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THE WHITE HOUSE

WASHINGTON

July 11, 1990

MEMORANDUM FOR SECRETARY JAMES D. WATKINS Jim

FROM: D. ALLAN BROMLEY Allan

SUBJECT: BASIC RESEARCH

You perhaps will recall from a decade or so ago when a group at MIT, under the auspices of the Club of Rome, carried out a major computer-base study that culminated in a publication entitled The Limits of Growth. In many ways it was the ultimate illustration of the famous garbage-in-garbage-out rule of computer usage. The first group that really pointed this out in detail and published a book in response entitled The Limits of Doom was the science policy research unit at the University of Sussex in England.

Recently under a grant from the National Science Foundation, John Irvine, Ben Martin, and Phoebe Isard, who are members of this research unit, have undertaken a study of how the U.S. Government supports academic research and in particular, how competitive from an international point of view that support is at the present time.

Erich Bloch recently sent me a copy of the paper that the group has produced and points out that there are two very important conclusions. They are the following:

1. In relation to its size and wealth, the United States invests less overall in academic and related research than leading scientific nations in Western Europe with the apparent shortfall being largest in the physical sciences.

2. While the U.S. is still the predominant world player in academic research, if life science is excluded, however, or if expenditure is normalized for difference in population, then the U.S. compares less favorably with the European countries.

I believe that both of these conclusions are matters of serious concern for us in the United States. We have long recognized that by any of the usual measures, such as fraction of gross national product and the like, our support of research and development overall is substantially less than that in Germany or Japan. What we have not recognized prior to this report was that the situation is more broadly based in Europe when we focus on academic research in comparison with the United States. It is also the case that once we face the European community in 1992, where there is substantial discussion and consensus building internal to the EC, I expect us to find ourselves crunched evermore effectively between Japan on the one side with the other Pacific Rim nations accelerating rapidly, and the European Community on the other.

This document from the University of Sussex simply underscores the conviction that I think we share that we, as a nation, are under-investing in research and development generally and in the support of academic research, particularly in the physical sciences.

I though that you would find this report interesting.

Enclosure

IS US GOVERNMENT SUPPORT FOR ACADEMIC AND RELATED RESEARCH INTERNATIONALLY COMPETITIVE?

John Irvine, Ben R. Martin and Phoebe A. Isard*

Abstract

In relation to its size and wealth, the United States invests less overall in academic and related research than leading scientific nations in Western Europe, with the apparent shortfall being largest in physical sciences.

New technologies are increasingly crucial to a nation's economic prosperity. Because many of these technologies depend on the results of science, basic research seems set to play a fundamental role in economic and social development.[1] Hence, the major industrial nations (and those that aspire to greatness) are all investing heavily in basic research, whether conducted in academic, government or industrial laboratories. Responsibility for developing and maintaining the necessary science base at present rests largely with federal and state governments rather than industry. This raises two questions. First, how much should government invest in research within universities and related laboratories? Given the increasingly competitive nature of science as well as technology, funding agencies need to know how their spending compares with that in other nations, both in overall terms and at the level of specific fields. Second, what funding mechanisms are most appropriate for supporting academic and related research? For example, what emphasis do different countries place on institutional core-funding of universities relative to peer-reviewed projects (or programmes) and intramural work conducted within agency laboratories? Such comparisons may provide some insights into which funding arrangements work most effectively.

In what follows, we examine the main trends in US government expenditure on academic and related research between 1975 and 1987, looking at the similarities and differences between the United States and five other industrial nations (the United Kingdom, Federal Republic of Germany, Netherlands, France and Japan). Our analysis draws upon the findings of a study undertaken for the National Science Foundation and the British Advisory Board for the Research Councils[2] which reported comparable

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figures on spending broken down into nine fields (e.g. physical sciences) and forty subfields (e.g. chemistry) for each country. In addition, we identify the factors underlying changes in the level and distribution of academic funding by government using information from the published literature and from interviews with agency officials and science-policy specialists. Among the issues addressed are the political priority given to basic science in general as well as to specific fields, and the pressures underlying the restructuring of research-support mechanisms that is underway in many countries. However, one question outside the study's remit relates to the changing balance between private and public-sector finance for academic research. When interpreting our results, therefore, the reader needs to bear in mind not only that industrial funding varies from country to country, but also that much academic research is supported by charitable foundations, especially in the biomedical and health fields.

