Research Policy

International comparisons of funding and output of research: bye bye Britain

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One thing that particularly distresses British scientific researchers is that just when the British government is cutting back on its expenditure on research other countries are rapidly increasing their investment. This is occurring at a time of tremendous scientific opportunity, and the scientists believe that Britain will ultimately pay a terrible price for its government being so shortsighted. Britain has lost its geographical empire, and now it may lose its empire of scientific knowledge and skills.

Kondratiev, a Russian economist eliminated by Stalin, identified long waves of economic ascent and decline based on important discoveries and innovations.¹ The years 1970-95 are years of decline, but then, he predicted, will begin a new upswing. If Kondratiev was right and if more money is not spent on research in Britain the next century may see the British becoming as marginal as the Mayans.

Comparing expenditure

The large amount Britain spends on defence research compared with most other countries distorts international comparisons. Britain does not do too badly until defence expenditure is excluded—then, as fig 1 shows, Britain does poorly. As a percentage of gross domestic product it already spends less on civil research than all the other countries belonging to the Organisation for Economic Cooperation and Development (OECD)—and is spending less as the other countries spend more. Fig 2 shows changes in gross domestic expenditure on research for 16 countries since 1978: Britain lies 12th, and its increase is only half of that of France and one quarter that of Japan.

These international comparisons are, unsurprisingly, fraught

FIG 1—Percentage of gross national product spent on civil research in five countries.

FIG 2—Increase in gross domestic expenditure on research since 1978 in 16 countries.

with difficulty, and the Science Policy Research Unit at Sussex University—sponsored by the Advisory Board for the Research Councils—has attempted to “clean up” the data for “academic and related research.”² There are four main problems with the data produced by the OECD: firstly, coverage of what constitutes higher education varies among countries; secondly, assessments on how much of the money spent on higher education is spent on research are difficult; thirdly, data tend to be lumped together in a way that makes comparisons difficult; and, fourthly, countries treat inconsistently over time general university funds and direct government funding of higher education research.³ These technicalities matter because, as the authors Irvine and Martin write, “Bids by the scientific community for increased funding made on the basis of comparison with international norms can all too easily be dismissed by those disinclined to accept them simply by pointing to the undoubted inadequacies of the OECD statistics.”²

Irvine and Martin’s data have their own problems, as they acknowledge, but they acquired them with the help of officials in the six countries that they studied, and when officials in the countries read the final report they thought the estimates “a significant

improvement on earlier international comparisons."² The results are shown in table I, and however the results are presented Britain spends less on academic and related research than its main European competitors, France and West Germany. From 1975 to 1982, however, expenditure in West Germany fell on all three measures, whereas in Britain it fell only as a percentage of gross domestic product. But the worst cuts in Britain have been since 1982, whereas expenditure in West Germany has increased according to the standard OECD data (fig 1). Assuming that government funding is an important influence on the extent and quality of scientific research (which not everybody, including the Treasury, would accept), Irvine and Martin conclude that "Britain's hopes of remaining a leading scientific power can only be described as slim in the light of the results from this international comparison of funding."

Irvine and Martin also looked at how the countries spend their research funds (table II). The comparisons are least reliable for expenditure on medicine and health, but it seems that in absolute terms Britain spends more on medical research than France but roughly half as much as West Germany and Japan and about a sixth as much as the United States.²

From input to output

The fledgling discipline of science policy is unsure about the relation between inputs and outputs in science—mainly because it is

TABLE I—Government funding of academic and academically related research in six countries 1975, 1980, and 1982 (reproduced by permission of *Nature*²)

	1975	1980	1982	% Change 1975-82
Total funding (1982 \$m):				
The Netherlands	780	900	900	15
United Kingdom	1820	1830	1930	6
France	1740	2120	2590	50
West Germany	3340	3290	3300	-1
Japan	2070	3010	3170	55
United States	8310	9370	9370	13
Funding per capita (1982 \$):				
The Netherlands	57.0	63.5	62.5	10
United Kingdom	32.5	32.5	34.5	6
France	33.0	39.5	47.5	45
West Germany	54.0	53.5	53.5	-1
Japan	18.5	26.0	26.5	45
United States	39.0	41.0	40.5	4
Funding as percentage of gross domestic product:				
The Netherlands	0.615	0.620	0.635	3
United Kingdom	0.390	0.365	0.375	-3
France	0.355	0.370	0.445	25
West Germany	0.580	0.485	0.490	-15
Japan	0.230	0.260	0.250	11
United States	0.325	0.310	0.310	-5

