British Industrial R&D, 1900-1970

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Supposed failure in research and development (R&D) has acquired an important place in explanations of the British economic 'decline'. This argument has not, however, been the subject of debate in the same way that the 'entrepreneurial failure' thesis has. This is not surprising since the role of technology in modern societies only rarely causes disagreement. Writing on science and technology, by scientists and non-scientists alike, is dominated by 'technocratic' assumptions. The most important of these is that science and technology have been the major determinants of growth and of differences in performance across nations. 'Technocrats' also tend to believe that the analysis of the historical role of science and technology involves little more than the marshalling of uncontroversial facts. If we were to follow them and bring together all the commentary on research and development and science and technology in twentieth-century Britain we would find, with very few exceptions, a consistent and seemingly convincing story: as a nation Britain has been deficient in its support of research and development and this has been an important cause of 'decline'. Particularly strong is the conviction that British *business* has been bad at supporting R&D. This paper will challenge this interpretation.

The current prevalence of the belief that British industry and the British state have been deficient in technology is closely connected with the influence of the broader 'declinist' literature on Britain. In the 1980s the two most important 'declinists' were Correlli Barnett and Martin Wiener but they were in many cases repeating arguments made in the 1950s by C.P. Snow and others, themselves replays of earlier complaints.[1] These works argue that Britain has been

[1] Correlli Barnett, *The Audit of War* (London, 1986); Martin Wiener, *English Culture*

anti-modern in its culture and hence hostile to science and, especially, technology. The 'declinists' have provided us with historical explanations for this anti-modern orientation of British culture, ranging from the character of the public schools (that is, elite private schools) to the nature of British capitalism. But generally they have not provided convincing evidence for the view that British culture, or British industry, or the British state, have indeed been hostile to science and technology.[2] We need to understand what is to be explained before we come up with explanations.

In this paper I will suggest that a careful, critical, reading of the literature shows that the conventional impression about British business is wrong. Indeed, I will show that much of the evidence deployed about R&D is flawed. Typical examples are 1) using arguments about state-funded civil R&D to make points about industrially-funded R&D; 2) using ratio measures of various kinds when absolute measures are needed; 3) taking the nation state as the unit of analysis rather than the region, industry or firm; and 4) making misleading and partial international comparisons. These errors are ones I have commonly come across in academic work, lectures, newspaper articles and so on. To pin them down to their sources is difficult, because there is no clearly defined literature on which people draw and because much of the confusion comes from misreading good sources. To untangle all this is more effort than it is worth. I have therefore avoided, in most cases, attribution. I leave it to readers to confirm (or reject) my view that these errors are common

and the Decline of the Industrial Spirit (Cambridge, 1981); C.P. Snow, *The Two Cultures* (Cambridge, 1959). Other 'declinist' works include D.S.L. Cardwell, *The Organisation of Science in England* (London 1957, 1972) and Hilary Rose and Steven Rose, *Science and Society* (Harmondsworth, 1969).

[2] For critiques see Christopher Harvie, 'Liturgies of National Decadence: Wiener, Dahrendorf and the British Crisis', *Cencrastus* No 21 Summer 1985, pp. 17-23; Bruce Collins and Keith Robbins (eds), *British Culture and Economic Decline* (London, 1990); David Edgerton, *England and the Aeroplane* (London 1991). For critiques of Barnett in particular see David Edgerton 'The Prophet Militant and Industrial: the Peculiarities of Correlli Barnett' *Twentieth Century British History* Vol. 2 (1991), pp. 360 - 79, and José Harris, 'Enterprise and Welfare States: A Comparative Perspective', *Transactions of the Royal Historical Society* 5th series vol. 40 (1990) pp. 175-195.

enough to merit analysis. In the second part of this paper I review the more solidly-grounded literature on industrial R&D, and how it has evolved over time. I have done so in order to guide readers to, and through, material that bears directly on the question of British industry's support of research and development. In the last section of the paper I draw out some 'stylized facts' from this literature.

