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Productivity, Innovation and R&D

Authors:

Richard A. L. Jones[x]

The University of Manchester

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[x]Vice-President for Regional Innovation and Civic Engagement

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Authors' contacts
r.a.l.jones@manchester.ac.uk

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The Productivity Institute is headquartered at Alliance Manchester Business School, The University of Manchester, Booth Street West, Manchester, M15 6PB. More information can be found on The Productivity Institute's website. Contact us at theproductivityinstitute@manchester.ac.uk

Productivity, Innovation and R&D

CHAPTER FOUR

Professor Richard A.L. Jones
Vice-President for Regional Innovation and Civic Engagement,
The University of Manchester

The long-run history of economic growth is a history of the development, adoption and diffusion of new technologies.[1] But economic growth depends on social innovations, as well as technological ones, and the idea of research and development (R&D) as a systematic way of innovating is one of these. But the link from R&D to productivity growth is not straightforward.

Indeed the policy questions facing the UK concerning the relationship between the UK's past record in R&D and its current productivity performance go beyond the question of what the total amount of R&D investment should be. In addition to how much R&D a country does, it is also important to consider what kind of R&D is being done, where in the country it happens, and in what kinds of institutions. The UK can improve on all these counts.

Over the last 40 years the proportion of the UK's national resources devoted to R&D has changed significantly with a significant drop in the 1980s and 1990s, a plateau through the 2000s and early 2010s, and then recent signs of some recovery. This decline to a persistently low level is one instance of the general tendency of the UK in recent years to underinvest, as Chapter Two described.

New technologies

New technologies have led to entirely new products that people value such as bicycles, automobiles, refrigerators, televisions, and mobile phones, to name just a few. New technologies also allow existing products – such as steel or staple foodstuffs – to be made more efficiently and at lower cost. Technological innovations have also underpinned new systems and infrastructures, like railways and the internet, that have facilitated trade and exchange, both of physical goods and of ideas. In broad terms, the connection between technological progress and economic growth is clear.[2]

But economic growth also depends on social innovations. Indeed, one such set of social innovations was central to the technological progress we have experienced over the last century. This is the idea of R&D itself as a systematic way of creating new knowledge, devising new inventions, developing them and bringing them to market. While the general link between economic growth and technological progress seems beyond question, though, there are some complications that stand in the way of making a direct connection between R&D inputs and productivity growth.

Adoption

Firstly, it is not the invention of a new technology that drives productivity growth across a whole economy, but rather its widespread adoption and, often, its subsequent adaptation in use. The very fact that economic productivity is uneven between and within nations tells us that innovations do not diffuse without frictions, even if the knowledge that underpins them is in principle widely available.

Secondly, as technological progress is not uniform across sectors, the relative prices of different goods and services can change dramatically, which complicates the long-run measurement of productivity. For instance, think about how the cost of computer power has fallen by orders of magnitude over the last 50 years, meaning that activities that depend on one-to-one human involvement have increased in relative terms.

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Research, innovation and the R&D landscape

What is the difference between research and innovation? As one old saying has it: "Research is turning money into ideas, but innovation is turning ideas into money".

In the context of the productivity puzzle it's important to ask whether the UK's R&D landscape is optimally configured to deliver the outcomes we want – to turn ideas into money, as well as to turn money into ideas. In particular, how has its shape evolved over time, and how might it be better configured?[3]

It is through the *process of innovation*, building on research, that more economic value is created from a given set of inputs, thus directly leading to increased productivity. One can distinguish between 'process innovation', which finds improvements in existing ways of making things or delivering services, and 'product innovation', which develops new goods or services to meet an unmet market demand or, indeed, to create that demand (see Chapter Five). Both process innovation and product innovation often depend on the development part of R&D – the deployment of new technologies, the improvement of existing technologies, or the combination of existing technologies in novel ways. These are usually the product of formal research and development.

R&D also requires *inputs of resources*. It needs inputs of highly skilled labour in the form of researchers, and of capital equipment and consumables. Invention and discovery are themselves characterised by efficiency improvements arising from the division of labour.

Many different kinds of activities are bundled into the category of R&D, with different goals. And these activities are carried out in different kinds of institutions, motivated by different incentive structures. Different aspects of the R&D process can also be classified in different ways and these classifications are problematic.