Approach

Disaggregated data were compiled for three categories of expenditure: (a) academic research financed through general university funds given to institutions by federal or state governments; (b) academic separately budgeted research provided in the form of grants, contracts and other finance earmarked for specific research projects by public-sector funding agencies; and (c) academically related research undertaken outside universities in (i) national or international laboratories operating central facilities for use by academic scientists (e.g. Fermilab or the National Optical Astronomy Observatory), and (ii) institutes financed primarily through government core-funding which are engaged in longer-term basic research similar to that conducted within universities in other nations (e.g. the intramural programs of the National Institutes of Health).

As can be seen from Figure 1, coverage of academically related research includes certain types of expenditure by Federally Funded R&D Centers (FFRDCs) and research council establishments in Europe together with basic work in agricultural and medical laboratories, many of which have a role in postgraduate training. Academically related research can be viewed partly as a residual category enabling funding for functionally equivalent organizations formally outside universities to be taken into account, hence ensuring that the financial statistics for different countries are truly comparable. This helps overcome a major limitation with data from the

Organization for Economic Cooperation and Development (OECD). Such figures are widely used in international comparisons of academic research, but reflect the varying definitions of the higher education sector employed in different countries. For example, the OECD statistics cover only doctorate-granting universities in the Netherlands, while junior and technical colleges are included for Japan and the US figures even encompass mission-oriented FFRDCs such as Los Alamos.

To compare trends in real terms from 1975 to 1987, expenditures for earlier years were converted to 1987 prices using the OECD deflators for gross domestic products. Although this procedure may understate the rate of inflation for research costs[3], especially in fields where there has been a significant increase in the sophistication of experimental equipment and facilities, the lack of internationally comparable R&D deflators means there is currently no alternative. National currencies were then converted into US dollars. Since official exchange rates fluctuate appreciably and rarely represent actual domestic spending power or labour costs, we have relied mainly on the 'purchasing power parity' (PPP) rates calculated by OECD. However, economists differ over whether this represents the best way to compare research expenditures so alternative figures based on average official exchange rates (OERs) are also reported. Finally, in presenting the results, we have frequently contrasted US spending with that for the four European nations combined (henceforth termed 'Europe') which have a not dissimilar aggregate population.

Trends in overall expenditure

Table 1 contains purchasing power parity-adjusted expenditure data broken down into general university funds (GUF), separately budgeted research (ASBR) and academically related research (ARR). Although GUF grew by over 50% in real terms in the United States between 1980 and 1987 (largely as a result of increased institutional finance from state administrations), it still represented only 20% of total academic and related research compared with around 45% for 'Europe' and over 65% for Japan. At the same time, 'Europe' appears to have begun to move a little towards the US funding model by giving less emphasis to GUF and more to project-based and other earmarked research support for universities, all four countries witnessing large increases of 20-40% in ASBR since 1980. Nevertheless, US expenditure on separately budgeted research ($9.9 billion in 1987) still dwarfed the total for the four European nations ($2.5 billion), with Japan far behind ($0.9 billion). In contrast, 'Europe' gave greater emphasis to academically related research, spending $3.3 billion compared to $1.9 billion by the United States despite the faster growth evident over recent years. For academic and related research combined, the total for the four European countries in 1987 ($11.0 billion) was approximately three-quarters of the US figure ($14.9 billion), while Japan's was about one-quarter ($3.7 billion). However, if official exchange rates are used, 'European' expenditure rises to $13.3 billion (i.e. much closer to the US total of $14.9 billion which, by definition, remains unaltered). In addition, the Japanese total increases to $5.5 billion, well over a third of the US figure.

What do the statistics show when spending is adjusted for differing country size and economic strength? One way to do this is to express the results in terms of expenditure per capita. Figure 2 reveals that, for academic and related research combined, US spending of $61 per capita in 1987 was broadly comparable with that by 'Europe' ($60) on a purchasing power parity basis. Although the Japanese figure of $31 was relatively low, it should be stressed that a considerable proportion of government research support is concentrated in mission-oriented laboratories falling outside our definition of academically related research - for example, the R&D institutes coming under the Ministry of International Trade and Industry. (Furthermore, the apparent gap compared with the other nations narrows considerably when official exchange rates are used; Japanese expenditure rises from $31 to $45 per capita - while the (unaltered) US figure ($61) is now somewhat below the 'European' average of $71.)