I

Ignoring Industry

Most of the literature on British R&D in the twentieth century is about a small proportion of the total; it focuses on state-funded civil R&D. It is usually assumed that industrially-funded R&D was deficient and that the state had to finance R&D instead. A very good example is provided by treatments of the interwar years. The usual story goes like this. At the beginning of the first world war Britain found itself short of key products because it had neglected science-based industry. This was recognised and the government acted by establishing the Department of Scientific and Industrial Research which encouraged the formation of, and partly funded, industrial research associations. These spent amounts of money clearly inadequate to deal with the problems in hand. Furthermore, the whole effort was flawed because the cooperative research the research association undertook was biased against innovations which might give individual firms a competitive advantage.

But an examination of the figures shows that in the interwar years the spending of the research associations was trivial by comparison with that of private industry. The research associations were nothing more than a significant detail in the history of interwar research and development. They were established to encourage and establish research in those industries which had no record of substantial industrial R&D, and where the firms were too small to support individual research and development programmes. The research association policy was premised on the fact that some major sectors

and major firms supported R&D already — what government had to worry about was the rest of industry. Nevertheless, David Mowery, in an influential article covering industrial R&D as a whole, has suggested that the research association was the typical agent of industrial R&D in interwar Britain, by contrast with the United States where the in-house corporate R&D laboratory dominated.

An undue focus on state-funded civil research and development has also skewed discussion of post-second-world war industrial R&D. Historians and commentators have highlighted the huge state investment in the development of nuclear power stations and civil aerospace, and the fact that these programmes led to huge losses. They also noticed that these programmes consumed a very high proportion of total R&D spending. They then go on to imply that these huge misdirected expenditures led to a 'crowding out' of industrial R&D spending. This argument is often allied to one highlighting the very high levels of government-funded defence R&D. But, as will be discussed further below, until the mid-1960s British industry spent more in absolute and relative terms on industrial R&D than the industry of any capitalist country other than the United States. Indeed, Britain was the strongest European performer of all types of R&D.

A related case of looking at the wrong thing concerns the question of state-funding of R&D. The vast majority of works, when dealing with the period before 1939, focus almost exclusively on civil R&D, in the way discussed above. But the state's funding of R&D was concentrated overwhelmingly in defence — the key government funders of R&D before 1914 were the navy ministry (the Admiralty) and the army ministry (the War Office); in the Great War the Ministry of Munitions funded the bulk of R&D. In the interwar years, the Admiralty, the War Office and a new service ministry, the Air Ministry, responsible for the most technically-oriented of the services, the Royal Air force, spent much more on R&D than civil ministries. The Air Ministry was the largest single spender on R&D in interwar Britain by a very considerable margin. All these ministries, furthermore, spent much of their R&D budgets in industry. One would not know any of this from reading the standard sources on the

British state and science; they systematically ignore warlike R&D spending. They also tend to ignore the civil R&D spending by service ministries, for example, the very costly programme to design two airships in the late 1920s, and the finance of aero-engine development through the interwar years.

It is also commonly assumed that the so-called 'Haldane principle' governed the funding of science by the British state. The 'Haldane principle' was that scientists were the best judges of what kind of science should be supported by government and that they should therefore have the most influence in determining spending priorities. But the 'principle' covered only a small fraction of state-funded research, that which was regarded as being of general applicability and which should therefore not be under the control of ordinary ministries. Such research was controlled through the non-departmental 'research councils', which included the DSIR. It emphatically did not cover research funded by mainline government departments like the service ministries, and thus covered only a small proportion of state spending.

The reason for this emphasis on state-funded civil R&D is clear. There was, and is, much more information about it than about business-funded R&D and defence R&D. Indeed, whole books were published on research associations alone. Furthermore, one can easily find historical actors complaining that British business was deficient in supporting R&D. Typically, they were scientists or engineers, organised in pressure groups like the British Science Guild. The emphasis on state support for civil R&D as opposed to defence R&D is also easily explained. In a broadly liberal culture like Britain's it is assumed that science is *essentially* civil, it is a peace-creating progressive force which is the antithesis of military values. Defence R&D is just ignored or regarded as a corruption of science.