One way of classifying R&D has become particularly important, as it is codified as the basis for the collection of national statistics, in the OECD's Frascati Manual.[4] This distinguishes between *basic research, applied research*, and *experimental development*.

The linear model

Lurking behind such classifications is the spectre of the *linear model* – the idea that the R&D that results in a new product or process proceeds in a single direction, from basic research, through applied research, to the development of a marketable product.

The linear model is perhaps a strawman in the sense that no serious student of innovation believes, or has ever believed, that it captures the reality of the process of technological development.[5] Nonetheless, unexamined assumptions of linearity have a ghost-like presence in many discussions of research and innovation policy.

One example of the way that linearity is made explicit in policy discussions is in the idea of *Technology Readiness Levels*, a concept that is frequently used to determine eligibility for funding by UK government agencies, and is codified as part of EU state aid rules.

Another even more fundamental distinction is between science and technology. Science is about knowledge, while technology is about the useful arts, about the machines, tools, and the systems that put these to work to create valuable outcomes. Technologies may sometimes result from the systematic application of new scientific knowledge, but very often the relationship works the other way. Working technologies have often been developed well in advance of the scientific knowledge that would explain how they work.

This more complex relationship between science and technology is implied by the idea of *technoscience* – a term used in a slightly different sense and from different perspectives by sociologists of science,[6] philosophers of science,[7] and innovation practitioners.[8] In any use, though, it always implies a more complicated offset of interactions between science and technology than the linear model implies.

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Different forms of R&D

"Most R&D in developed countries takes place in the private sector and the UK is no exception."

What does all this mean in the context of productivity? The variety of different forms that R&D takes is reflected in the variety of different institutions in which it is carried out, different ways it is funded, and different incentive structures that influence the directions it takes. All of these influence the turning of ideas into money, or economic value and productivity.

Most R&D in developed countries takes place in the private sector and the UK is no exception. Private sector R&D shades, with blurred boundaries, into activities classified in other ways. On the one hand there are activities like routine testing and quality assurance, that rely on the existing stock of scientific knowledge and employ scientifically trained people. On the other, activities such as market research and identification of potential new markets, or product development using existing technology, are not classified as R&D, even though they may lead to economically significant innovation. What's more, R&D may itself be supplied as a service to other companies by contract research firms.

Private sector R&D

Private sector R&D may be paid for from retained profits from the existing business, and this accounts for much of R&D expenditure in large corporates. In spin-outs that have yet to achieve profitability, R&D is supported directly by venture capital. More generally, however, it may be difficult to fund R&D through borrowing because it is hard to use the intangible assets created (such as patents) as loan collateral.[9] Additionally, R&D that takes place in the private sector is often partially funded by the state, either directly in the form of grants for particular projects, or through fiscal incentives such as R&D tax credits.[10]

What kind of R&D is carried out in the private sector? Naturally, the emphasis will be on experimental development rather than basic research. However, historically some major corporate laboratories – such as Bell Labs in the USA – have made important fundamental discoveries. In the UK large corporate laboratories in the post-war period included those of ICI and GEC, in chemicals and electronics respectively. It has been argued that these corporate laboratories, integrating basic science and technological development, were particularly powerful institutions for accelerating 'technoscience'.

Research labs

However, corporate laboratories have substantially withdrawn from more fundamental research since the 1980s,[11] with remaining institutions of this type concentrated in the large US tech firms such as Alphabet and Microsoft.

University research labs are usually thought of as the domain for basic research. However, they are also important in terms of training the future scientific workforce to PhD level. Other expectations of university research include collaboration with industry, clinical research carried out in collaboration with teaching hospitals, and the production of intellectual property which can subsequently be licensed or used as the basis for spin-out companies.

University research is supported by governments both through direct funding and through competitive funding from government agencies for individual projects. In addition, some research is supported by contracts with industry, and much is underpinned by cross-subsidies from other university income.

Governments also support research institutes developing and applying the science and technology that is needed to underpin strategic functions of the state, including defence. For instance, historically the technology needs of the armed forces have been an important motivation for national laboratories.

