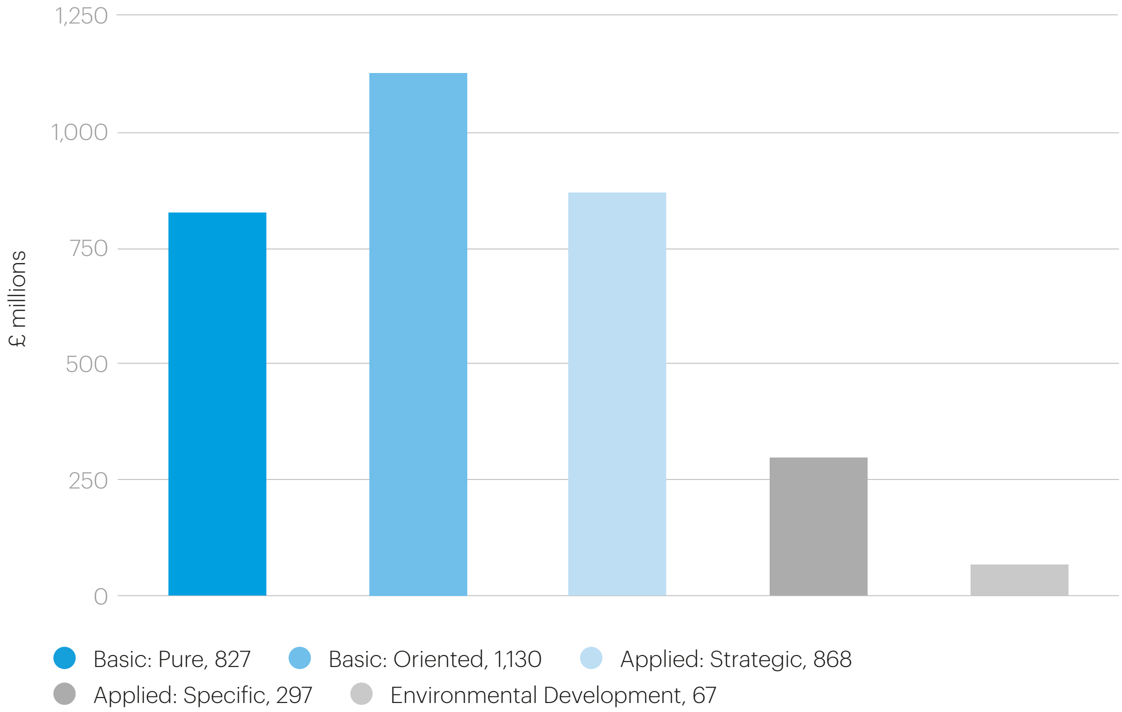
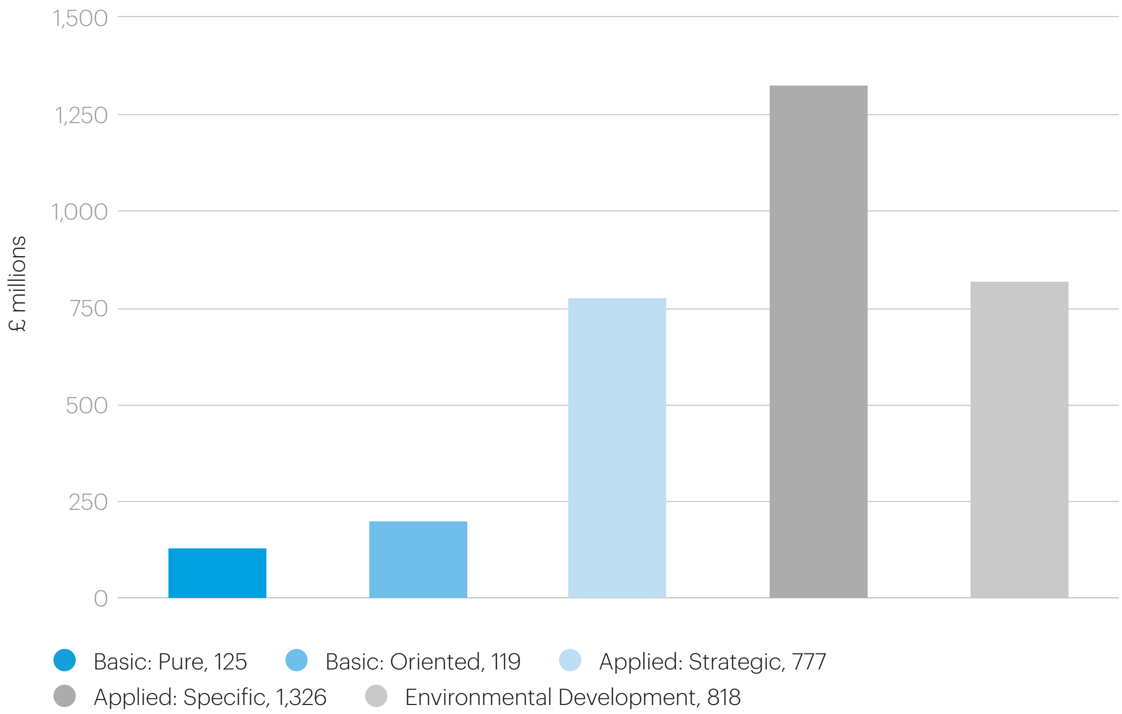



**Figure 12** **UK Government Net Expenditure on Civil Department R&D by Frascati Type of Research Activity, 2016**




Source for both
*ONS (2018), Analysis of UK government net expenditure on research and development by Frascati type of research activity and department, 2009 to 2016*

**Figure 13** **Expenditure on R&D Performed in UK Government by Frascati Type of Research, 2015-2016 (over two years)**

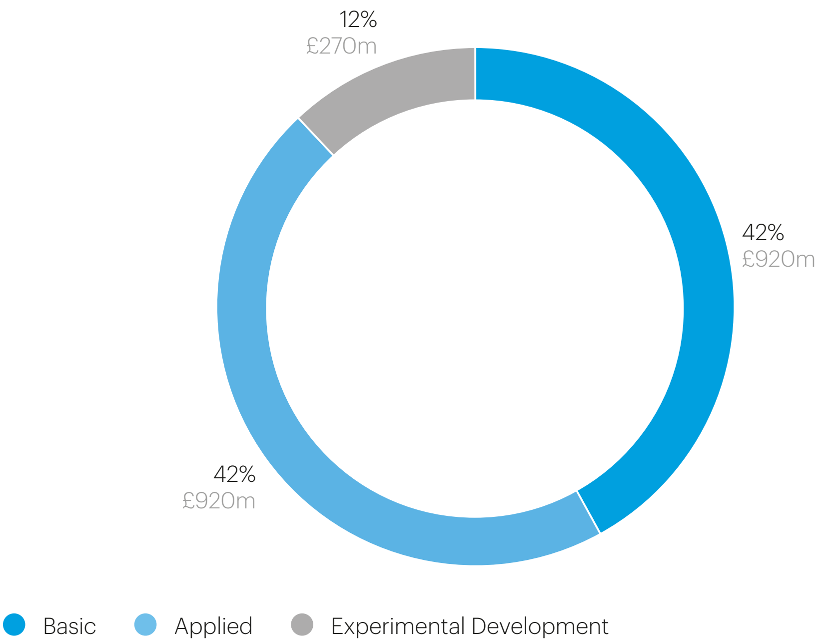
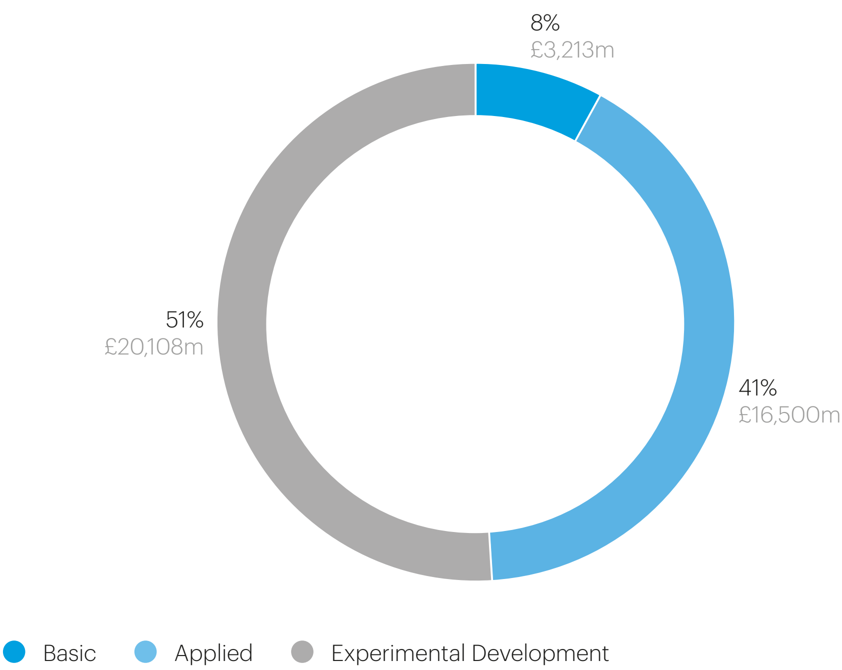



**Figure 14** **Expenditure on R&D Performed in UK Businesses by Frascati Type of Research, 2015-2016 (over two years)**




Source for both
*ONS (2018), Analysis of current expenditure on research and development performed in UK businesses and government departments by country or region and Frascati type of research activity, 2014 to 2016.*

# Chronology: a timeline of science policy milestones in the UK

**1915** **Creation of Advisory Council for Scientific and Industrial Research**

Composed of scientists and individuals employed in industries that were dependent upon scientific research, the Advisory Council was tasked with creating proposals for: “instituting specific researches”; “establishing or developing institutions or departments for the scientific study of problems affecting particular industries”; “the establishment and award of Research Students”.[85] The Advisory Council operated “under the aegis” of the Board of Education.[86]

**1916:** **Creation of the Department of Scientific and Industrial Research (DSIR)**

The Department of Scientific and Industrial Research was created with the following remit: to be “responsible for the organisation, development and encouragement of scientific and industrial research and the dissemination of its results.”[87] It aimed to do so by “encouraging and supporting scientific research in universities, technical colleges and other institutions, establishing and developing its own research organisations for investigation and research relative to the advancement of trade and industry, and taking steps to further the practical application of the results of research.”[88] The Department of Scientific and Industrial Research was the first department explicitly designed to promote organised research and funding from Whitehall.[89] It existed under this title for 49 years, until its abolishment in 1965.[90] It operated 15 laboratories at the time of its dissolution, which included the National Physical Laboratory (from 1918), The Building Research laboratory and the Road Research Laboratory.[91] The Department was the forerunner to the Research Council structure, which was created in 1965.