A case of misplaced concreteness

By far the most common measure of the R&D expenditure of

a nation, industry or firm is not the absolute amount of R&D done, but rather the ratio of R&D to Gross Domestic Product, the output of an industry, or the sales of a firm. These last two ratios are called the 'research intensity' of an industry or firm. Unfortunately, however, these 'research intensities' are used *as if* they were absolute quantities of R&D. Thus, Chris Freeman has argued that:

> From 1925 to 1933 ..., in absolute terms, ... (IG Farben's) total R&D programme was the biggest in the world. IG Farben's total R&D expenditure averaged just over 7 per cent of turnover from 1925 to 1939. From 1925 to 1931, IG's expenditure was between 7 and 10 per cent, but in the world recession it was cut back fairly drastically to 4.9 per cent in 1933. From 1934 to 1939 it rose again to between 5 and 6 per cent of turnover. [3]

In the first sentence a point is made about IG Farben's R&D in absolute terms. In the second, its R&D expenditure is related to its turnover. But, in the third and fourth sentences 'IG's expenditure' is given in terms of the ratio measure and this is described as if it were the absolute measure. However, because the quotation tells us nothing about changes in turnover we cannot tell how actual R&D expenditure changed, even though we are told it was 'cut back fairly drastically' and then 'rose again'.

Just as common is the use of R&D/GDP ratios to answer the question: how much do countries spend on R&D? Countries with a high ratio are said to spend more on R&D than those with a low ratio. This does not follow. In the 1950s and 1960s the United Kingdom and the US had approximately the same R&D/GDP ratio, but the American R&D effort was in absolute terms many times larger than the British. This was true for the economy as a whole, individual industrial sectors, and individual firms. This is the key fact about any Anglo-American comparison, reflected in the fact that the United States is the most important source of innovations in the twentieth century, especially after the Second World War.

Let me take as an example of another misleading use of ratio

[3] Chris Freeman, *The Economics of Industrial Innovation* 2nd edn. (London 1982), p. 52.

measures: David Mowery's comparison of British and American R&D in the 1930s and 1940s. Mowery argues that British industry spent less on R&D than American industry. He justified this by using the ratio of R&D employment to manufacturing employment which yielded the following figures: 1933 - USA 0.18%, UK 0.03%; 1946 - USA 0.39%, UK 0.08%.[4] These figures look quite damning, but most, though not all, of the difference between the British and American figures is probably not due to differences in R&D spending at all. It is probably due to the large gap in labour productivity between British and American industry. If we assume that the productivity of R&D personnel was the same in each country, a reasonable assumption, but remember the productivity of labour was some two to three times larger in America, we can explain away most of the discrepancy. In other words, in terms of R&D expenditure output ratios, the difference is much smaller. But the key point of the Anglo-American comparison remains that American industry, and American firms, spent more than British industry and British firms on R&D. Thus although in the 1930s ICI had a higher research intensity than Du Pont, the latter spent more on R&D than did ICI.

A particularly unfortunate use of a ratio measure in international comparisons is the use of shares of particular kinds of R&D in national totals. It is common to see tables giving shares of national R&D budgets of a given country accounted for by defence and civil R&D, or government-financed and privately-financed R&D. They are useful, but they are often misused. A typical example would be this. In Britain and the USA defence R&D has accounted for around 30% of total R&D since the 1950s, while in Germany and Japan the levels are trivial. Therefore, it is implied, more was spent on civil R&D in Germany and Japan, and this was reflected in higher economic growth in these two countries. This does not follow and, in fact, both Britain and the United States spent more on civil R&D than Germany or Japan into the 1960s, whether in absolute or ratio terms.

[4] David C. Mowery 'Industrial Research, 1900-1950', in B. Elbaum and W. Lazonick (eds) *The Decline of the British Economy* (Oxford, 1986), pp. 191-2.

Given these problems with ratio measures, why are they used? The answer is simple: they allow simple international comparisons without the necessity of getting into the complexity of exchange rates. Let me take as an example another ratio measure which is much used: the growth rate of economies. This is the most common comparative measure of economic performance in economic history. It is the increase in output of an economy over a year as a percentage of the output of the previous year. This can be calculated easily for each economy one wants to compare. Confusing these growth rates with actual output, or efficiency, is in fact very common. Thus, because for much of this century British growth rates were behind German it is assumed that Germans were richer or more efficient. Similarly, Japan is often (wrongly) believed to be the richest and most efficient country in the world because its economy has grown fast.