The conventional approach to normalizing research expenditures for differences in size of national economies is to express them as a proportion of gross domestic product (GDP). Figure 3 shows that the United States devoted 0.34% of GDP to academic and related research in 1987, appreciably less than 'Europe' (0.47%). However, the US figure increased by 12% during the 1980s whereas that of 'Europe' remained constant and Japan's dropped from 0.26 to 0.23 as rises in research spending failed to keep pace with rapid economic growth.

In short, allowing for variations in country size suggests that the United States probably invested less relative to 'Europe' in 1987. Certainly, when comparisons are made excluding life sciences (i.e. biological, agricultural and medical research - areas where, as we show below, support has been much higher than elsewhere), then US expenditure emerges as appreciably lower than the 'European' average irrespective of whether expressed in per capita or GDP terms.

Distribution across fields

Table 2 contains data on academic and related research expenditure in 1987 broken down by field. To take engineering research first, US spending of $2.0 billion was 40% greater than that for the European countries and more than twice Japan's. The United States and 'Europe' both committed 13% of their overall funds to engineering (including materials research), much less than the 22% figure for Japan. In contrast, physical sciences (i.e. physics, chemistry and astronomy) accounted for under 15% of the Japanese total, well below the six-country average of 21%. The US emphasis on physical sciences (16% of overall effort) was also far lower than in the European nations (25%). Indeed, this is the only major scientific field where 'Europe' outspent the United States. The budgetary share received by life sciences in the US (49%) was well above that in 'Europe' and Japan (34% in both cases), reflecting the high level of funding for the National Institutes of Health. However, government support for arts and humanities ($0.4 billion) was considerably less than in 'Europe', this being the result of a difference in cultural priorities as well as the greater emphasis on general university funding in Western Europe.

International comparisons of the distribution of research effort across fields are made easier if we consider the Relative Expenditure Priority (REP) index shown in Figure 4. This is defined as follows:

$$\text{REP for field A in country X} = \frac{\text{\% share of field A in country X}}{\text{\% share of field A for all six countries}}$$

Hence, for physical sciences where the US share (15.6%) was just under three-quarters of the six-country average in 1987, one obtains an REP of 0.74. After increasing between 1975 and 1984, this figure began to slip back. Engineering, professional/vocational studies (e.g. architecture, education, law, management science) and arts/humanities also had index values well below 1.0, although in the first two cases there have been modest increases since 1980. The largest improvement was in mathematics and computer science where the REP rose to 0.90. By contrast, appreciable declines were recorded in environmental and social sciences. As might be expected, the field with the largest REP in the US is life sciences with 1.35 in 1987, followed by environmental sciences (i.e. atmospheric science, geosciences and oceanography) with 1.20.

A similar analysis can be carried out at the subfield level, although with a lower degree of statistical confidence. Among US priorities for academic and related research in 1987 were aerospace engineering (with an REP of 1.8), materials research (1.6), biological sciences (1.4), agricultural and medical research (both 1.3), psychology (1.3) and political science (1.3). Lower priority areas included languages (0.3), history (0.4), astronomy (0.4), sociology (0.4), and chemical and civil engineering (both 0.7). Also well below 1.0 were physics (0.75) and chemistry (0.77) - in other words, it would appear that physical science is given only just half the funding priority of life sciences in the United States.

Research-support mechanisms

Let us now turn to certain policy issues concerning research-support mechanisms which have surfaced over recent years. Within universities, a central concern in Europe and Japan has been the balance between general university funds (GUF) provided to institutions relative to finance for separately budgeted research (ASBR). Table 3 shows how the proportion of academic research accounted for by separately budgeted grants - i.e. the ratio ASBR/(GUF + ASBR) - has varied over time. Since GUF is largely tied to the salaries of tenured university faculty who often cannot easily transfer from one field to another, this index may be regarded as an indicator of the degree of 'flexibility' available to policy-makers to set new research priorities in line with changing scientific or societal needs. The top half of the table reveals appreciable increases in the index since 1980 for Britain, West Germany and especially the Netherlands. Although the gap has narrowed, the French figure (0.51) remains higher since much of the nation's academic research is supported through CNRS and other agencies. The United States has by far the largest index value, primarily because, unlike the others, it does not operate a formal dual-support system for university research. However, there are signs of a change here as state governments have begun to provide universities with increased core-funding for facilities and infrastructure to help overcome problems associated with over-reliance on generally shorter-term federal project funding.