TABLE II—Government funding of research in six countries in 1982 (\$m) according to discipline (reproduced by permission of *Nature*²)

	The Netherlands	United Kingdom	France	West Germany	Japan	United States
Main discipline:						
Engineering	90	300	210	410	680	1140
Physical sciences	180	420	840	840	450	1420
Environmental sciences	20	130	120	150	100	590
Maths and computing	30	90	140	110	70	280
Life sciences	350	660	940	1190	1050	4630
Social sciences	100	110	120	160	130	590
Professional and vocational	60	100	60	180	330	270
Arts and humanities	70	120	170	230	340	290
Other (multidisciplinary)	—	—	—	20	—	170
Total	890	1930	2590	3300	3170	9370
Subdiscipline:						
Chemical engineering	18	20	17	14	110	100
Electrical engineering	19	65	65	80	150	250
Mechanical engineering	18	45	15	75	120	150
Chemistry	40	120	200	230	85	390
Physics	100	200	550	500	260	800
Computer sciences	12	35	50	45	—	150
Biological sciences	60	250	650	330	140	1700
Agricultural and veterinary	45	65	40	150	190	700
Medicine/health	230	340	230	700	700	2000

not confident about how to measure either. Irvine and Martin's cleaning up the OECD data was an important development in measuring input. They and others have also tried to measure output, and the results point to a decline in British science that parallels the decline in inputs.³⁻⁶ (These results are, however, disputed by at least one "scientometrician," Dr Loet Leydesdorff of Amsterdam University; he uses the same source of data as the others yet finds that Britain's scientific output is increasing. Ironically, he has had trouble getting his work published in an English language journal.)

The easiest way to measure research output is to count the number of published papers, and the National Science Foundation in the United States keeps a database that covers about 2000 of the world's leading scientific journals. Figure 3 shows the change in total number of scientific papers published by five countries from 1973 to 1982, and table III changes in Britain's share of publications from the whole world. The figure shows a steady decline in the number of papers published by Britain, which contrasts with a steady increase from Japan. Between 1973 and 1982 Britain's share of world publications fell by 10%,⁴ and between 1980 and 1984 it fell by 4%.⁶ Between 1973 and 1982 there were falls in the shares of the United States (3%), Canada (8%), and France (9%), most of the increase being in that of Japan (40%).

FIG 3 (left)—Total number of scientific research papers published by five countries 1973-82 (reproduced with permission of *Nature*⁴). FIG 4 (right)—Total citations received each year to papers published that year and the three previous years for five countries 1976-82 (reproduced with permission of *Nature*⁴).

FIG 5—Comparative changes in world export shares of technology intensive products.

Source: *The Economist*. 18 April 1987.

FIG 6—Scientific Nobel prizes won by the United States and Britain (as a proportion of the total) from 1901-5 to 1980-5 (reproduced with permission of the *Economist*).

The fall in the British share is not the same in all disciplines, and table IV shows subjects that increased their world share by 15% or more and those whose share fell by 15% or more between 1973 and 1982. Table V shows medical subjects that were growing and declining by these measures, and table VI shows stronger and weaker medical subjects. Overall, Britain's strengths are mainly in medical and biological specialties, and sadly from the economic view the sharpest decline is in applied scientific and engineering specialties.⁶ (One caveat is that these bibliometric analyses are at their weakest when measuring the output of this sort of research because some of it is not published for commercial and military reasons and also much of this type of output is in the form of tangible products.)