**1918** **First formal meeting of all UK university vice chancellors**

Having helped persuade Oxford University to create Britain’s first doctorate programme in 1917, Arthur Balfour, then Foreign Secretary, recognised the need for British universities to communicate as a group exactly what the British academic system had to offer to American graduate students, given that America had entered the war and studying in Germany was no longer an option. In March 1918, therefore, Balfour proposed a meeting: “I am venturing now to invite representatives of all the Universities of Great Britain and Ireland to [...] the Foreign Office and confer upon the whole subject”.[92] The Vice Chancellors all met Balfour at the Foreign Office where they requested funding from the government to improve the quality of facilities offered by British

85 Ian Varcoe, ‘Scientists, Government and Organised Research in Great Britain 1914-16: The Early History of the DSIR’, Minerva, 8/2 (1970), p.207.
86 Ibid., p.208.
87 The National Archives, ‘Records created or inherited by the Department of Scientific and Industrial Research’, http://discovery.nationalarchives.gov.uk/details/r/C89 [Accessed 14 November 2018].
88 Ibid.
89 David Willetts, 100 Years of Science Policy (Strand Group Lecture, 2016).
90 David Willetts, A University Education (Oxford: Oxford University Press, 2017), p.97.
91 Philip Gummett, Scientists in Whitehall, p.24.
92 Quoted in David Willetts, *A University Education*, p. 96.

institutions, providing the impetus to form the University Grants Committee (UGC) in 1919 to distribute public funding to universities.[93] In 1930 this group became the Committee of Vice-Chancellors and Principals (CVCP), which in turn became Universities UK (UUK) in 2000.[94]

## 1918 Haldane Committee's *Report on the Machinery of Government*

In 1918, Viscount Haldane published the *Report on the Machinery of the Government*. He was tasked by the government to "enquire into the responsibilities of the various Departments of the central executive Government, and to advise in what manner the exercise and distribution of the Government of its functions should be improved".[95] A recommendation of the report was to separate research work supervised by administrative departments from 'general use research' and intelligence, the latter to be undertaken by 'Advisory Councils' (i.e. Research Councils) and overseen by a Minister who would lead a new Department of Intelligence and Research rather than the recently created DSIR.[96] Following Haldane's report, a Medical Research Council (MRC) was created in 1920, followed by the creation of an Agricultural Research Council (ARC) in 1931 and Nature Conservancy, the body tasked with organising and developing research on the natural environment, in 1949.[97] The 'Haldane Principle' - that decisions on individual research proposals (and the allocation of funding) are best taken by researchers via peer review – supposedly arises from this report.[98] Some historians dispute this.[99] For example, Professor David Edgerton argues that the principle is derived from 1964 when Conservative MP Quintin Hogg opposed his Labour opposition's plans to centralise control of research by saying "since 1915 it has been considered axiomatic that responsibility for industrial research and development is better … on what I have called the Haldane principle through an independent council of industrialists, scientists and other eminent persons … not directly by a Government Department".[100]

## 1918 Department of Scientific and Industrial Research takes over the National Physical Laboratory (NPL)

From 1 April 1918, the Department of Scientific and Industrial Research assumed responsibility for the National Physical Laboratory (NPL), the institution for "standardising and verifying instruments, for testing materials and for the determination of physical constants".[101] However, the responsibility remained with the Royal Society over the NPL's programme of work and for its "appointment, promotion and dismissal of staff".[102]

93 David Willetts, A University Education, p. 96
94 Universities UK, 'Our History', https://www.universitiesuk.ac.uk/about/Pages/our-history.aspx [Accessed 25 October 2018].
95 *Report of the Machinery of Government Committee,* Cd. 9230 (London: H. M. Stationery Office, 1918). (Available here).
96 Houses of Parliament, 'History of the Haldane Principle', https://publications.parliament.uk/pa/cm200809/cmselect/cmdius/168/16807.htm#note119 [Accessed 25 October 2018].
97 The National Archives, 'Nature Conservancy', http://discovery.nationalarchives.gov.uk/details/r/C134 [Accessed 31 October 2018].
98 Department for Education, 'Higher Education and Research Bill: UKRI Vision, Principles and Governance (2016)', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/559210/Higher_Education_and_Research_Bill-UKRI_Vision_Factsheet.pdf [Accessed 25 October 2018].
99 See, for example, Professor David Edgerton, 'The "Haldane Principle" and other invented traditions in science policy', http://www.historyandpolicy.org/policy-papers/papers/the-haldane-principle-and-other-invented-traditions-in-science-policy [Accessed 25 October 2018].
100 Houses of Parliament, 'History of the Haldane Principle', https://publications.parliament.uk/pa/cm200809/cmselect/cmdius/168/16807.htm#note119 [Accessed 25 October 2018].
101 The National Archives, 'Records of the National Physical Laboratory', http://discovery.nationalarchives.gov.uk/details/r/C864 [Accessed 8 January 2019].
102 Ibid.

**1918** **First Industrial Research Associations launched**

International competition and the strain on productive capacity as a result of the First World War helped convince British manufacturers that co-operation in research offered significant advantages, for example in the improvement of processes via testing and experimentation.[103] The first industrial research associations to be created included the British Photographic Research Association, founded on 5 May 1918, and the British Scientific Instrument Research Association, founded 23 May 1918.[104]

**1919** **Creation of the University Grants Committee (UGC)**

The University Grants Committee was created after the First World War to "advise on the distribution of recurrent and capital resources from Government in the form of grants to university institutions".[105]

**1920** **Creation of the Medical Research Council (MRC)**

Though the Medical Research Council was formally constituted in 1920, it was effectively created in 1913 in the form of the Medical Research Committee.[106]

**1926** **Launch of the Empire Marketing Board**

Founded in May 1926, the Empire Marketing Board (EMB) was tasked with encouraging trade in the British Empire and was "given committees for research, marketing and publicity."[107] It took the form of a "small government body" and amongst its key priorities was improving the "quality, storage and distribution" of British and colonial produce.[108] It was abolished in 1933.[109]

**1931** **Creation of the Agricultural Research Council (ARC)**

The Agricultural Research Council was established on 23 July 1931 following a recommendation in 1930 from the Economic Advisory Council on Agricultural Research Organisation that a single body should assume responsibility for the "coordination and supervision of agricultural research".[110]

103 Ian Varcoe, 'Research Associations in British Industry, 1918-34', Minerva, 19/3 (1981), pp.433-434.
104 Ibid., p.438.
105 Michael Shattock and Robert Berdahl, 'The British University Grants Committee 1919-83: Changing Relationships with Government and the Universities', Higher Education, 13 (1984), p.472.
106 Jane Ferrie and Shah Ebrahim, 'EDITORIAL: One hundred years of Medical Research – the UK Medical Research Council Centenary, International Journal of Epidemiology, 42 (2013), p.930.
107 Karl Hack, 'Selling Empire: The Empire Marketing Board', The Open University, 20 January 2013. (See here).
108 Ibid.
109 Ibid.
110 The National Archives, 'Agricultural Research Council and Agricultural and Food Research Council: Reports, Minutes and Papers', http://discovery.nationalarchives.gov.uk/details/r/C10600 [Accessed 8 January 2019].

**1939** **Creation of the Ministry of Supply (MoS)**

Formed by the Ministry of Supply Act 1939, the ministry was responsible for the "administration of the Royal Ordnance Factories" and for the "design, inspection, research and experimental work" related to the supply of munitions and other stores to the War Office and Air Ministry.[111] It was disbanded and reconstituted as the Ministry of Aviation in October 1959.[112]

**1940** **Colonial Development and Welfare Act**

The Colonial Development and Welfare (CDW) Act assigned £50 million per annum to 1950 for development and welfare.[113] Of that sum, £5 million was the maximum allowed annual spend, but an additional annual sum of £500,000 was set aside for 'colonial research'.[114] The Act made provision for the Secretary of State for the Colonies to "make schemes for any purpose likely to promote the development of resources of any colony" and widened the scope of potential projects to include capital expenditure and expenditure on education.[115] Officials intended to form a 'self-contained' Research Department at the Colonial Office – to create a "DSIR to the Colonial Office".[116]

**1942** **Creation of the Colonial Research Committee (CRC)**

The CRC, created in 1942, a body of leading British scientists, oversaw the spending of the research funds allocated to colonial research through the CDW Act. At its first meeting in June 1942, the committee was comprised of Edward Mellanby (Secretary of the MRC), W.W.C. Topley (Secretary of the ARC), Edward Appleton (Secretary of the DSIR) and A.V. Hill (President of the Royal Society). It was chaired by Lord Hailey, the chief proponent of the notion of a large fund for colonial research. They formed an ideologically cohesive group in their views on the conditions necessary for research to flourish. The basic tenets of this liberal ideology of research were that knowledge in science was only really gained through fundamental research, and that this research must be 'free' and not subject to interference by individuals without experience of research themselves, such as government administrators.[117]