The UK's changing R&D landscape

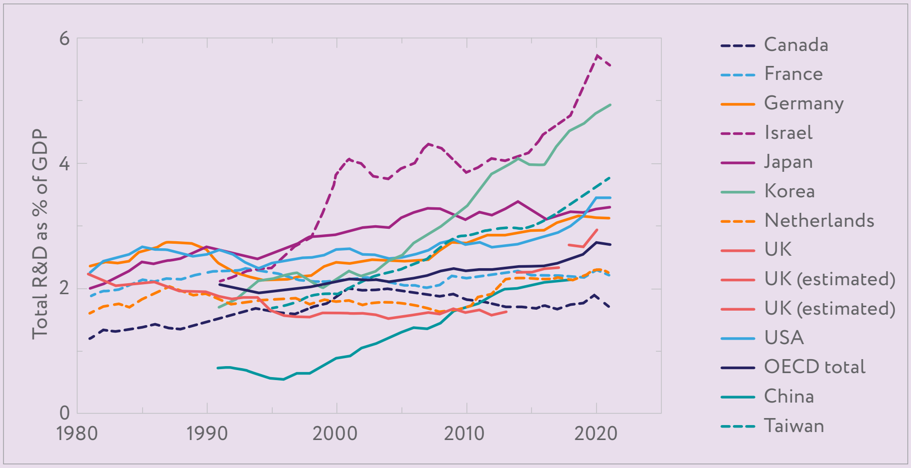
The result of all this is a patchwork of different institutions that constitute the UK's R&D landscape. To work effectively, the relative scale of the different parts of the landscape needs to be appropriate, and they need to be linked up effectively. A landscape which focuses entirely on basic research will not have the capacity to turn ideas into the new products and process improvements that underlie productivity growth, while a landscape focusing entirely on experimental development will lack novel ideas.

In the technoscience framing described above, if the direction of growth of the stock of scientific knowledge is not sufficiently driven by the questions arising from the attempt to extend technological capability, that technological growth will stall.

Figure 1 shows how the R&D intensity of the UK economy has changed over the last four decades, as compared to other countries. In 1981 the UK was one of the most R&D intensive countries in the world. It was, with the USA and Germany, one of the three world leaders in terms of R&D intensity. Before 1980 government research laboratories accounted for about 60% of public sector R&D, with 40% taking place in universities. Defence-oriented R&D has remained a large proportion of government R&D.

Between 1980 and 1995 there was a significant fall in the UK's R&D intensity, associated with the shifting ideological perspective of the Thatcher governments. In particular, the late 1980s and early 1990s saw a significant decline. This was associated with a sharp shift in science policy away from government support for near market research, with more emphasis on "curiosity driven" research in the public sector.[12] This was associated with the turn to the free market and the view that government support for applied science 'crowded out' private sector R&D. As Figure 2 (see right) shows, this theory was falsified by what then happened. By 1996 government R&D intensity had halved, but business R&D, instead of rising in response, also fell significantly.

Figure 1: R&D intensity of selected countries since 1980



Source: Gross Expenditure on R&D, OECD Main Science & Technology Indicators.
The UK data includes two recent breaks in methodology, whose significance is discussed in the text.

Decline stabilises

The decline stabilised between about 1995 and 2010, though the composition of R&D expenditure changed significantly over this period. Moreover, while the UK's R&D intensity remained roughly constant, R&D intensity in other countries significantly increased during this period, particularly in the rapidly developing countries in East Asia.

The post-1997 Labour governments recognised the problem of falling business R&D intensity, responding in 2004 with a ten-year Science and Innovation Framework,[13] setting a target for business R&D intensity of 1.7% of GDP by 2014. This was a supply side policy which assumed that if spending on basic science was increased, and a supply of skilled people was assured, increasing business R&D would follow.

As Figure 2 shows, there was a substantial increase in R&D spending in UK universities in the late 1990s and 2000s. However, this was balanced by a continuing drop in R&D investment by the rest of the UK government, driven partly by a post-cold-war fall in defence spending, and partly by the continuation of a policy to privatise public sector research establishments. The net result was rather flat overall public sector R&D intensity.

The low point of UK business R&D intensity was 2005. A number of factors may have contributed to its weakness. These include a shift to more short-term attitudes by firm managers and owners in response to the 'shareholder value' movement,[14] more general pressure on the manufacturing sector due to an uncompetitive exchange rate, and an emerging ownership structure in the privatised industries that emphasised sweated current assets rather than investing. For example, in 1994 in the privatised utility sector as a whole (comprising electricity, gas and water supply), £170 million was spent on R&D, but by 2005 the total was down to just £15 million.