Another measure of output—and one that takes more account of impact (which is in some disputed way related to quality)—is the number of times papers are cited in other research papers; fig 4 shows a progressive decline in Britain's overall share of citations. Table IV shows changes in Britain's world share of citations for different disciplines. Britain showed an overall decline of 15% between 1973 and 1982, while Japan showed the biggest increase, of 65%; and then between 1980 and 1984 Britain declined by 4%, while Japan increased by 7%.⁶

Patents may also be studied as a rough measure of the output of scientific research, and a study of foreign patents registered in the United States over 20 years up until the early 1980s showed that Britain's share declined from 20% to 8%. Over the same time Japan's share increased from under 10% to over 35%, and West Germany's share remained constant at about 25%. Changes in the

world share of exports of technology intensive products (fig 5) also show Britain declining.

Science policy researchers also use what they call "esteem measures," the best of these being the number of Nobel prize winners. Figure 6 shows the decline in the numbers of Britain's Nobel prize winners. The Royal Society has also produced data showing that an increasing number of its fellows live abroad.

None of these measures of research performance is perfect, but together they point to a decline in British performance in science. Almost all of the medical researchers whom I met also saw decline in Britain's scientific performance. There is some evidence, however, that the perception of the decline is worse than the actual decline, and in 1982 Britain still published more scientific papers than any other country except the United States, and the papers received far more citations than papers from any other country except the United States.

Decline in biomedical research and genetics?

The study undertaken by the Royal Society science policy unit looked specifically at the important specialty of genetics and gave some more general information on biomedical research.³ Figure 7 shows changes in the total number of biomedical papers published by British authors between 1973 and 1982: the number was fairly constant, whereas the United States, already far ahead of the rest of the world, increased its number dramatically; Japan also showed an increase. Depressingly, however, the total number of times that

FIG 7—Number of biomedical research papers published by five countries 1976-82 (Advisory Board to the Research Councils, Royal Society, Economic and Social Research Council).

FIG 8—Citations received by all biomedical research papers published that year and in the preceding three years by five countries 1976-82 (Advisory Board to the Research Councils, Royal Society, Economic and Social Research Council).

TABLE III—Changes in Britain's world share of publications and citations 1976-84 (reproduced by permission of Nature⁶)

	Publications			Citations			
	1976	1980	1984	% Change		1984	% Change
				1976-80	1980-4		1976-80 1980-4
Biology	10.5	10.2	10.3	-2	+1	12.8	-3 -5
Biomedical research	9.2	8.4	7.8	-8	-7	10.2	-4 -5
Chemistry	8.2	6.8	6.0	-18	-11	8.7	-12 -3
Clinical medicine	10.1	9.3	9.7	-8	+5	10.8	-9 -2
Earth and space sciences	8.7	9.5	8.3	+10	-13	9.6	+6 -5
Engineering and technology	10.9	9.5	8.1	-13	-14	10.3	-8 -8
Mathematics	6.9	7.0	6.7	+2	-4	8.4	+5 -3
Physics	6.9	5.9	5.7	-14	-4	7.1	-6 -6
All fields combined	9.2	8.3	8.1	-9	-3	9.9	-6 -4

TABLE IV—Subjects in which British researchers increased their share of world publications by more than 15% between 1973 and 1980 and subjects in which the share fell by 15%. Figures are percentage increases or decreases (reproduced by permission of New Scientist)

Share increased by more than 15%		Share fell by more than 15%	
Entomology	59	General engineering	50
Parasitology	58	Acoustics	47
General biology	53	Dermatology and venereal disease	38
Tropical medicine	51	Clinical medicine—pharmacy	34
Nuclear technology	36	Materials science	32
Radiology and nuclear medicine	35	Nuclear and particle physics	32
Astronomy and astrophysics	34	Applied physics	31
Oceanography and limnology	23	Neurology and neurosurgery	31
		Applied chemistry	28
		Chemical engineering	28
		Computer engineering	28
		Chemical physics	27
		Endocrinology	27
		Inorganic and nuclear chemistry	24
		Ophthalmology	22
		Dentistry	21
		General biomedical research	21
		Obstetrics and gynaecology	21
		Veterinary medicine	21
		General physics	19
		Genetics and heredity	19
		Solid state physics	19
		Physical chemistry	18
		Ecology	17
		Clinical medicine—cardiovascular	15
		Metallurgy	15
		Organic chemistry	15

British papers were cited declined appreciably over the same time (fig 8). This suggests that British authors are publishing just as much but that the papers are of declining impact/quality. This fits with the impression of the editorial staff of the *BMJ*. (We thus encouraged a medical student, Debbie Newton, to investigate this impression by comparing British and Scandinavian papers published in the *BMJ*. She confirmed that the journal was publishing proportionately more Scandinavian and fewer British papers but found no significant difference in how often the papers were cited.)