**1945** **Publication of Vannevar Bush's *Science - The Endless Frontier***

Vannevar Bush, who oversaw the United States Office of Scientific Research and Development during the Second World War, published in 1949 a report called *Science – The Endless Frontier* in which he argued that government should actively support research in areas which private sources may inadequately fund. He said that areas including research on military problems, agriculture, housing, public health, certain medical research and research involving expensive capital equipment, if supported by governments, could have a tangible impact on societies: "As long as [universities] are vigorous and healthy and their scientists are free to pursue the truth wherever it may lead,

111 The National Archives, 'Records created or inherited by the Ministry of Supply and successors, the Ordnance Board, and related bodies', http://discovery.nationalarchives.gov.uk/details/r/C251 [Accessed 8 January 2019].
112 Ibid.
113 E.R. Wicker, 'Colonial Development and Welfare, 1929-1957: The Evolution of a Policy', Social and Economic Studies, 7/4 (1958), p.181.
114 E.R. Wicker, 'Colonial Development and Welfare, 1929-1957: The Evolution of a Policy', Social and Economic Studies, 7/4 (1958), p.181.
115 Ibid., p.181.
116 Sabine Clarke, "A technocratic imperial state? The colonial office and scientific research, 1940-1960", Twentieth Century British History 18 (2007), p. 464.
117 Sabine Clarke, "A technocratic imperial state? The colonial office and scientific research, 1940-1960", Twentieth Century British History 18 (2007), pp. 453-480.

there will be a flow of new scientific knowledge to those who can apply it to practical problems in Government, in industry, or elsewhere".[118]

**1945**

## National nuclear power and bomb programmes launched

In 1945, Prime Minister Clement Attlee commissioned GEN 75, a ministerial Cabinet Committee on Atomic Energy.[119] In December of that year, GEN 75 approved the construction of an atomic pile to produce plutonium at the Windscale facility in Cumbria, England.[120] The decision to research and develop a British atomic weapon was then taken in January 1947.[121]

**1946**

## Publication of *Scientific Man-Power: Report of a Committee by the Lord President of the Council*

The committee was appointed in 1945 and tasked with consider "the policies which should govern the use and development of our scientific man-power and resources during the next ten years".[122] It identified the main challenges for the coming decade: bringing qualified scientists back from the armed forces to civil life, including guiding them into peace-time occupations dictated by the requirements of reconstruction and repairing the physical damage that had been inflicted on universities and research institutions.[123] The report also outlined a longer-term problem: the need to ensure that supply of qualified scientists for Britain's reconstruction needs was met.[124]

**1947**

## Creation of the Advisory Council on Scientific Policy (ACSP)

The Advisory Council on Scientific Policy (ACSP) was created in 1947, its function to advise "the Lord President of the Council in the exercise of his responsibility for the formulation and execution of Government scientific policy".[125] It comprised six government scientists and six non-government scientists, and evolved from the Scientific Advisory Committee to the War Cabinet which had been formed in 1940.[126]

**1947**

## Defence Research Policy Committee established

Created in 1947, the Defence Research Policy Committee (DRPC) reported to the Chiefs of Staff Committee and the Minister of Defence. The DRPC would provide advice and 'formulate the scientific programs that would fulfil the Chiefs of Staff's strategic objectives'.[127] It was replaced in 1963 by three new bodies: the Defence Research Committee (DRC); the Weapons Development Committee (WDC); and an Operational Requirements Committee (ORC).[128]

118 Vannevar Bush, 'Science – The Endless Frontier', https://www.nsf.gov/od/lpa/nsf50/vbush1945.htm [Accessed 31 October 2018].
119 Peter Hennessy, Cabinets and the Bomb (Oxford: OUP for The British Academy, 2007), p.4.
120 Ibid., p.8.
121 Ibid., p.8.
122 The Barlow Report (1946), Scientific Man-Power: Report of a Committee by the Lord President of the Council (London: HMSO, 1946), p.3.
123 Ibid., p.3.
124 Ibid., p.3.
125 The Royal Society, 'The Royal Society and the genesis of the Scientific Advisory Committee to Britain's War Cabinet, 1939-1940', https://royalsocietypublishing.org/doi/abs/10.1098/rsnr.1978.0007 [Accessed 8 January 2019].
126 Ibid.
127 Jon Agar and Brian Balmer, 'British scientists and the Cold War: The Defence Research Policy Committee and information networks, 1947-1963', *Historical Studies in the Physical and Biological Sciences*, 28/2 (1998), p. 209.
128 Ibid., p.246.

**1948** 
## The Colonial Research Committee becomes the Colonial Research Council

The Colonial Research Council was formed in February 1948, replacing the Colonial Research Committee that had been appointed in June 1942. The new Colonial Research Council would co-ordinate "the work of various committees advising on special aspects of research" and would itself consider and matters that did not fall within the remits of those committees.[129] In 1959 it was replaced by the Overseas Research Council.

**1949** 
## National Research Development Corporation (NRDC) established

The National Research Development Corporation was created in 1949 to "encourage and stimulate the development of the British computer industry".[130] It invested directly in the computer industry by placing contracts with firms such as Ferranti and also funded computer science studentship at the University of Cambridge and Manchester University across the 1950s.[131]

**1949** 
## Creation of the Nature Conservancy research council

Nature Conservancy was formed as a body "under the aegis of a committee of the Privy Council".[132] It had three primary functions: "to provide scientific advice on the conservation and control of the natural flora and fauna of Great Britain; to establish, maintain and manage nature reserves in Great Britain, including the maintenance of physical features of scientific interest; and to organise and develop the research and scientific services related thereto".[133] In 1965, it became part of the new Natural Environment Research Council.[134]

**1954** 
## Creation of the United Kingdom Atomic Energy Authority (UKAEA)

In 1954, the Atomic Energy Act created the United Kingdom Atomic Energy Authority. Its original functions "covered the entire field of atomic energy and radioactive substances" and it took the form of a public corporation with a board and chairman appointed by the Lord President of the Council, who was responsible to Parliament for the authority's activities.[135] It still exists today and researches 'fusion energy and related technologies' with the goal of making the United Kingdom a leader in 'sustainable nuclear energy.'[136]

129 The National Archives, 'Colonial Research Committee and Colonial Research Council: Minutes and Papers', http://discovery.nationalarchives.gov.uk/details/r/C5089 [Accessed 8 January 2019].
130 JISC Archive Hub, 'The National Research Development Corporation (NRDC) Collection', https://archiveshub.jisc.ac.uk/search/archives/36d1305b-cdcc-301a-bf93-d676ed108883 [Accessed 8 January 2019].
131 Ibid.
132 The National Archives, 'Records created or inherited by the Nature Conservancy, the Nature Conservancy Council and English Nature', http://discovery.nationalarchives.gov.uk/details/r/C134 [Accessed 8 January 2019].
133 Ibid.
134 Ibid.
135 The National Archives, 'Records of the United Kingdom Atomic Energy Authority and its predecessors', http://discovery.nationalarchives.gov.uk/details/r/C2 [Accessed 8 January 2019].
136 GOV.UK, 'UK Atomic Energy Authority', https://www.gov.uk/government/organisations/uk-atomic-energy-authority [Accessed 8 January 2019].

**1959** **Creation of an Office of the Minister for Science**

This creation of the Office of the Minister for Science in December 1959 marked the first time that the United Kingdom had a designated Minister for Science, in the form of the Conservative Viscount Hailsham, who as Lord President from 1957 had overseen the main civil scientific Departments and Lord Privy Seal in 1959 was responsible for the four research councils.[137] The Minister of Science was to assume responsibility for the Department of Scientific and Industrial Research (DSIR), the research councils, atomic energy and space research and other general matters of civil science policy.[138] However, in keeping with the 'Haldane Principle' which was supposedly established in 1915, the Minister would not be responsible for departmental research programmes.[139] Both the Conservative and Labour Parties in their manifestos for the October 1959 general election had proposed a senior, full-time Minister for Science.[140] This was the first time that the United Kingdom had a designated Minister for Science.

**1960** **Blue Streak missile development programme ended**

The programme to develop a 'long-range liquid-fuelled missile' which was launched in 1955 and known as Blue Streak, was cancelled in 1960.[141] Blue Streak would be launched from fixed sites which took up to thirty minutes to prepare, which was deemed as making Britain vulnerable to Soviet attacks.[142] The project would have required significant extra investment if it were not scrapped.[143]

**1961** **The Gibb-Zuckerman report or Report of the Committee on the Management and Control of R&D is published**

The Gibb-Zuckerman stressed the need to establish "a common, improved process in which the development of every major project", particularly in relation to defence procurement.[144] For example, it argued that each project should have the milestones including a Staff Target, defining the military capability require and a Feasibility Study, evaluating the scientific and technical issues involved in meeting the Staff Target.[145]

**1963** **OECD publishes the Piganiol Report**

The 1961 Piganiol Report argued the case for all OECD countries producing 'explicit policies and mechanisms' for the 'management and effectiveness of the science system', which it called 'policies for science'.[146] As well as recommending that each government set up "some central mechanism to

137 Houses of Parliament, 'Hansard – 9 December 1959', p.4. https://api.parliament.uk/historic-hansard/lords/1959/dec/09/science-in-civil-life [Accessed 31 October 2018].
138 Kieron Flanagan and Michael Keenan, 'Trends in UK science policy' in Paul Cunningham (ed.), Science and Technology in the United Kingdom (London: Cartermill Publishing, 1998), p.3.
139 Ibid.
140 Houses of Parliament, 'Hansard – 9 December 1959', https://api.parliament.uk/historic-hansard/lords/1959/dec/09/science-in-civil-life [Accessed 31 October 2018].
141 The National Archives, 'The Blue Streak Rocket', http://www.nationalarchives.gov.uk/films/1951to1964/filmpage_rocket.htm [Accessed 8 January 2019].
142 Ibid.
143 Ibid.
144 Parliament.uk, 'Equipping The Forces', https://publications.parliament.uk/pa/cm199798/cmselect/cmdfence/138/13821.htm#n878 [Accessed 9 January 2019].
145 Ibid.
146 Mary Hawkesworth and Maurice Kogan (eds), 'Science and Technology Policy', *Encyclopaedia of Government and Politics, Volume 2* (London: Routledge, 1992), p.764.