Recent trends in R&D

The second half of the 2010s saw a real increase in government R&D spending, as part of the more explicit industrial strategy introduced by the May government. This was directly linked to the need to improve the UK's poor productivity performance. In fact, between 2010 and 2020 the UK's R&D intensity significantly increased. There is some uncertainty about the comparability of these figures, both across countries, and in time, since there are two breaks in the UK data series due to changes in methodology, and these figures are still provisional, for reasons to be discussed below.

Figure 3 shows the evolution of government R&D spending in the 2010s, showing the significant real increase in funding after 2016, and the introduction of UK Research and Innovation, a new agency combining the research councils, Research England, and Innovate UK. Direct government spending on R&D increased by 14% in real terms between 2016 and 2021.

But, as the figure makes clear, the really significant increase in government support for R&D came through the R&D tax credit scheme. Its cost had increased to nearly £7 billion by 2021 – nearly half as much as the government's total direct spending on R&D.

This substantial increase poses a statistical puzzle. The way in which business R&D has been measured by the Office for National Statistics is through a survey of businesses (the BERD survey). Over the 2010s a substantial gap between the R&D identified by the BERD survey and R&D tax credits opened up, reaching £16.8 billion in 2018. The growth in R&D tax credit claims has been concentrated largely in SMEs.

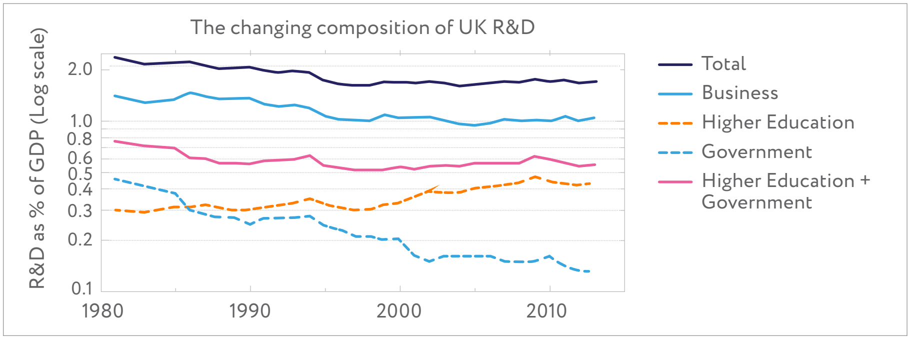
In the light of this discrepancy, ONS has revised its methodology,[15] hence the uplifts in recorded business R&D which underlie the discontinuities in UK total R&D shown in Figure 1. ONS identifies the systematic under-sampling of SMEs in the BERD survey as a major reason for the discrepancy, and has provided corrected estimates in recent data to account for this, before improving its survey sample for future data collection. This under-sampling could arise from a combination of the identification of an existing, but previously unobserved, population of R&D active SMEs with a rise in activity by new R&D intensive active spin-outs.

In partial support of the latter hypothesis, the new equity raised by UK university spin-outs increased from £387 million in 2013 to £2.73 billion in 2021 – a significant uplift, though still not enough to explain the whole of the uplift.[16]

On the other hand, the generosity of the R&D tax credit scheme presents an obvious temptation for companies to exploit the grey area in the definitions between R&D and normal business expenditure, and this may be exacerbated by the rapid growth in agents who are incentivised to maximise claims.

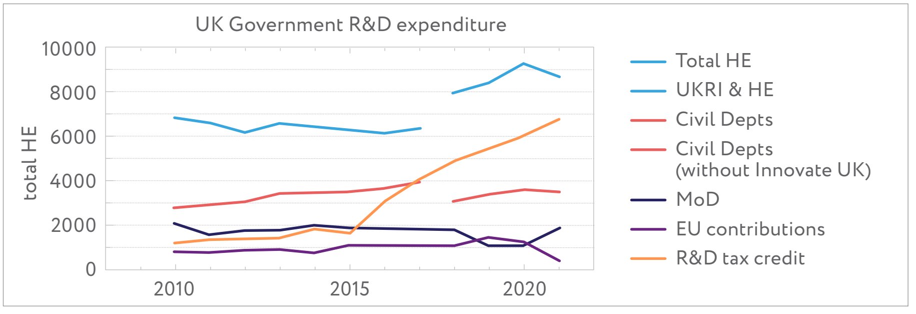
HMRC has recently increased its estimate of the rate of error and fraud in the 2021 figures from £336 million to £1.13 billion,[17] comprising 24.4% of the total for SMEs, and 3.6% for claimants for the large company scheme. This is based on a total of £6.8 billion of spending which does not, after all, fall into the definitions of R&D. So there remains some uncertainty about current R&D levels.