For agencies, an equally important question during the 1980s has been the balance between expenditure on intramural laboratories (i.e. ARR) and separately budgeted finance for university research (i.e. ASBR), especially peer-reviewed grants for individual investigators. The lower section of Table 3 relates to trends in the ASBR/ARR index - that is, ASBR divided by ASBR plus academically related research (ARR). Since intramural funding is often linked to the support of permanent staff in laboratories while ASBR mostly takes the form of shorter-term commitments, this ratio may again give an indication of the 'flexibility' to redeploy resources. There has been a rapid increase in the British and Dutch indices, bringing them up to the French level of approximately 0.5. In the United States and Japan, the ratio has historically been much higher (between 0.7 and 0.8) because government-supported research is generally conducted either on university campuses or in mission-oriented laboratories falling outside our definition of academically related research (e.g. Los Alamos, Lawrence Livermore and the Jet Propulsion Laboratory).

<u>A US expenditure 'gap'?</u>

Given the earlier indications of a shortfall in US spending on academic and related research relative to 'Europe', it is worth exploring the nature and magnitude of the difference in greater detail. One way to do this is to express expenditures in each field as a ratio of the average for the four European nations (the 'European' average) - that is, in terms of the Relative European Funding Index (REFI) shown in Figure 5. This is defined as follows:

$$\text{REFI for field A in country X} = \frac{\text{Spending on field A in country X}}{\text{'European' average spending on field A}}$$

Thus, overall US funding of $61.1 per capita for academic and related research in 1987 translates into a REFI value of 1.03 when compared with the 'European' average of $59.5 (based on purchasing power parities). At the level of fields, the index for the US was particularly high for life sciences (1.48) and environmental research (1.26), with engineering (1.08) also supported rather more generously than in 'Europe'. In contrast, physical science was accorded lower priority (0.66) - less than social sciences (0.77) and only slightly higher than professional/vocational studies (0.62) and arts/humanities (0.40), fields traditionally receiving the least government support in the United States. Mathematics and computing fared just a little better with a REFI of 0.84 in 1987. These figures again point to a difference in political and cultural priorities between the two continents.

Given the wide range of REFI values in Figure 5, an obvious question is, 'How much more or less would the United States have to invest in order to attain the 'European' level?' The results in Figure 6 indicate that expenditure on life sciences in the US was no less than $2.4 billion greater than the 'European' average in 1987. This was apparently at the expense of physical sciences (with a funding 'deficit' of $1.2 billion) and arts and humanities (where there was a $0.6 billion 'gap'). Indeed, for all the main fields excluding life sciences, there was a net 'deficit' of $2.0 billion compared to the 'European' mean.

Similar calculations suggest that Japan would also need to spend vastly greater sums to bring it up to the four-country average - perhaps of the order of $3.5 billion per annum according to this indicator - primarily on physical and life sciences.

How has the 'gap' between the United States and 'Europe' changed over time? As regards the funding for all fields combined, after worsening between 1975 and 1982, the situation then improved over the next five years. However, if we examine the field breakdown, it is apparent that the turnaround stems largely from increased funding for life sciences. In contrast, the relative situation of the least well-endowed area - physical sciences - has scarcely changed since 1984. Figure 6 also reveals a decline in the fortunes of social sciences (including psychology), which slipped from being $220 million ahead of 'Europe' in 1975 to a position where there was an apparent 'shortfall' of $230 million in 1987 following major cutbacks at the beginning of the decade.