discuss science policy" it also suggested that a meeting of OECD Ministers responsible for science policy was convened, and such a conference occurred in Paris in 1963.[147]

**1963**

### The Trend Report- The Report of the Committee of Enquiry into the Organisation of Civil Science - is published

The Report stated how the UK's current system of research funding was not fit for purpose: "the various agencies concerned with the promotion of civil science do not, in the aggregate, constitute a coherent and articulated pattern of organisation; second that the arrangements for co-ordinating the Government's scientific effort and for apportioning the available resources between the agencies on a rational basis are insufficiently clear and precise".[148] Trend proposed a structure of four research councils, with an identifiable minister responsible for them and an advisory body co-ordinating research council issues.[149] One of the Report's key recommendations – that a new Department of Education and Science (DES) should be created to take responsibility for the research councils – was enacted in 1964.[150] While the newly-elected Labour government in 1964 rejected the idea of a Minister for Science, they implemented Trend's recommendation to form a Science Research Council and Natural Environment Research Council to sit alongside the pre-existing Medical Research Council and Agricultural Research Council.[151] The Trend Report effectively argued to disband the Department of Scientific and Industrial Research (DSIR), which then occured in 1965.[152] Trend's proposed structure regarding research councils could be recognised as the modern research council model.[153]

**1964**

### Creation of the Department of Education and Science (DES)

Launched prior to the 1964 general election, the Department of Education and Science was formed from a merger of the Ministry of Education and the Office of the Minister for Science.[154] It took responsibility for oversight of the research councils.[155]

**1964**

### Creation of the Ministry of Technology (MinTech)

The incoming Labour government under Prime Minister Harold Wilson created a new Ministry of Technology, which took control over the industrial arm of the Department of Scientific and Industrial Research.[156] MinTech was in existence from 1964-70 and was given a 'sponsorship' role over crucial industrial sectors, namely computing, electronics, telecommunications and machine tools. It absorbed the Ministry of Aviation in 1967 and in 1969 absorbed the Ministry of Power, while also extending the breadth of industry

147 John Pulparampil, *Science and Society: a Perspective on the Frontiers of Science Policy* (Delhi: Concept Publishing, 1978), p.44.
148 Report of the Committee of Enquiry into the Organisation of Civil Science, Cd 217 (London: H. M. Stationery Office, 1963).
149 Willetts, *100 Years of Science Policy* (Strand Group Lecture, 2016).
150 Kieron Flanagan and Michael Keenan, 'Trends in UK science policy' in Paul Cunningham (ed.), Science and Technology in the United Kingdom (London: Cartermill Publishing, 1998), p.4.
151 *Bulletin of The Atomic Scientists,* April 1968, p.22.
152 Willetts, *A University Education,* p.97.
153 Willetts, 100 Years of Science Policy (Strand Group Lecture, 2016).
154 The National Archives, 'Department of Education and Science', http://discovery.nationalarchives.gov.uk/details/r/C101 [Accessed 31 October 2018].
155 Kieron Flanagan and Michael Keenan, 'Trends in UK science policy' in Paul Cunningham (ed.), Science and Technology in the United Kingdom (London: Cartermill Publishing, 1998), p.4.
156 Ibid.

sectors it 'sponsored'.[157] Historian Kevin Theakston has described MinTech after 1969 as a "giant and powerful industry/production conglomerate".[158] After his election in 1970, Conservative Prime Minister Edward Heath merged the Ministry of Technology with the Board of Trade to create the Department of Trade and Industry.[159] At the time of its creation, MinTech was part of a sweeping change to the organisation of Whitehall, with four other new departments, including the Department of Economics Affairs, created by Harold Wilson at the same time. Wilson described this as "the biggest single revolution in the structure of Government ever carried out".[160] The Ministry of Technology was part of a Wilson's focus on harnessing science and technology "for national purposes".[161]

**1964**

**Creation of the post of Chief Scientific Adviser to HM Government**

Prime Minister Harold Wilson created the post of Chief Scientific Adviser to HM Government, a post first filled by Sir Solly Zuckerman.[162] The role holder in the UK also became Head of the Scientific Civil Service, a position that had management responsibility for 10,000 people when Zuckerman assumed the title.[163] Departmental Chief Scientific Advisers were in existence from decades earlier, as was the case when Sir Alfred Daniel Hall was made Chief Scientific Adviser to the Ministry of Agriculture and Fisheries in 1920.[164] Dr Robert Doubleday and Professor James Wilsdon describe the contemporary purpose of the Chief Scientific Adviser to the UK Government as follows: "a point of connection between science, politics and public policy: their role is to act as a personal adviser to the prime minister and the Cabinet, to lead the Government Office for Science, and to speak to the public and the media".[165]

**1965**

**Science and Technology Act**

This Act created two additional research councils: the Science Research Council (SRC)[166] and the Natural Environment Research Council (NERC), which absorbed Nature Conservancy.[167]

**1965**

**Creation of the Social Science Research Council (SSRC)**[168]

The Social Science Research Council (SSRC) was founded in 1965 to 'encourage and support by any means research in the social sciences by any other person or body'.[169] In 1984 it was renamed the Economic and Social Research Council (ESRC).[170]

157 M.W. Kirby, 'Blackett in the "White Heat" of the Scientific Revolution: Industrial Modernisation under the Labour Governments, 1964-70', *The Journal of the Operational Research Society,* 50/10 (1999), p.988.
158 Kevin Theakston, 'The 1964-70 Labour Governments and Whitehall Reform', *POLIS Working Paper No. 2* (2004) (Available here);
159 The Science Museum, 'Ministry of Fuel and Power', http://collection.sciencemuseum.org.uk/people/ap25470/ministry-of-fuel-and-power [Accessed 20 November 2018].
160 Quoted in Kevin Theakston, 'The 1964-70 Labour Governments and Whitehall Reform', *POLIS Working Paper No. 2* (2004) (Available here);
161 Hennessy, *The Prime Minister,* p.287.
162 The National Archives, 'Records of the Chief Scientific Adviser', http://discovery.nationalarchives.gov.uk/details/r/C1376 [Accessed 31 October 2018].
163 Professor Jon Agar, 'GCSA at 50 – UCL Blog', https://blogs.ucl.ac.uk/sts-observatory/2014/11/12/gcsa-at-50-some-thoughts/ [Accessed 31 October 2018].
164 House of Lords Science & Technology Committee, Fourth Report of Session 2010-12, 'The role and functions of departmental Chief Scientific Advisers', Paper 264, 2012.
165 Ibid., p.301.
166 EPSRC, 'Our Beginnings', See https://epsrc.ukri.org/about/history/ourbeginnings/ [Accessed 31 October 2018].
167 NERC, 'Report on the economic and social impact of selected NERC-funded research - 2015', https://nerc.ukri.org/about/perform/evaluation/evaluationreports/deloitte-report/ [Accessed 31 October 2018].
168 ESRC, 'Our History', https://esrc.ukri.org/about-us/what-we-do/our-history/ [Accessed 31 October 2018].
169 Legislation.gov.uk, 'Science and Technology Act 1965', http://www.legislation.gov.uk/ukpga/1965/4/ni/enacted [Accessed 9 January 2019].
170 ESRC, 'Our History', https://esrc.ukri.org/about-us/what-we-do/our-history/ [Accessed 9 January 2019].

**1965** **Creation of the Council for Scientific Policy (CSP)**

An independent body charged with advising the Secretary of State for Education and Science on science policy, such as how resources were distributed between the research councils.[171]

**1965** **Lord Plowden publishes *The Report of the Committee of Inquiry into the Aircraft Industry***

Lord Plowden's report put forward the idea that aircraft projects should be argued for on economic grounds and that the industry had received exceptional government support compared to other industries, meaning that a decrease was 'desirable'.[172] Plowden also recommended co-operation between British and European firms in order to compete with American firms.[173]

**1965** **Britain orders an Advanced Gas-cooled nuclear Reactor (AGR)**

Advanced Gas-cooled nuclear Reactors (AGRs) were the second generation of nuclear reactors which superseded the first-generation Magnox reactors.[174] A British designed AGR was chosen over an American design, which was seen as a triumph for British nuclear technology.[175]

**1968** **The Central Advisory Council for Science and Technology publishes Technological Innovation in Britain**

The Council, a Cabinet-level body, was established in 1967 to "Advise the Government on the most effective national strategy for the use and development of our scientific and technological resources".[176] *Technological Innovation in Britain* was the only report the Council ever published.[177] The report said that basic science was the origin of "all new knowledge without which opportunities for further technical progress must rapidly become exhausted".[178]

**1970** **Ministry of Technology publishes a green paper entitled *Industrial Research and Development in Government Laboratories: A New Organisation for the Seventies***

The green paper, published on 27 January 1970, recommending that six reactor research and development institutions merge together along with five Ministry of Technology laboratories and the National Research Development Corporation to form one government research corporation.[179]

171 Kieron Flanagan and Michael Keenan, 'Trends in UK science policy' in Paul Cunningham (ed.), Science and Technology in the United Kingdom (London: Cartermill Publishing, 1998), p.4.
172 David Edgerton, *Warfare State: Britain, 1920-1970* (Cambridge: Cambridge University Press, 2006), p.242.
173 G.C.Peden, *Arms, Economics and British Strategy: From Dreadnoughts to Hydrogen Bombs* (Cambridge, Cambridge University Press, 2007) p.313.
174 Donna Gore, *Decommissioning of Nuclear Power Stations* (House of Commons Library: Research Paper 96/83, 1996), p.8.
175 Ibid.
176 JISC Archives Hub, 'Zuckerman Archive: Central Advisory Council for Science and Technology', https://archiveshub.jisc.ac.uk/search/archives/949a06bb-ed7a-3090-82c9-0ff12705614f [Accessed 9 January 2019].
177 David Edgerton, *Warfare State: Britain, 1920-1970* (Cambridge: Cambridge University Press, 2006), p.254.
178 Quoted in J. Stanley Metcalfe (ed.), 'Science Policy and Technology Policy When Competition is an Evolutionary Process' in J. Stanley Metcalfe, *Evolutionary Economics and Creative Destruction* (London: Routledge, 1998), p. 109.
179 Sage Journals, 'Calendar of Economic Events: January – April 1970', https://journals.sagepub.com/doi/pdf/10.1177/002795017005200108 [Accessed 9 January 2019].