Figure 2: Composition of UK R&D by sectors of performance



Source: OECD Main Science & Technology Indicators

Figure 3: UK government R&D spending by department, in constant (2021) £ millions



Sources: ONS Research and Development expenditure by the UK government, 2021, March 2023 release; HMRC Research and Development Tax Credits Statistics 2022 (corrected for inflation using GDP deflators). Prior to 2018, Innovate UK funding was included in BEIS expenditure, from 2018 it is included in UKRI.

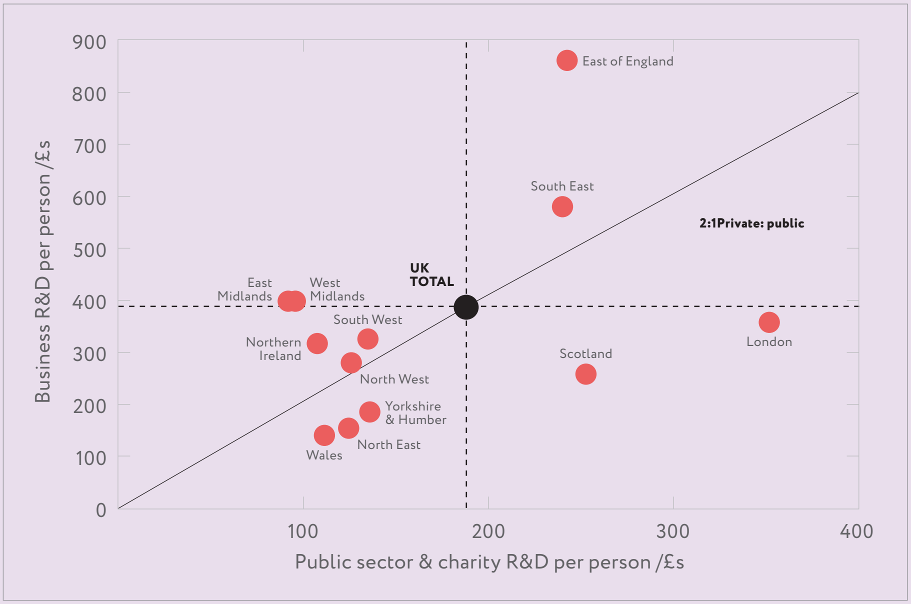
The geographical dimension

Public sector R&D in the UK is highly concentrated in London and the South East, the most productive parts of the UK, so to the extent that public R&D spending is intended to support productivity growth, it is currently acting as an anti-regional policy.

Figure 4 shows that there is a mismatch between where the public and private sectors make their investments. In the East of England and the South East, high public sector investments lead to even higher private sector investment, and these are successful innovation economies where the public sector and private sector mutually reinforce each other.

On the other hand, in London and Scotland relatively high public sector investment does not seem to be matched by private sector funding, while in the Midlands high private sector funding co-exists with low public sector funding. This mismatch between public and private sector investments may be impeding beneficial interaction between public and private R&D in these areas.[18]

Figure 4: The distribution of public and private R&D in the UK



Source: R&D data from ONS, Country and regional breakdown of expenditure on R&D in the UK: by sector of performance, 2019, with population taken from ONS mid-2019 population estimates. Note that this, the most recent available data for regional R&D, does not use the revised methodology so may be subject to revision.

"There is a mismatch between where the public and private sectors make their investments. In the East of England and the South East, high public sector investments lead to even higher private sector investment."

Policy implications

To summarise, the UK has experienced a long period of disinvestment in R&D by the UK, especially in the business and government sector, with business R&D intensity reaching a low point in 2005. This should be viewed in the light of a wider slowdown in public and private investment discussed in Chapter Two.