Such per capita-based estimates of absolute funding 'gaps' clearly need to be treated with greater caution than the earlier data relating to differences in relative expenditure priorities across countries. In particular, the statistical dangers involved in relying on figures derived by subtracting one large and uncertain number (for the United States) from another (for the 'European' average) should be recognized. Nevertheless, the example of the 'balance of payments gap' statistics in the field of economics illustrates that there is sometimes little alternative but to employ imperfect indicators of this sort in policy-making. In such circumstances, the best that can be done to minimize the uncertainties is to explore a range of indicators. The preference of certain politicians to view spending on academic research as a 'consumption' item (i.e. a cultural luxury which can best be afforded by more affluent nations), and not just as an investment in the future, is another reason why one needs to consider parallel statistics on funding differences calculated from comparisons of expenditure expressed as a percentage of GDP.

The results in Figure 7 illustrate how important it is not to rely on a single indicator in assessing the relative level of spending by the United States. For all fields combined, adoption of a GDP-based approach points to a considerably larger US 'gap' of $5.9 billion compared to 'Europe' in 1987. This is much the same irrespective of whether life science is excluded, and compares with the non-life science 'shortfall' of $2.0 billion suggested by the earlier per capita figures. The reason for such a discrepancy between the two estimates is not obvious (although the fact that using official exchange rates rather than purchasing power parities substantially reduces the divergence may be significant). Nevertheless, it is clear that both sets of indicators show a large deficit in five of the eight main fields. In other words, it would appear that the United States invests proportionately less than 'Europe' in a wide range of academic research areas, though life science is relatively well funded. Moreover, there seems little doubt that the amount by which US spending lags behind that of 'Europe' is considerable for physical sciences, our estimates ranging from $1.2 to $2.7 billion in 1987.

Conclusions

Before summarizing the main findings, we must again emphasize the intrinsic uncertainties involved in comparing spending levels across countries with rather different systems for financing and conducting research. Any attempt to assess the 'adequacy' of US funding relative to 'Europe' must therefore allow for the fact that our figures exclude the growing sums given to universities by industry and charitable foundations. Decisions on funding policy also need to take into account other measures of scientific activity such as numbers of researchers. Furthermore, indicators of research output (e.g. publication data) and of scientific impact (e.g. citation statistics) are often at least as important as those relating to inputs.

With these provisos in mind, let us turn to the conclusions which may be drawn. First of all, in terms of absolute spending, US support for academic and related research in 1987 ($14.9 billion) was similar to the combined expenditure of Japan and the four European nations ($14.7 billion). Hence, the United States is still by far the dominant world player in the sphere of academic research. However, if life science is excluded, or if expenditure is normalized for differences in population, then the United States compares less favourably with the European countries. Similarly, 'Europe' invests appreciably more in academic and related research relative to GDP. Irrespective of the basis used for comparison, Japanese spending has remained extremely low in international terms. This is despite the government's expressed intention to strengthen fundamental science in response to criticisms voiced especially in America that Japan has been 'free-riding' on the scientific efforts of the United States and Western Europe instead of contributing its 'fair share' of resources to the support of basic research.

At the field level, the picture is more complicated as a result of the dominance of US expenditure on life sciences – in 1987, the figure of $7.3 billion amounted to 45% more than the total spent by the other five nations combined. The effect of the expansion in NSF support for engineering can be seen in the gradual increase in the Relative Expenditure Priority (REP) index, although it was still only 0.92 in 1987. Conversely, investment in environmental sciences remained at a level 20% higher than the international average in 1987 despite a decline in the field's share of total US government spending in recent years.

While the low priority given to social sciences, professional/vocational studies and arts/humanities is perhaps predictable, the relative funding situation of physical sciences in the United States may cause some concern not least because of the technological and economic significance of much of the research within the field. In 1987, the Relative Expenditure Priority index stood at 0.74, little higher than the value for Japan (0.69) and considerably lower than for the Federal Republic of Germany (1.19) and France (1.41). Furthermore, although the REP rose between 1980 and 1984, it has since begun to fall back. At the subfield level, US expenditure priorities include aerospace engineering, materials research, biological sciences and medical research. In contrast, chemical and civil engineering, physics, chemistry, astronomy and several humanities areas all have low REPs.