One reason for the misuse of ratio measures is the psychological one. They can be too easily interpreted as measures of commitment, especially in the case of R&D. A high R&D/GDP ratio can appear to represent a nation's great commitment to science, technology and modernity, which is often thought to be a good thing in itself. But, a high R&D/output ratio is not in itself a good thing. It may simply reflect low output. What firms, and nations, presumably want is to invest in R&D which leads to innovations which increase output, thus, at a first approximation, decreasing the R&D/output ratio. In fact, what has tended to happen is that as countries grow richer they tend to invest a higher proportion of output in R&D; that is, their R&D grows faster than their output. But it is not correct to deduce that a high R&D/GDP ratio is essential to rapid growth. One can have too much of a good thing: it is possible to over-invest in R&D, just as it is possible to over-invest in general. Indeed, the former centrally-planned economies provide excellent cases of over-investment, and of high R&D/GDP ratios.

Nations and Nationalism

Although there is an influential rhetoric which claims that

technology is international and internationalising (for example, the standard argument that technical advance creates a 'global village'), most writing on R&D and growth focuses on the nation-state. This is partly explained by the fact that statistics are collected nationally, but it also reveals certain assumptions which are commonly made about the role of nation states. These are often seen as being in competition with each other, with R&D being an important weapon in the economic armoury of a nation. It is also assumed that the interconnections between science, technology, industry and economic growth take place primarily at the level of the nation: one influential formulation highlights the importance of 'national systems of innovation'. Each 'national system' determines the performance of the nation concerned and the world's technological and economic level. Technological breakthroughs are sometimes associated with a particular 'national system': pre-1914 Germany with synthetic organic chemistry, and post-second-world war Japan with consumer electronics.

Such an approach suggests that international comparisons of R&D should be important for analytical and policy purposes, and indeed these have become increasingly common. Nevertheless, systematic international comparisons are rare. Indeed, the most common comparisons made by British analysts appear to be designed to highlight British weakness. A typical comparison made for the period before 1914 is with Germany. In terms of industrial research the Anglo-German contrast relies almost entirely on an analysis of the dyestuffs and fine chemicals industry. The German industry dominated world markets and had very substantial research laboratories, but Britain was by no means unique in not having German chemical industry; neither did the United States or France. For the interwar period, and the immediate postwar period, comparisons are invariably made with the United States. This comparison ignores the sheer wealth and power of the American economy by comparison with all the European economies. More strikingly still analysts ignore the fact that Britain was clearly ahead of Germany, France and Japan into the 1960s: Britain was the R&D

powerhouse of Western Europe. And yet studies of changes even of absolute levels of R&D spending between countries from the mid-1960 stress the British relative decline, rather than the very high position from which Britain started.[5] For more recent years the favoured comparison is with Germany and Japan, and not with the USA, or say Italy or Spain.

The choice of comparator has thus varied over time, and for particular time periods particular comparisons are favoured over others. One way of highlighting the arbitrariness of much of what is written is to recall that one country was a specially favoured comparator in two distinct historical periods: in the late 1930s and the late 1950s the USSR was held up as a scientific and technological paragon. Not many would use it today, or use it as a historical comparator. To keep the comparisons in proportion we need to keep in mind that only a few countries were major scientific and technological powers in 1900 and the same ones remain so today with the exception of Japan. In Table I have sketched out some rankings for these major countries excepting Russia/USSR and Austria-Hungary. What the comparison shows, above all, is that the *relative* decline of British R&D is largely a phenomenon postdating the mid-1960s.

However, these international comparisons, even if properly done, may be beside the point. Is the nation-state in fact the proper unit of analysis of R&D and its economic effects? For some substantial amounts of state-funded civil R&D (for example in civil aerospace and nuclear power) that case is a strong one but for industry-funded R&D the case is by no means obvious. Of course, in many cases the R&D programmes of firms will be shaped by the preferences of governments if those governments are prepared to act to create protected markets. A good example is the huge oil-from-coal programmes of the 1930s, which were carried out because many governments wanted to reduce their dependence on imported oil, even when this was cheaper than synthetic oil. But it is remarkable

[5] Keith Pavitt, 'Technology in British Industry: a Suitable Case for Improvement', in Charles Carter (ed.) *Industrial Policy and Innovation* (London, 1981), pp. 88-115.

that even in the interwar period R&D was highly concentrated in large, *multinational* companies. Furthermore the world's major R&D performing corporations had transnational market-sharing and technology-sharing agreements. At least in the interwar years, then, business R&D was not nationally organised. Furthermore, the very high concentration of research in large firms, everywhere in the capitalist world, suggests that the appropriate unit of analysis for industrially-funded R&D is the large firm, not the nation. Two other units of analysis other than the firm suggests themselves. The first is the industrial sector. Thus, it is plausible to suggests that the technical health of, say, the British shipbuilding industry was more dependent on the state of world shipping and the world shipbuilding industry, than conditions characterising the British economy. The second is the industrial district. Thus, is may be more relevant to compare steel-making R&D in Sheffield and the Ruhr, rather than in the United Kingdom and Germany, and so on.