**1970** **Ministry of Technology becomes Department of Trade and Industry (DTI)**

The Ministry of Technology was merged with the Board of Trade in October 1970 to form the new Department of Trade and Industry (DTI).[180] The DTI took over all of its functions apart from those relating to aerospace research, development and procurement, which a new Ministry of Aviation Supply took over.[181]

**1971** **Lord Rothschild, Head of the Prime Minister's Central Policy Review Staff (CPRS), publishes a report entitled *The Organisation and Management of Government R&D***

Lord Rothschild, head of the Prime Minister's Central Policy Review Staff (CPRS) – commonly referred to as the No. 10 'Think-Tank' – published in 1971 The Organisation and Management of Government R&D. The report proposed that research for government departments should be organised on a 'customer-contractor' principle: the "customer says what he wants; the contractor does it (if he can); and the customer pays." Rothschild proposed that chunks of applied research money would be moved from the research councils' budgets to those of the corresponding customer departments. The report said: "However distinguished, intelligent and practical scientists may be, they cannot be so well qualified to decide what the needs of the nation are, and their priorities, as those responsible for ensuring that those needs are met. This is why applied R & D must have a customer." Whitehall was Rothschild's envisaged customer.

**1971** **OECD publishes *the Brooks Report***

The *Brooks Report* supplied a number of recommendations which framed science and technology within the wider context of challenges facing governments and societies.[182] It suggested aligning science policy with social objectives, opposing the OECD's approach of developing science policy with an emphasis on economics considerations.[183]

**1971** ***The Future of the Research Council System,* known as the Dainton Report, is published**

The Dainton Report concluded that the Council for Scientific Policy (created in 1965) should be disbanded and replaced by a Board of Research Councils, a "stronger, statutory body" intended to "strengthen the independence of the councils".[184]

**1972** **Council for Scientific Policy (CSP) replaced by the Advisory Board for the Research Councils (ABRC)**

The Advisory Board for the Research Councils (ABRC), an 'independent body'

180 The National Archives, 'Records of the Ministry of Technology', http://discovery.nationalarchives.gov.uk/details/r/C145 [Accessed 9 January 2019].
181 Ibid.
182 Peter Tindemans, 'Post-war research, education and innovation policy-making in Europe' in Henri Delanghe et al (eds), *European Science and Technology Policy: Towards Integration Or Fragmentation?* (Cheltenham: Edward Elgar, 2009), p.9.
183 Benoit Godin, *Measurement and Statistics on Science and Technology: 1920 to the Present* (London: Routledge, 2005), p.287.
184 Neil Calver and Miles Parker, 'The Logic of Scientific Unity? Medawar, the Royal Society and The Rothschild Controversy 1971-72', *Notes and Records*, 70, p.97.

whose membership included the Heads of the Research Councils, senior academics and industrialists, replaced the Council for Scientific Policy.[185] The ABRC was created with the remit of advising 'in future on the allocation of the science budget … between the Research Councils and other bodies in the Research Council system'.[186]

**1975**

### Creation of the National Enterprise Board

Set up under the Industry Act 1975, the National Enterprise Board was part of Prime Minister Harold Wilson's plans to increase public ownership of British industry.[187] It took ownership of British Leyland, absorbing 'enormous amounts of capital without a return to profitability' in the mid-1970s and later semi-nationalised Ferranti which returned to the private sector as a profitable company.[188]

**1976**

### Formation of Advisory Council for Applied Research and Development (ACARD)

ACARD was created to "advise and publish reports on applied research and technology", supported financially and with a secretariat by the Cabinet Office.[189] Specifically, it was to publish and advise on: applied research and development in the UK; the articulation of this R&D; the future development and application of technology; and the UK's role in international collaboration on applied R&D.[190]

**1981**

### House of Lords Select Committee on Science and Technology publishes its *Science and Government* report

The report made a number of recommendations with the goal of strengthening co-ordination, including: re-creating the post of chief [government scientist]; creating a Cabinet-level Council on Science and Technology; and an annual report on the state of science and technology.[191] It also argued for an annual review of government funded research and the appointment of a minister for science.[192]

**1981**

### Science Research Council (SRC) becomes the Science and Engineering Research Council (SERC)

The SERC replaced the SRC in order to "reflect the increased emphasis on engineering research" that the Council oversaw.[193] Its responsibilities included oversight for all publicly-funded scientific engineering and research work, including: astronomy; biotechnology; biological sciences; space research;

185 William Lea, *Reorganisation of the Science Research Councils* (House of Commons Library: Research Paper 94/19, 1994), p.6.
186 Ibid., p.6.
187 The National Archives, 'Glossary', http://www.nationalarchives.gov.uk/cabinetpapers/help/glossary-n.htm#National_Enterprise_Board [Accessed 10 January 2019].
188 The National Archives, 'National Enterprise Board', http://www.nationalarchives.gov.uk/cabinetpapers/themes/national-enterprise-board-neb.htm [Accessed 10 January 2019].
189 The National Archives, 'Advisory Council on Applied Research and Development (ACARD)', http://discovery.nationalarchives.gov.uk/details/r/c3d6341a-b33e-4381-bdb4-b600d12dd667 [Accessed 10 January 2019].
190 UK Parliament, 'Hansard: 20 March 1978, Volume 946', https://hansard.parliament.uk/Commons/1978-03-20/debates/562d075c-dc56-4429-8554-092ffe834a91/ResearchAndDevelopment(AdvisoryCouncil) [Accessed 10 January 2019].
191 Kieron Flanagan, 'Trends in UK Science Policy' in P. Cunningham (ed.), *Science and Technology on the United Kingdom* (London: Cartermill, 1998), p.6.
192 Ibid., p.6.
193 EPSRC, 'Our beginnings', https://epsrc.ukri.org/about/history/ourbeginnings/ [Accessed 10 January 2019].

and particle physics.[194] In 1994 SERC was split into the Engineering and Physical Sciences Research Council (EPSRC) and the Particle Physics and Astronomy Research Council (PPARC).[195]

1982

**Government's response to *Science and Government***

The Government's response to *Science and Government* accepted the report's view that greater focus was required on co-ordinating science and technology matters in Government, but rejected the proposal for a science minister.[196]

1983

**First *Annual Review of Government-Funded R&D* is published**

The *Annual Review of Government-Funded R&D* was published by the science Group in the Cabinet Office.[197] The review was published annually until 1993.[198]

1983

**Beginning of Alvey programme of collaborative research in information technology**

The Alvey programme ran from 1983 to 1988 and defined a 'set of strategic priorities' for Britain's information technology research.[199] In support of those priorities, the programme part-funded collaborative projects between industry and academia which focused on technologies that included microelectronics and artificial intelligence.[200]

1983

**ABRC and ACARD publish first joint report identifying key policy issues that could protect or enhance a science base useful to industry in the United Kingdom**

Published in July 1983, the first joint report stressed the "interaction and the interdependence of fundamental science and the day-to-day application of technology".[201] It outlined the decline of the United Kingdom's manufacturing industry and argued the need to recover its position as a "leading manufacturing nation".[202]

1983

**The Social Science Research Council (SSRC) is relaunched as the Economic and Social Research Council (ESRC)**

The Rothschild review of 1982 recommended 'greater focus on empirical research and research related to public concerns' and it is in this context that the Social Science Research Council became the Economic and Social Research Council.[203]

194 Ibid.
195 Ibid.
196 Kieron Flanagan, 'Trends in UK Science Policy' in P. Cunningham (ed.), *Science and Technology on the United Kingdom* (London: Cartermill, 1998), p.7.
197 New Scientist, 9 January 1986, p.28.
198 Davies, SM (2017) Organisation and Policy for Research and Development: the Health Department for England and Wales 1961 to 1986. PhD thesis, London School of Hygiene & Tropical Medicine, p.51.
199 Daniel Clery, 'Alvey: the betrayal of a research programme', *New Scientist*, 11 May 1991.
200 Ibid.
201 Hansard, 'Research and Development: ACARD/ABRC Report, 10 February 1984, vol. 447', https://api.parliament.uk/historic-hansard/lords/1984/feb/10/research-and-development-acardabrc-report#S5LV0447P0_19840210_HOL_67 [Accessed 10 January 2019].
202 Ibid.
203 ESRC, 'Our history', https://esrc.ukri.org/about-us/what-we-do/our-history/ [Accessed 10 January 2019].