This history of declining R&D expenditure in the UK has occurred in the context of the marked slowdown in productivity growth since the mid-2000s. There has been some recovery in R&D intensity, especially from 2016 onwards. It appears that there has been a particularly strong uplift in private sector R&D, particularly in SMEs, but measurement issues are still not resolved. This recovery in R&D intensity cannot, at least not yet, be associated with a recovery growth. There could be a number of reasons for this:

- Many other factors could have been suppressing productivity growth in the UK since 2016, and this could outweigh any positive benefits that might be arising from an increase in R&D intensity.

- There is some evidence that R&D in general, across the world, is suffering from diminishing returns.[19] As Figure 1 shows, R&D intensity has been increasing in many developed countries, while productivity growth in a number of those countries is also slowing. There are some sector specific issues which may have a particular relevance to the UK. Pharmaceuticals, for example, is one of the most R&D intensive sectors in the UK, yet a slowdown in productivity growth in this sector is a significant contributor to the UK's overall productivity slowdown.[20] This reflects a worldwide trend of decreasing productivity of R&D in the pharmaceutical sector.[21]

- As not all R&D is the same, it may be that the UK's R&D landscape has changed in ways which make the UK's overall R&D effort less effective in leading to productivity growth. For instance, it is possible that there's been an overemphasis in the public sector on university-based science, rather than research carried out in laboratories more focused on applied or strategic science. It has long been recognised that the UK's intermediate R&D institutions, positioned to bridge a gap between basic research and private sector development, remain subscale, despite the positive impact of the Catapult Network of sectoral technology and innovation centres. In the private sector, the UK has few examples of R&D intensive small firms scaling up into corporations with larger-scale development, compared to comparator countries.

There is still much to understand about the links from R&D to productivity growth, distinguishing between different types of R&D, the different institutions in which it is carried out, and the way these all interact to produce productivity enhancing innovations.

The R&D landscape has changed substantially over the last 40 years and it is unlikely, given the UK's productivity stagnation, that it is in good shape.

A better landscape would reflect the existing sectoral mix of the UK economy, recognising both the role of R&D intensive sectors such as manufacturing and ICT on the one hand, and determining how best to support innovation in currently less R&D intensive service sectors. It must also anticipate the opportunities offered by new and emerging technologies.

Challenges

Crucially, the national R&D landscape needs to respond to the challenges the nation currently faces, not all of which are directly connected to the productivity challenge. As Chapter Seven discusses, the transition to a net zero energy economy will be a wrenching economic change, and innovation at scale is required to lower the system-wide costs of a low carbon economy.

The UK's health and social care system is under severe strain, and innovation is needed to improve outcomes in an affordable way, as Chapter Eight argues. And a worsening geopolitical outlook will increase the attention given to R&D for defence. It is possible that in these areas of innovation, productivity will benefit from spillovers but this is by no means automatic, so new institutions and funding mechanisms will need to be carefully designed to maximise them.

The UK's decades of low R&D investment – part of a pattern of lack of wider investment, both by public and private sectors – needs to be corrected. But in rebuilding the infrastructure for the UK's innovation economy there needs to be as much focus on translation and innovation diffusion as on discovery.

In particular, to help correct the UK's regional economic imbalances, especially the underperformance of the UK's second-tier cities as described in Chapter Nine, we need to incorporate the role of R&D in rebuilding local innovation ecosystems and in promoting technology diffusion. The international environment, and the challenges the UK faces, have changed, and the UK's R&D landscape must change in response.

Key takeaways

The UK has experienced a long period of disinvestment in R&D, in both state and private sectors. But in rebuilding the innovation economy there needs to be as much focus on translation and innovation diffusion as on discovery.

The national R&D landscape needs to respond to national challenges such as the transition to net zero and stresses in the health and social care system.

The innovation ecosystems in economically lagging regions need to be rebuilt, strengthening institutions for R&D and innovation diffusion.

Professor Richard A.L. Jones
Vice-President for Regional Innovation and Civic Engagement, The University of Manchester

r.a.l.jones@manchester.ac.uk

"In 1981 the UK was one of the most R&D intensive countries in the world. It was, with the USA and Germany, one of the three world leaders in terms of R&D intensity."

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