II

In this section of the paper I will review the key literature on British industrial R&D in roughly chronological order. This is not, however, to say that all later work builds on previous work. Indeed it is a feature of our knowledge of industrial R&D that it does not appear to be cumulative. This is ironic since science, technology and R&D are themselves widely believe to grow cumulatively.

J.D. Bernal's *The Social Function of Science* is one of those books more cited than read. [6] It is rightly regarded as a pioneering study of the social and economic relations of science, though it is best known as a manifesto for the planning of science. Bernal was a leading physicist and one of Britain's most important marxist intellectuals of the 1930s. One of the remarkable things about Bernal's book is that it got the broad outlines of the British R&D effort of the 1930s right.

6 (London, 1939).

More surprising still, given the paucity of contemporary information, it got the scale of industrial R&D approximately right too. Bernal, as a marxist, put great emphasis on the influence of monopoly on industrial R&D, a theme that was picked up again by Lilley in 1948. [7]

It was not until 1943 that reasonable statistics for industrial research in the 1930s were compiled, by the Federation of British Industries. [8] Government surveys started in the mid-1950s and the first academic survey of postwar industrial research was done by Carter and Williams in the mid-1950s; [9] an excellent survey of industrial innovation in the interwar years was published by R.S. Sayers in 1950. [10] The early 1960s saw a very important comparison of British and American industrial R&D in the postwar years by Chris Freeman. [11] The first broader international comparisons were done in the 1960s by the OECD. [12] At the same time the first examinations of the relationship between R&D spending and economic growth across countries were made. They revealed that the links were by no means obvious. [13]

The academic study of the history of British industrial R&D was in abeyance until Michael Sanderson's important paper of 1972. This showed that British industry did much more research before 1914 and 1939 than had by then come to be believed and also made clear that the spending of the research associations was trivial compared with that of firms. The major flaw in the paper was that it did not recognise the concentration of R&D spending in a few large

[7] S. Lilley, *Men. Machines and History* (London, 1948).

[8] Federation of British Industries, *Industry and Research* (London 1943); see also *Scientific and Technical Research in British Industry* (London 1947) and *Industrial Research in Manufacturing Industry, 1959-60* (London, 1961).

[9] C.F. Carter and B.R. Williams, *Industry and Technical Progress* (London, 1957).

[10] 'The Springs of Technical Progress in Britain, 1919-1939', *Oxford Economic Papers* Vol. 60 (1950), pp. 275-91.

[11] C. Freeman, 'Research and Development: A Comparison between British and American Industry' *National Institute Economic Review* No. 20 (1962).

[12] OECD, *International Statistical Year for Research and Development: A Study of the Resources Devoted to R&D in OECD Member countries 1963/64* 2 Vols (Paris, 1968).

[13] B.R. Williams, *Technology, Investment and Growth* (London, 1967); D. Landes, *The Unbound Prometheus* (Cambridge, 1969).

firms; it did not mention, for instance, ICI.[14] In 1979 S.B. Saul published a very useful paper of broader scope than Sanderson's which reviewed the case for and against the claim that British industry was poor at innovating. He also debunked the myth that in the postwar years industrial R&D was crowded out by defence and state-civil R&D.[15] The next significant study of industrial R&D in the interwar years was David Mowery's comparative study of British and American industry.[16] This paper, though well received, suffered from a number important weaknesses, some already noted. It assumed that industrial R&D deficiencies were an important cause of the British decline and that American R&D was more efficient than British R&D. Mowery argued that central corporate laboratories attached to modern, large, multi-divisional corporations were the key to successful R&D. David Edgerton, in a paper published in 1987 criticized Mowery, and more generally noted the 'inverted Whiggism' of most writing on science and technology in twentieth-century Britain. He reviewed the coverage of R&D in business histories and found it wanting, but presented new evidence to show the high concentration of R&D in a few firms.[17] Two useful collections of case studies of industrial innovation were also published in the 1980s.[18] More recently Edgerton and Horrocks have provided new data on industrial R&D before 1945, including firm-by-firm figures for expenditure and employment.[19]

[14] Michael Sanderson, 'Research and the Firm in British Industry' *Science Studies* Vol. 2 (1972), pp. 107-51.