The picture for genetics is better than for all of biomedical research. Figure 9 shows the total numbers of "genetics and heredity" papers published: Britain has increased the number of papers that it is publishing. The science policy unit then conducted three citation studies (of *Drosophila* genetics, genetic instability and transposable genetic elements, and genetics papers cited in patents), and these all showed that British genetics papers were cited much more than those from West Germany, Japan, and France.

"Esteem indicators" were less encouraging. The researchers sent questionnaires asking about the status of British genetics to 89 eminent scientists in Britain with an interest in genetics and received back 80. Questionnaires were also sent to 112 overseas scientists, but only 33 were returned—so that less confidence can be placed in the representativeness of their opinions. Over half (57%) of all the respondents thought that Britain had been among the world leaders in genetics in the 1960s, but the percentage declined to 34% for the early 1970s and 10% for today. The opinion of overseas respondents was consistently less favourable than that of the British respondents, meaning that the findings "cannot be ascribed to some national trait of self denigration."

At a meeting of geneticists held to discuss the results of the study the "general view was that in most areas of genetics the UK had already lost a substantial degree of its claim to world importance and would in all likelihood lose the remainder sooner rather than later." The conflict between the bibliometric indicators showing that Britain is not doing too badly and the general opinion of decline among geneticists themselves may be explained by the time lag inherent in the data. The geneticists thought that the data would soon show a sharp decline.

All a matter of money?

How much is the decline in British science a consequence of underfunding? Science policy research cannot answer this question with confidence, but fig 10, taken from the 1985 paper by Irvine *et al*, plots together research council expenditure and the British world

TABLE V—Medical subjects in which British researchers were increasing their share of world publications and citations during 1981-4 and subjects in which they were declining (derived from Martin *et al*)

Growing subjects	% Change		Declining subjects	% Change	
	Papers	Citations		Papers	Citations
Surgery	+43	+8	Biomedical engineering	-32	-13
Endocrinology	+22	+1	Ophthalmology	-31	-4
Paediatrics	+16	-2	Obstetrics and gynaecology	-24	+11
Anaesthetics	+13	-4	Hygiene and public health	-18	-6
			Dermatology and venereology	-15	-7
			General biomedical research	-14	-3

TABLE VI—Medical subjects in which British researchers have a high world share of publications and citations and subjects in which they have a low share (derived from Martin *et al*)

Strong subjects	World share (%)		Weak subjects	World share (%)	
	Papers	Citations		Papers	Citations
Anaesthetics	21.7	19.0	General biomedical research	5.6	10.0
Respiratory system	16.7	12.8	Cardiovascular system	5.8	6.3
Pathology	15.0	15.0			
Gastroenterology	14.4	16.8			
General and internal medicine	13.0	16.4			
Psychiatry	11.3	14.0			
Hygiene and public health	11.0	15.4			
Endocrinology	10.8	8.8

FIG 9—Total numbers of genetics and heredity papers published by five countries 1973-82 (Advisory Board to the Research Councils, Royal Society, Economic and Social Research Council).

FIG 10—The relation between research council expenditure and British world share of publications and citations (reproduced with permission of *Nature*⁶).

share of publications and citations. The figures were not subjected to statistical analysis, but the researchers saw a "certain similarity between the trends" and noted that shares in publications tend to lag three years behind funding. If this is the case then the real decline may not yet have been recorded because funding began to decline sharply only in the early 1980s.

Conclusion

Objective indicators show that British basic science is in decline. Among scientists the perception is that the decline is sharper than is shown by the indicators, which may be explained by the lag inherent in most of the indicators. It is not clear how much of this decline is attributable to decline in government funding for research, but most scientists whom I met consider this to be the main cause.

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