**1986**

### House of Lords Select Committee on Science and Technology publishes *Civil Research and Development*

This 1986 report addressed four core topics: the organisation of R&D; the sources of funds for basic, strategic and applied R&D; the working of the customer/contractor principle which was presented in the 1971 report by Lord Rothschild; and the civil implications of defence research.[204]

**1986**

### The UK's first Research Assessment Exercise (RAE) takes place

The Research Assessment Exercise introduced for the first time "an explicit and formalised assessment process of the quality of research" undertaken in Higher Education in the United Kingdom.[205] It was technically known as the Research Selectivity Exercise (RSE) in 1986 and 1989.[206] Launched by the Chair of the University Grants Committee, Peter Swinnerton-Dyer, the purpose of the exercise was to 'standardise and assess' the information received with a view to greater selectivity in research funding support and the redistribution of resources between institutions, while also encouraging institutions to allocate funding internally towards work of particular strength.[207] The UK was the first country to assess the quality of research undertaken in its universities.[208] Further exercises were held in 1989, 1992, 1996, 2001 and 2008, the system becoming increasingly comprehensive and systematic with each exercise, before becoming the Research Exercise Framework (REF) in 2014.[209] The next Research Exercise Framework (REF) will be published in 2021. Its purpose is described as threefold: "to provide accountability for public investment in research and produce evidence of the benefits of this investment; to provide benchmarking information and establish reputational yardsticks, for use within the HE sector and for public information; and to inform the selective allocation of funding for research".[210]

**1986**

### Launch of the pressure group Save British Science (SBS)

In early 1986, an advertisement appeared in *The Times* newspaper which had been paid for by 1500 scientists, under the heading 'SAVE BRITISH SCIENCE'.[211] The text warned that "British science is in crisis" and urged support for basic research, "Britain's investment for the future".[212]

**1986**

### ACARD publishes *Exploitable Areas of Science*

This report by the Advisory Council for Applied Research and Development (ACARD) included a preface from Prime Minister Margaret Thatcher, in which she endorsed the report's recommendation that a new process should be established for identifying "areas of science worthy of backing for their

204 Hansard, 'Civil Research and Development', https://api.parliament.uk/historic-hansard/lords/1987/feb/19/civil-research-and-development [Accessed 10 January 2019].
205 RAE2008, 'History of the RAE', https://www.rae.ac.uk/aboutus/history.asp [Accessed 7 November 2018].
206 Lord Nicholas Stern, 'Building on Success and Learning from Experience An Independent Review of the Research Excellence Framework;', July 2016, p.39.
207 Ibid., p.39.
208 Research Exercise Framework, 'Building on Success and Learning From Experience – 2016', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/541338/ind-16-9-ref-stern-review.pdf [Accessed 31 October 2018].
209 RAE2008, 'History of the RAE', https://www.rae.ac.uk/aboutus/history.asp [Accessed 7 November 2018].
210 REF2021, 'Initial decisions on the Research Excellence Framework 2021', September 2017, p.4.
211 Campaign for Science and Engineering, 'From "Save British Science", to "CaSE", to the future', http://www.sciencecampaign.org.uk/news-media/guest-blog/from-save-british-science-to-case-to-the-future.html [Accessed 10 January 2019].
212 Ibid.

commercial potential".[213] The report said that the development of science policy had historically failed to give sufficient consideration to economic and social factors.[214]

**1987** **ABRC publishes its report *A Strategy for the Science Base***

*A Strategy for the Science Base* advocated a 'division of labour' between research and teaching in the United Kingdom's university system.[215] The report's aim was to strengthen the "framework within which the funding and management of interdisciplinary research in institutions of higher education can flourish".[216]

**1987** **Government response to *Civil Research and Development***

*Civil Research and Development* brought about changes in the machinery of government around science policy. The Advisory Council on Science and Technology (ACOST) was created, absorbing the Advisory Council for Applied Research and Development (ACARD) while also adding four new academic members.[217] ACOST therefore became the "most senior science policy advisory body" in the United Kingdom.[218]

**1988** **Creation of the Centre for the Exploitation of Science and Technology (CEST)**

Set up in February 1988, the Centre for the Exploitation of Science and Technology (CEST) was created by a consortium of 18 companies based in Britain, an independent body that was to "develop plans and methods that enable the cycle of exploitation to flow more freely".[219]

**1989** **ABRC given control over research council and allocation of resources between them – previously decided by the Secretary of State with ABRC advice**

The ABRC, from 1989, would explicitly recommend the allocation of funds based on the corporate plans of each research council.[220]

**1992** **Creation of the Office of Science and Technology (OST)**

According to John Major's Government, the OST was to provide a centralised focus for developing government policy on science and technology, "stewarding the research system in order to maximise its contribution to national economic performance and the quality of life".[221] Significantly, for the first time, science was represented by a single minister at the Cabinet level – the Chancellor of the Duchy of Lancaster – who was responsible for the Office of Public Service and Science (OPSS) where the OST was located.

213 Roger Williams, 'The decline of the British science empire', *Bulletin of the Atomic Scientists,* October 1987, p. 46.
214 Ibid.
215 Kieron Flanagan, 'Trends in UK Science Policy' in P. Cunningham (ed.), *Science and Technology on the United Kingdom* (London: Cartermill, 1998), p.7.
216 Hansard, 'Civil Research and Development', https://api.parliament.uk/historic-hansard/lords/1987/nov/18/civil-research-and-development [Accessed 10 January 2019].
217 Kieron Flanagan, 'Trends in UK Science Policy' in P. Cunningham (ed.), *Science and Technology on the United Kingdom* (London: Cartermill, 1998), p.9.
218 Philip Gummett, 'United KingdomP.271.
219 Bob Whelan, 'Answering to the markte', *New Scientist*, 12 November 1988, p.2.
220 Howard Newby, 'The economic and social research council: Policies and prospects', *Policy Studies*, 10/2 (1989), p.5.
221 Flanagan, 'Trends in UK science policy', p1.

**1993** ***Realising our Potential: A Strategy for Science, Engineering and Technology White Paper* is published**

*Realising Our Potential,* launched in May 1993, had three key themes: that the United Kingdom was "potentially very strong in science and technology"; that steps should be taken to 'harness that strength ... to the creation of wealth"; and that the "direction and management of the Government's own research and development" efforts in recent years had been "broadly correct".[222] *Realising Our Potential* was the first general review of science, engineering and technology policy and organisation since the 1971 Rothschild Report entitled *The Organisation and Management of Government R&D* and the Dainton Report on *The Future of the Research Council System* of the same year.[223]

**1994** **Research Council Reorganisation**

Following the White Paper, in an effort to bring research efforts into closer contact with potential users, the Government undertook the most extensive reorganisation of the research councils since the splitting of the DSIR. The biology programmes of the SERC were merged with the AFRC, resulting in the creation of the Biological Sciences and Biotechnology Research Council (BBSRC), the Particle Physics and Astronomy Research Council (PPARC), and the Engineering and Physical Sciences Research Council (EPSRC). Each research council was expected to appoint a part-time Chairman and a full-time Chief Executive and Deputy Chairman, and to formulate mission statements that accounted for the needs of user communities.[224] In terms of governance, the Government reaffirmed its commitment to the Haldane principle, delegating day to day decisions on the scientific merits of different strategies, programmes and projects to the research councils (these were to be made without government involvement).

**1995** **Office of Science and Technology moved to Department of Trade and Industry from Cabinet Office**

The Office of Science and Technology, formed when the Science Branch of the Department of Education and Science joined the Office of the Chief Scientific Adviser in the Cabinet Office.[225] Lord Waldegrave, Science Minister from 1992-1994, regarded the move as a mistake and thought that the Office of Science and Technology should be put back 'at the centre' with a Minister in Cabinet.[226]

**1998** **Creation of the Arts & Humanities Research Board (AHRB)**

The AHRB was established October of 1998 by the British Academy, the higher education funding councils for England, Scotland and Wales, and the Department for Employment and Learning in Northern Ireland.[227] Its creation was in response to a recommendation of the Dearing Report (1997) and its function would be to provide "support for research and postgraduate training in the arts and humanities" alongside the other research councils.[228]

222 UKRI, 'Realising Our Potential', https://epsrc.ukri.org/newsevents/pubs/realising-our-potential-a-strategy-for-science-engineering-and-technology/ [Accessed 11 January 2019].
223 House of Commons Science & Technology Committee, Sixth Report of Session 2000-01, 'Are We Realising Our Potential?', 2001.
224 Flanagan, 'Trends in UK science policy', p16.
225 Parliament.UK, 'From OST to OSI', https://publications.parliament.uk/pa/cm200607/cmselect/cmsctech/203/20305.htm [Accessed 10 January 2019].
226 Parliament.UK, 'Are We Realising Our Potential?' https://publications.parliament.uk/pa/cm200001/cmselect/cmsctech/200/20007.htm#n173 [Accessed 10 January 2019].
227 History.ac.uk, 'Making History', https://www.history.ac.uk/makinghistory/resources/articles/AHRC.html[Accessed 10 January 2019].
228 Ibid.