[15] S.B. Saul, 'Research and Development in British Industry from the end of the Nineteenth Century to the 1960s' in T.C. Smout (ed.) *The Search for Wealth and Stability* (London, 1979).

[16] David C. Mowery, 'Industrial Research, 1900-1950' in B. Elbaum and W. Lazonick (eds.), *The Decline of the British Economy* (Oxford, 1986).

[17] D.E.H. Edgerton, 'Science and Technology in British Business History', *Business History* Vol. 29 (1987), pp. 84-103.

[18] *Business History* Vol. 26, No. 4 (1984); Jonathan Liebenau (ed.), *The Challenge of New Technology* (Aldershot, 1988).

[19] D.E.H. Edgerton and S. M. Horrocks, 'British Industrial Research and Development before 1945' *Economic History Review* (forthcoming 1994).

III

In this last section of this paper I will pull together this literature to present a brief account of the main features of British industrial R&D. The basic story of British business-funded R&D is that it has grown through the century. The only exceptions were the cutbacks in the early 1930s; the period between 1939 and 1945 when spending was probably static; and after 1967, when there was a fall in spending to 1975. R&D spending grew faster than industrial output, though from the late 1960s growth in R&D was less than in industrial output. In expenditure terms research intensity increased from around 0.4% in 1946 to a peak of 3.27% in 1967. Growth in R&D expenditure was thus extraordinarily fast.

In the years before the Great War it was very difficult to distinguish research from the wider scientific and technological activities of firms. Nevertheless there were a significant number of firms which carried out systematic scientific investigations of their products and processes. Even in the steel industry there were some very significant laboratories. In dyestuffs, British firms' research activities were on a small scale compared to that of German firms, but the Great War saw the creation of two very substantial research organisations in the firms British Dyes and Levinstein. After the war these two merged to form the British Dyestuffs Corporation, and their joint research programme was probably the largest in British industry.

In the 1920s industrial research was a recognised feature of large-scale industry. The great electrical firms, Metropolitan-Vickers, British Thomson-Houston and GEC, all had significant research laboratories. In chemicals Brunner Mond maintained a research laboratory in Cheshire, and the synthetic ammonia programme of its Billingham subsidiary, Synthetic Ammonia & Nitrates had a major research task on its hands. Nobel explosives had an important research facility at Ardeer. These firms, merged together with the United Alkali Company and the British Dyestuffs Corporation, to form Imperial Chemical Industries, from that day to this, Britain's largest private financer of R&D. ICI's most important research

programme of the early 1930s was its oil-from-coal programme, but by the late 1930s its largest laboratory was concerned with organic chemistry.

By the mid-1930s *hundreds* of British firms were doing research but business research was, and has remained, heavily concentrated in the electrical and chemical sectors, and in a few large firms. On a crude estimate, in the 1930s four firms accounted for one-third of R&D employment. These were ICI, easily the largest R&D performer, and the large electrical firms mentioned above. After 1939, expansion of research expenditure was largely due to the expansion of existing research facilities rather than to firms starting research from scratch. Many of the largest spenders on R&D in British industry today were in the same position in the 1930s. The pre-eminent example is ICI, but the modern GEC's ancestors, which include the three electrical firms listed above, as well as Unilever, Lucas, BP, Pilkington, and Courtaulds, were among the leaders in the 1930s. The most obvious change between the 1930s and the 1990s is the entry into the very first rank of R&D performers of the pharmaceutical companies, and the relative decline in R&D in the textile and steel industries.

The R&D effort of the major R&D performers of the 1930s cannot be treated as a purely British question. ICI had a close scientific and technical agreement with Du Pont, probably the largest American spender on R&D; Metropolitan-Vickers and British Thomson-Houston were by the 1930s both subsidiaries of General Electric of the United States. and GEC was closely entwined in the world-wide electrical cartels and technology-sharing regimes. If we take the photographic industry we find that by the late 1930s Eastman Kodak was doing more R&D in Britain than the whole of the British-owned photographic industry. The research effort of foreign controlled companies represented a significant proportion of the total. This ceased to be the case after the second world war.