As regards mechanisms for financing research, the United States relies predominantly on separately budgeted grants, whereas the 'dual-support system' operated in European countries results in academic research receiving two-thirds of its finance through general university funding. This may be one reason why concern about inadequate investment in facilities and instrumentation has so far been more muted in Europe. However, during the 1980s the Netherlands, United Kingdom and Federal Republic of Germany have begun to move somewhat closer to the US model by giving greater emphasis to separately budgeted funding. The hope is that this will result in academic research becoming more responsive to changing scientific and societal needs.

Finally, our analysis of differences in government funding across countries suggests that overall spending by the United States at best matched that of 'Europe' in 1987. At worst, there was a sizeable funding 'gap'. While life science was supported reasonably well, the indications are that physical sciences received far lower support than elsewhere - by $1-2 billion less per annum relative to the 'European' average. Of course, there is no reason why the same disciplinary priorities should be adopted in the United States as in 'Europe'. However, the magnitude of the difference does suggest that US policy-makers should at the very least reconsider whether existing priorities are in line with national needs.

Such a reassessment might possibly conclude that most of the existing scientific advances over coming decades are likely to occur in new areas of life sciences. This would imply that Europe is placing too much faith in the physical sciences, having failed to recognize that the rapid rate of advance seen in the post-war era is now slowing. However, an alternative conclusion could be that the high political visibility of health research is primarily responsible for the situation in which the agency responsible for supporting this one field (i.e. the National Institutes of Health) has a budget several times greater than that of the National Science Foundation (whose task it is to support all areas of natural science, engineering and social sciences). If so, a systematic appraisal of the country's social and economic needs might well indicate that the balance of efforts between physical and life sciences should be adjusted.

Acknowledgements

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3. E. Mansfield, A. Romeo and L. Switzer, Research Policy, 12, 105 (1983).

Figure 1. Coverage of academic and related research in the six countries surveyed[a]

	General university funds (GUF)	Academic separately budgeted research (ASBR)[b]	Academically related research (ARR)
USA	- institutional research funds in public doctorate-granting universities - faculty salary contribution by public universities to government-funded projects	- federally financed academic research (current and capital) - state and local government financed academic research (current and capital) - federal fellowship programmes	- academic research facilities provided by federally funded R&D centers (FFRDCs) - academically related research in university-administered FFRDCs - NIH intramural programs
JAPAN	- general finance for national and public university faculties including 'koza' funding) - institutional research finance from government for private universities	- Monbusho research grants to national public and private universities - support for national and public university institutes - finance for 'joint-use' and Inter-University Research Institutes - JSPS programs, fellowships and studentships - contract research from central and prefectural government agencies	- Monbusho intramural institutes - basic research in national agricultural and medical institutes - academically related research funded by STA (e.g. at RIKEN) - international subscriptions
UK	- UGC-funded universities - polytechnics and Scottish central institutions - the Open University	- academic grants from the five research councils (e.g. SERC) - government contract research - Royal Society and British Academy grants and fellowships	- intramural research council work financed by the 'Science Vote' - international subscriptions
FRG	- universities - integrated universities - theological, arts and teacher-training colleges	- academic grants from DFG and BMFT - federal government contract research - separately budgeted finance from state ministries - federal fellowship and doctoral studentship programs	- Max Planck Institutes (apart from the fusion field) - National Research Center support for academic central facilities and/or fundamental science - academically related 'blue list' institutes and similar establishments - basic research in federal agricultural laboratories - various national academy programs - international subscriptions
FRANCE	- universities - grandes écoles - various specialized doctorate-granting institutions	- separately budgeted Ministry of National Education funding - CNRS support for 'associated laboratories/teams' at universities - grants from INSERM, INRA, IFREMER and BRGM - other government grants and contracts (e.g. from MRT)	- intramural CNRS and INSERM research - basic research in INSERM, BRGM, IFREMER and INRA establishments - various academically related institutes (e.g. IRF and the Pasteur Institute) - international subscriptions
NETHERLANDS	- general funds for universities (including agricultural and technical) - conditional financing for universities	- grants from research councils (NWO/ZWO and STW) - independent academic research institutes - Institute/Foundation for Educational Research - government contract research	- intramural/academically related research financed by NWO/ZWO, STW and KNAW - Ministry of Education and Science Institutes - Institute of Applied Physics (TNO) - basic agricultural and health research in MAF and TNO institutes - other academically related research in government institutes - international subscriptions

NOTES: (a) Coverage relates only to the principal expenditure elements for each country and therefore excludes some minor categories of spending.