**2000**

### House of Lords Select Committee on Science and Technology publishes *Science and Society* report

*Science and Society* explored the relationship between the public and science and technology. It recommended that "increased openness and dialogue from scientific institutions should play an integral role in scientific decision-making".[229]

**2000**

### Department of Trade and Industry publishes *Excellence and Opportunity: a science and innovation strategy for the 21st century*

*Excellence and Opportunity,* published in July 2000, sets out 10 agendas, including "better science in schools" and "Foresight as a Driver of the Knowledge Economy", to build upon the UK's "record of scientific excellence".[230]

**2002**

### Government publishes *Investing in Innovation: a strategy for science, engineering and technology*

*Investing in Innovation* outlined how the UK Government's science, engineering and technology research strategy was "intimately connected" to its economic goals.[231] It also said that despite the UK's history of excellence in science and technology, it had been far less successful in capitalising on "earlier waves of scientific and technological break-throughs".[232]

**2002**

### HM Treasury publishes SET *for Success: the supply of people with science, technology, engineering and mathematics skills: the report of Sir Gareth Roberts' review*

*Set for Success* found that despite a 'relatively large' and 'growing' number of students studying scientific and technical qualifications and the increasing demand in the economy for such graduates and postgraduates, this growth was due to more students studying IT and biological sciences, which masked a downward trend in the amount of people studying maths, engineering and the physical sciences.[233]

**2003**

### Department of Trade and Industry publishes *Competing in the Global Economy: the innovation challenge*

*Competing in the Global Economy* proposed the creation of a Technology Strategy and noted that despite strong performance relative to other countries, for example in areas like aerospace innovation, the UK performed at an average level when comparing business R&D and patenting.[234]

229 Parliamentary Office of Science and Technology, 'Science and Society: three years on', https://www.parliament.uk/documents/post/13-may-proceedings.pdf [Accessed 10 January 2019].
230 The National Archives, 'Implementation Plan – Lord Sainsbury, Minister for Science and Innovation', https://webarchive.nationalarchives.gov.uk/20060715232105/http://www.dti.gov.uk/files/file14470.pdf [Accessed 11 January 2019].
231 The Foundation for Science and Technology, 'Briefing Note for Searching for the Holy Grail of a science and innovation strategy that makes a difference: a discussion at Royal Academy of Engineering and the Royal Society', 18 October 2017, p.4
232 Ibid., p.11.
233 The National Archives, 'SET for success', https://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/d/robertsreview_introch1.pdf [Accessed 11 January 2019].
234 The Foundation for Science and Technology, 'Briefing Note for Searching for the Holy Grail of a science and innovation strategy that makes a difference: a discussion at Royal Academy of Engineering and the Royal Society', 18 October 2017, pp.11-12.

**2004** **Government publishes its *Science and innovation investment framework, 2004-2014***

In its *Science and innovation investment framework, 2004-2014,* the Labour Government outlined how it would invest in British science, technology and innovation to thrive in the global economy by attracting “the highest-skilled people” and the “companies which have the potential to innovate and to turn innovation into commercial opportunity”.[235] The 2006 report entitled *Next Steps* which reported on the framework’s implementation was the ‘inspiration’ for creating a Technology Strategy Board, which became Innovate UK in 2014.[236]

**2004** **Technology Strategy Board (TSB) created within the Department of Trade and Industry**

The primary aim of the Technology Strategy Board, established in October 2004, was to “increase business investment in R&D”.[237] Its remit was to “boost UK growth and productivity’ via ‘highly targeted investment in business innovation”.[238]

**2005** **Council for Science and Technology publishes *Policy through dialogue: informing policies based on science and technology***

Published in March 2005, *Policy through dialogue* made 9 key recommendations to government, including the need to adopt an ‘explicit framework’ for the “use of public dialogue to inform science and technology related policies”.[239] It warned that returns on the government’s ten-year investment framework for science and innovation would be at risk “if there is not broad public support for its policies in areas related to science and technology”.[240]

**2005** **Arts and Humanities Research Council (AHRC) is created, replacing its predecessor, the Arts and Humanities Research Board (AHRB)**

In 2002 a government review of arts and humanities research funding had recommended that an Arts and Humanities Research Council should be created alongside the other research councils.[241] In 2003, this intention was confirmed by Secretary of State for Education and Skills, Charles Clarke, and the AHRC was launched in 2005.[242]

**2007** **Minister of Science, Lord Sainsbury, publishes *The Race to the Top: A Review of Government’s Science and Innovation Policies***

Published in October 2007, *The Race to the Top* made recommendations for “more effective ways to exploit” investment in research and stated that a “major campaign to improve science, technology, engineering and maths (STEM)

235 HM Treasury et al, *Science & innovation investment framework 2004-2014,* July 2004, p.1.
236 Ibid., p.5.
237 Parliament.UK, ‘Government response: Select Committee on Science and Technology’, https://publications.parliament.uk/pa/cm200607/cmselect/cmsctech/635/63504.htm [Accessed 11 January 2019].
238 Ibid.
239 The National Archives, ‘Policy through dialogue’, https://webarchive.nationalarchives.gov.uk/+/http:/www2.cst.gov.uk/cst/reports/files/policy-through-dialogue/report.pdf [Accessed 11 January 2019].
240 Ibid.
241 History.ac.uk, ‘Making History’, https://www.history.ac.uk/makinghistory/resources/articles/AHRC.html [Accessed 10 January 2019].
242 Ibid.

teaching in schools" was required.[243] The report stated that the best way for the UK to compete in an era of globalisation was to move into high-value goods, service and industries, for which an "effective science and innovation system" was deemed "vital".[244]

**2007**

### Creation of the Department of Innovation, Universities and Skills (DIUS), replacing the DTI

Created in June 2007, the Department of Innovation, Universities and Skills (DIUS) was given the mission of investing in "science and research, skills and innovation to secure the future prosperity of the UK".[245]

**2008**

### Department of Innovation, Universities and Skills launches a consultation entitled *A Vision for Science and Society*

This DIUS consultation set out its key goal as achieving a "society that is excited about science and values its importance to our social and economic wellbeing".[246] It stated that there was a "pressing" need to both "strengthen the level of high quality engagement with the public" on major science issues and "increase the number of people who choose to study scientific subjects and work in research and scientific careers".[247]

**2009**

### Department for Business, Innovation & Skills (BIS) replaces Department of Innovation, Universities and Skills

In June 2009, Prime Minister Gordon Brown announced that the Department of Innovation, Universities and Skills (DIUS) would merge with the Department for Business, Enterprise and Regulatory Reform (BERR) to form the Department for Business, Innovation and Skills (BIS).[248] Peter Mandelson, the Secretary of State for Business, Innovation and Skills described this merger as putting the "policy levers to compete in a global economy and create the jobs of the future in one place".[249]

**2010**

### Launch of the UK Space Agency

The UK Space Agency was launched on 1 April 2010.[250] It replaced the British National Space Centre which was an 'umbrella organisation of 10 Government departments, research councils and non-departmental public bodies'.[251]

243 The Royal Society of Chemistry, 'The Race to the Top', http://www.rsc.org/images/sainsbury_review051007_tcm18-103118.pdf [Accessed 11 January 2019].
244 Ibid.
245 Gov.UK, 'Department for Innovation, Universities & Skills: Departmental Report 2009', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/238617/7596.pdf [Accessed 11 January 2019].
246 Gov.UK, 'A vision for Science and Society', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/36747/49-08-S_b.pdf [Accessed 11 January 2019].
247 Ibid.
248 Gov.UK, 'Department for Innovation, Universities and Skills: Resource Accounts 2008-09', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/248326/0457.pdf [Accessed 11 January 2019].
249 Gov.UK, 'Department for Innovation, Universities and Skills: Departmental Report 2009', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/238617/7596.pdf [Accessed 11 January 2019].
250 Gov.UK, 'House of Commons Science and Technology Committee: The UK Space Agency, 8 September 2010', https://publications.parliament.uk/pa/cm201011/cmselect/cmsctech/445/445-i.pdf [Accessed 11 January 2019].
251 Ibid.

**2010** **Government announces it will protect science and research budget for the next four years**

In the October 2010 Spending Review, Chancellor George Osborne announced that a 'ring-fence' would be maintained around the science and research budget to "ensure continuity of investment in science and research", meaning that the budget for science and research was kept the same in cash terms.[252]

**2014** **Technology Strategy Board renamed Innovate UK**

From August 2014, the Technology Strategy Board became Innovate UK, as part of a drive to focus on 'customer needs', improve its communications and to make it easier for businesses to understand what the body's function was.[253]

**2014** **The Research Exercise Framework (REF) replaces the Research Assessment Exercise (RAE)**

The Research Exercise Framework, which assessed the quality of research submitted by UK higher education institutions, replaced the Research Assessment Exercise, conducted previously in 2008.[254]

**2015** **Publication of *Ensuring a successful UK research endeavour: A Review of the UK Research Councils* by Paul Nurse**

The review published a number of recommendations about research guidelines and principles, the research councils themselves, the wider research endeavour and governance and structures.[255] It described the UK's research councils as "rightly" having a "prestigious reputation, built on a dedication to excellence through high quality and rigorous peer review".[256]

**2016** **Publication of *Case for the Creation of UK Research and Innovation* by the Department for Business, Innovation and Skills**

In June 2016, BIS published this report, putting forward the case for "a new public body in place of the seven Research Councils, Innovate UK, and the research and knowledge exchange functions of the Higher Education Funding Council for England".[257] The case states that the new body offered the opportunity to "strengthen the strategic approach to future challenges and maximise value from Government's investment of over £6 billion per annum in research and innovation".[258]

252 Gov.UK, 'Spending Review 2010', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/203826/Spending_review_2010.pdf [Accessed 11 January 2019].
253 Innovate UK, 'We have rebranded', https://interact.innovateuk.org/competition-display-page/-/asset_publisher/RqEt2AKmEBhi/content/we-have-rebranded [Accessed 11 January 2019].
254 The National Archives, 'Selection of staff for inclusion in the REF 2014', https://webarchive.nationalarchives.gov.uk/20180322111439/http://www.hefce.ac.uk/pubs/year/2015/201517/ [Accessed 11 January 2019].
255 Gov.UK, 'Ensuring a successful UK research endeavour', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/478125/BIS-15-625-ensuring-a-successful-UK-research-endeavour.pdf [Accessed 11 January 2019].
256 Ibid.
257 Gov.UK, 'Case for the Creation of UK Research and Innovation', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/527803/bis-16-291-ukri-case-for-creation.pdf [Accessed 11 January 2019].
258 Ibid.