For most of this century, British businesses have been the main source of funds for research and development. To give an indication: in the 1930s ICI's R&D expenditure was about the same as that of the DSIR. The clear exception to this rule is the 1940s and most of the

1950s when state-funded defence R&D was larger. Until the late 1960s state-funded civil R&D was below state-funded defence R&D. Since defence R&D is not directed at economic growth we may state categorically that British businesses have throughout the century paid for the bulk of R&D designed for promoting economic change. A general presumption is made that civil R&D, and within this industrially-funded R&D especially, is an important cause of economic growth. Certainly for American industry economic studies show a positive correlation between R&D and output growth. This is just as we would expect since R&D is an important — though not the only — source of innovation, which itself leads to higher productivity and competitive advantage.

But, it is important to note that this positive relationship between R&D and industrial growth need not hold everywhere. It does not follow that British growth was influenced positively by British R&D, or that, as is often argued, British growth was slow because of inadequate R&D. What became clear to some acute observers in the 1960s was that, across countries, there was no correlation between investment in R&D and economic growth. For example, David Landes noted that in the early 1960s British civil R&D was running at four times the level of French civil R&D, but the French economy had a higher growth rate. [20] An industry-by-industry study of British industrial R&D and industrial performance covering the 1960s found no satisfactory correlation. [21] Indeed in 1968 a British government report argued that Britain and British business was spending *too much* on R&D. [22] Since then it has become clearer that in the 1960s and 1970s Britain was overtaken in absolute economic performance by countries whose firms had spent less on R&D, by any measure, than had British firms.

What needs to be explained by historians is why British businesses invested an increasing proportion of their turnover in

[20] David Landes, *The Unbound Prometheus* (Cambridge, 1969), p. 521.
[21] C.T. Taylor and Z.A. Silberston, *The Economic Impact of the Patent System: A Study of the British Experience* (Cambridge, 1973) chapter 4.
[22] Central Advisory Council for Science and Technoloy, *Technological Innovation in Britain* (July 1968), p. 9.

R&D rather than examine reasons why they supposedly did not do so. Explanations of failure to invest in R&D should focus on the late 1960s and 1970s, not the 1870s. Could it be that one of the reasons was a certain disillusion among British business with R&D?.

IV

To conclude. The story of British industrial R&D is a simple and straightforward one. As the British economy grew and became more efficient, British businesses, especially large firms in chemicals and electrical engineering, increased the proportion of their output going to research and development until 1967. Throughout the century this spending was the main contribution to the total British civil R&D spending. This spending has been either ignored or massively underestimated by commentators on British R&D who have been concerned to argue that deficiencies in British R&D have been an important cause of the British 'decline'. In this, as in many aspects of science, there is a vast gulf between rhetoric and reality. In studying the literature on British R&D we should treat all arguments and evidence with great caution. We should be prepared to believe that the opposite of what is implied could be true. Could it be that in the twentieth century Britain has been the most scientific nation in Europe, and its relative economic 'decline' has been caused by too much R&D?

Further Reading

Peter Alter, *The Reluctant Patron: Science and the State in Britain, 1950 - 1920* (Oxford, 1987).

Correlli Barnett, *The Audit of War: the Illusion and Reality of Britain as a Great Nation* (London, 1986).

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Table 1
RANKINGS OF ABSOLUTE R&D BY COUNTRY
(EXCLUDING RUSSIA AND USSR)

1900-1914	1918-1935	1935-1945	1945-1965	1965-1980
Gross expenditure				
Germany	USA	USA	USA*	USA*
UK	UK	Germany	UK*	Japan*
				Germany*
				UK/France*
Defence				
UK	UK	USA*	USA*	USA*
Germany	USA/France	Germany	UK*	UK*
		UK*	France	France*
				Germany*
Industry-Funded				
Germany	USA*	USA*	USA*	USA*
USA	UK*	Germany	UK*	Japan*
UK	Germany	UK*	Germany*	Germany*
	France			UK/France*

Figures before 1960 are largely guesses. Certain comparisons are marked*