**2016**

### Department for Business, Energy & Industrial Strategy (BEIS) replaces Department for Business, Innovation and Skills

In July 2016, the Department for Business, Innovation and Skills (BIS) merged with the Department of Energy and Climate Change (DECC) to form the new department BEIS, responsible for business, industrial strategy, science and innovation, energy, and climate change.[259]

**2017**

### Higher Education and Research Act receives Royal Assent, making provision for establishing United Kingdom Research & Innovation (UKRI), which began operation in 2018

UKRI was launched in 2018 and works in partnership with "universities, research organisations, businesses, charities, and government" to "create the best possible environment for research and innovation to flourish".[260] As planned, it brings together the seven research councils, Innovate UK and Research England.[261]

**2017**

### UK-US Science and Technology Agreement signed

The UK-US Science and technology Agreement includes a commitment to "collaborate on world-class science and innovation ... to further scientific research" and strengthen both economies.[262] The first project under the agreement is a study to increase knowledge on the origin and structure of the universe.[263] The US-UK Science and Technology Agreement is the first 'umbrella agreement' between the two nations on the subject.[264]

**2017**

### UK Industrial Strategy launched

The *Industrial Strategy* stated its aim to "create an economy that boosts productivity and earning power throughout the UK" based on five foundations: ideas; people; infrastructure; business environment; and places.[265] It included a policy to raise total R&D investment to 2.4% of GDP by 2027.[266]

259 Gov.UK, 'From BIS to BEIS: changing the machinery of government', https://beisdigital.blog.gov.uk/2016/09/01/from-bis-digital-to-beis-digital/ [Accessed 11 January 2019].
260 UKRI, 'UK Research and Innovation', https://www.ukri.org/ [Accessed 11 January 2019].
261 Ibid.
262 Gov.UK, 'First-ever UK-US Science and Technology Agreement paves the way for closer research collaborations', https://www.gov.uk/government/news/first-ever-uk-us-science-and-technology-agreement-paves-the-way-for-closer-research-collaborations [Accessed 21 November 2018].
263 Ibid.
264 Gov.UK, 'First-ever UK-US Science and Technology Agreement paves the way for closer research collaborations', https://www.gov.uk/government/news/first-ever-uk-us-science-and-technology-agreement-paves-the-way-for-closer-research-collaborations [Accessed 21 November 2018].
265 Gov.UK, 'Industrial Strategy: 2017', https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf [Accessed 11 January 2019].
266 Ibid.

# Milestone summary list

| Date | Milestone |
|---|---|
| 1915 | Creation of Advisory Council for Scientific and Industrial Research |
| 1916 | Creation of the Department of Scientific and Industrial Research (DSIR) |
| 1918 | First formal meeting of all UK university vice chancellors |
| 1918 | Haldane Committee's Report on the Machinery of Government |
| 1918 | Department of Scientific and Industrial Research takes over the National Physical Laboratory (NPL) |
| 1918 | First Industrial Research Associations launched |
| 1919 | Creation of the University Grants Committee (UGC) |
| 1920 | Creation of the Medical Research Council (MRC) |
| 1926 | Launch of the Empire Marketing Board |
| 1931 | Creation of the Agricultural Research Council (ARC) |
| 1939 | Creation of the Ministry of Supply (MoS) |
| 1940 | Colonial Development and Welfare Act |
| 1942 | Creation of the Colonial Research Committee (CRC) |
| 1945 | Publication of Vannevar Bush's Science - The Endless Frontier |
| 1945 | National nuclear power and bomb programmes launched |
| 1946 | Publication of Scientific Man-Power: Report of a Committee by the Lord President of the Council |
| 1947 | Creation of the Advisory Council on Scientific Policy (ACSP) |
| 1947 | Defence Research Policy Committee established |
| 1948 | The Colonial Research Committee becomes the Colonial Research Council |
| 1948 | National Research Development Corporation (NRDC) established |
| 1949 | Creation of the Nature Conservancy research council |
| 1954 | Creation of the United Kingdom Atomic Energy Authority (UKAEA) |
| 1959 | Creation of an Office of the Minister for Science |
| 1960 | Blue Streak missile development programme ended |
| 1961 | The Gibb-Zuckerman report or Report of the Committee on the Management and Control of R&D is published |
| 1963 | OECD publishes the Piganiol Report |
| 1963 | The Trend Report - Report of the Committee of Enquiry into the Organisation of Civil Science - is published |
| 1964 | Creation of the Department of Education and Science (DES) |
| 1964 | Creation of the Ministry of Technology ("MinTech") |
| 1964 | Creation of the post of Chief Scientific Adviser to HM Government |
| 1965 | Science and Technology Act |
| 1965 | Creation of the Social Science Research Council (SSRC) |
| 1965 | Creation of the Council for Scientific Policy (CSP) |
| 1965 | Lord Plowden publishes The Report of the Committee of Inquiry into the Aircraft Industry |
| 1965 | Britain orders an Advanced Gas-cooled nuclear Reactor (AGR) |
| 1968 | The Central Advisory Council for Science and Technology publishes Technological Innovation in Britain |

| Date | Milestone |
|---|---|
| 1970 | Ministry of Technology publishes a green paper entitled Industrial Research and Development in Government Laboratories: A New Organisation for the Seventies |
| 1970 | Ministry of Technology becomes Department of Trade and Industry (DTI) |
| 1971 | Lord Rothschild, Head of the Prime Minister's Central Policy Review Staff (CPRS), publishes a report entitled The Organisation and Management of Government R&D |
| 1971 | OECD publishes the Brooks Report |
| 1971 | The Future of the Research Council System, known as the Dainton Report, is published |
| 1972 | Council for Scientific Policy (CSP) replaced by the Advisory Board for the Research Councils (ABRC) |
| 1975 | Creation of the National Enterprise Board |
| 1976 | Formation of Advisory Council for Applied Research and Development (ACARD) |
| 1981 | House of Lords Select Committee on Science and Technology publishes its Science and Government report |
| 1981 | Science Research Council (SRC) becomes the Science and Engineering Research Council (SERC) |
| 1982 | Government's response to Science and Government |
| 1983 | First Annual Review of Government funded R&D is published |
| 1983 | Beginning of Alvey programme of collaborative research in information technology |
| 1983 | ABRC and ACARD publish first joint report identifying key policy issues that could protect or enhance a science base useful to industry in the United Kingdom |
| 1984 | The Social Science Research Council (SSRC) is relaunched as the Economic and Social Research Council (ESRC). |
| 1986 | House of Lords Select Committee on Science and Technology publishes Civil Research and Development |
| 1986 | The UK's first Research Assessment Exercise (RAE) takes place |
| 1986 | Launch of the pressure group Save British Science (SBS) |
| 1986 | ACARD publishes Exploitable Areas of Science |
| 1987 | ABRC publishes its report A Strategy for the Science Base |
| 1987 | Government response to Civil Research and Development |
| 1988 | Creation of the Centre for Exploitation of Science and Technology (CEST). |
| 1989 | ABRC given control over research council and allocation of resources between them – previously decided by the Secretary of State with ABRC advice |
| 1992 | Creation of the Office of Science and Technology (OST) |
| 1993 | Realising our Potential: A Strategy for Science, Engineering and Technology White Paper is published |
| 1994 | Research Council Reorganisation: SERC split and the Engineering and Physical Sciences Research Council (EPSRC) was created; Merging of the Agricultural and Food Research Council and the biology programmes of the Science and Engineering Research Council (SERC) resulted in the creation of the Biological Sciences and Biotechnology Research Council (BBSRC); and creation of Particle Physics and Astronomy Research Council (PPARC). |
| 1995 | Office of Science and Technology moved to Department of Trade and Industry from Cabinet Office |
| 1998 | Creation of the Arts & Humanities Research Board (AHRB) |
| 2000 | House of Lords Select Committee on Science and Technology publishes Science and Society report |
| 2000 | Department of Trade and Industry publishes Excellence and Opportunity: a science and innovation strategy for the 21st century |
| 2002 | Government publishes Investing in Innovation: a strategy for science, engineering and technology |
| 2002 | HM Treasury publishes SET for success: the supply of people with science, technology, engineering and mathematics skills: the report of Sir Gareth Roberts' review |
| 2003 | Department of Trade and Industry publishes Competing in the Global Economy: the innovation challenge |

| Date | Milestone |
|---|---|
| 2004 | Government publishes its Science and innovation investment framework, 2004-2014 |
| 2004 | Technology Strategy Board (TSB) created within the Department of Trade and Industry |
| 2005 | Council for Science and Technology publishes Policy through dialogue: informing policies based on science and technology |
| 2005 | Arts and Humanities Research Council (AHRC) is created, replacing its predecessor, the Arts and Humanities Research Board (AHRB) |
| 2007 | Minister of Science, Lord Sainsbury, publishes The Race to the Top: A Review of Government's Science and Innovation Policies |
| 2007 | Creation of the Department of Innovation, Universities and Skills (DIUS), replacing the DTI |
| 2008 | Department of Innovation, Universities and Skills launches a consultation entitled A Vision for Science and Society |
| 2009 | Department for Business, Innovation & Skills (BIS) replaces Department of Innovation, Universities and Skills |
| 2010 | Launch of the UK Space Agency |
| 2010 | Government announces it will protect science and research budget for the next four years |
| 2014 | Technology Strategy Board renamed Innovate UK |
| 2014 | The Research Exercise Framework (REF) replaces the Research Assessment Exercise (RAE) |
| 2015 | Publication of Ensuring a successful UK research endeavour: A Review of the UK Research Councils by Paul Nurse |
| 2016 | Publication of Case for the Creation of UK Research and Innovation by the Department for Business, Innovation and Skills |
| 2016 | Department for Business, Energy & Industrial Strategy (BEIS) replaces Department for Business, Innovation and Skills |
| 2017 | Higher Education and Research Act receives Royal Assent, making provision for establishing United Kingdom Research & Innovation (UKRI), which began operation in 2018 |
| 2017 | UK-US Science and Technology Agreement signed |
| 2017 | UK Industrial Strategy launched |

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