(b) The generic term 'academic grants' in some cases covers not just project and program funding but also support for fellowships and doctoral studentships.

FIG 2. TRENDS IN EXPENDITURE PER CAPITA

(in 1987 $ calculated using PPPs)

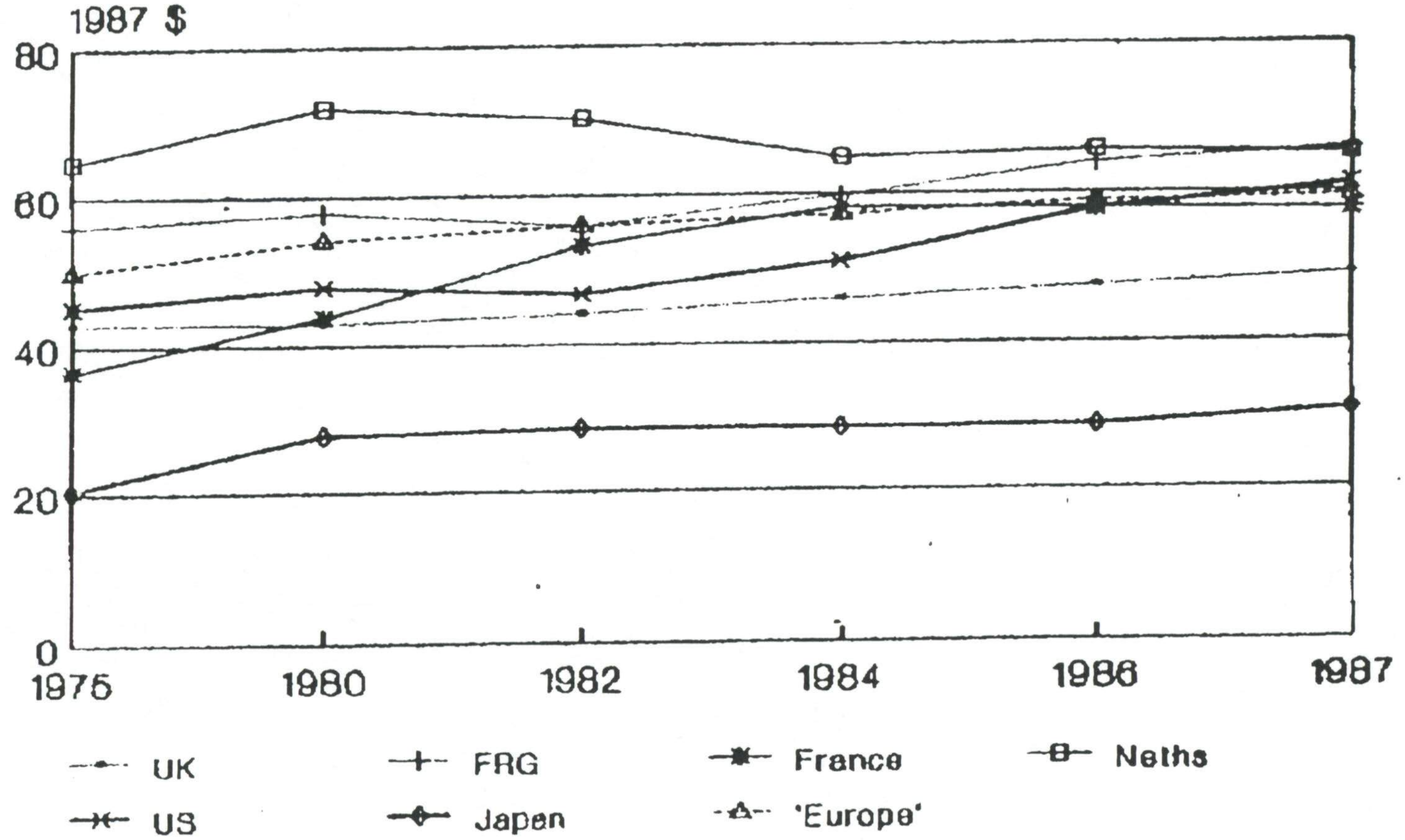

FIG 3 TRENDS IN EXPENDITURE AS % OF GDP

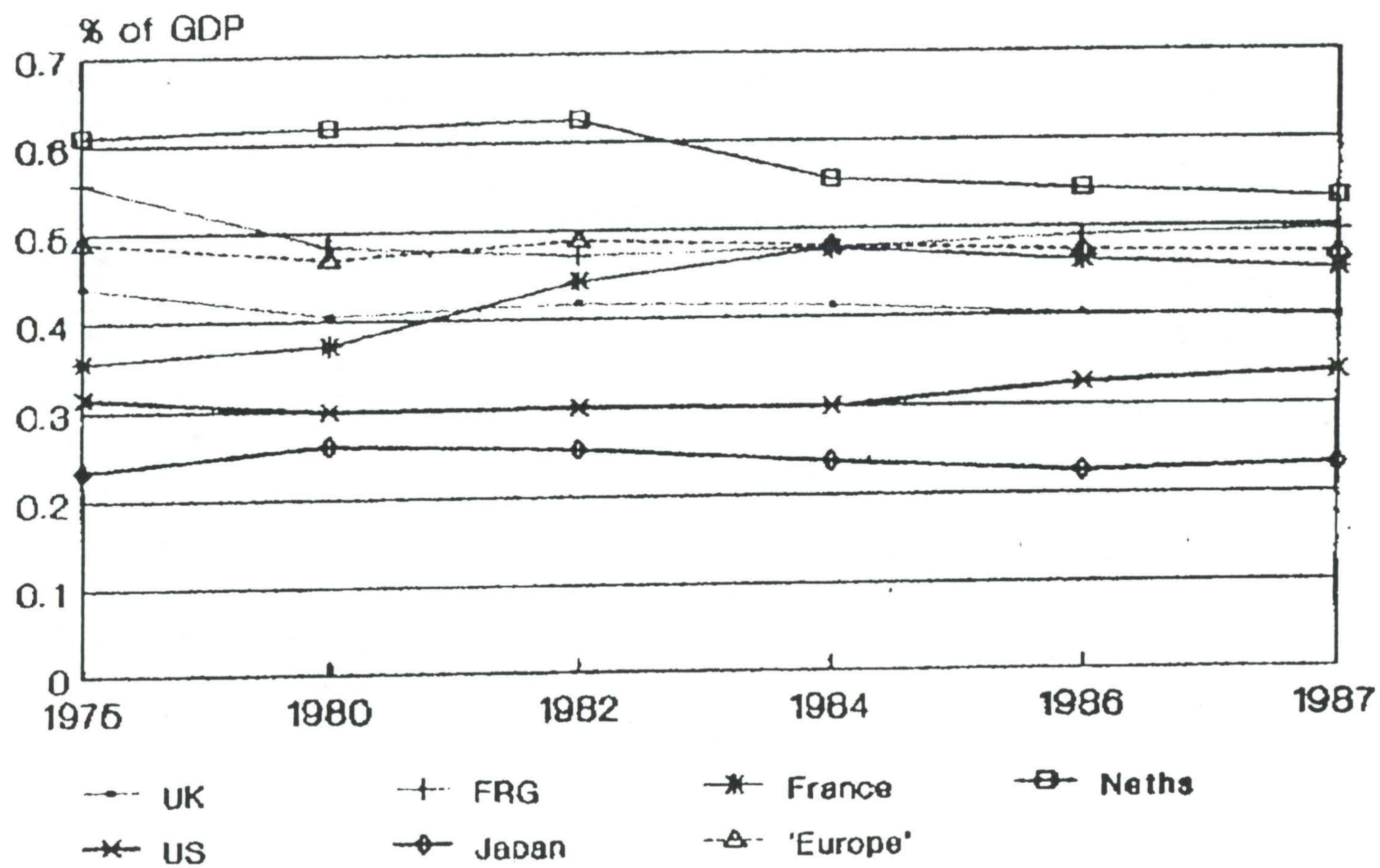

FIGURE 4 RELATIVE EXPENDITURE PRIORITIES FOR THE US (Breakdown by field, 1975-87)

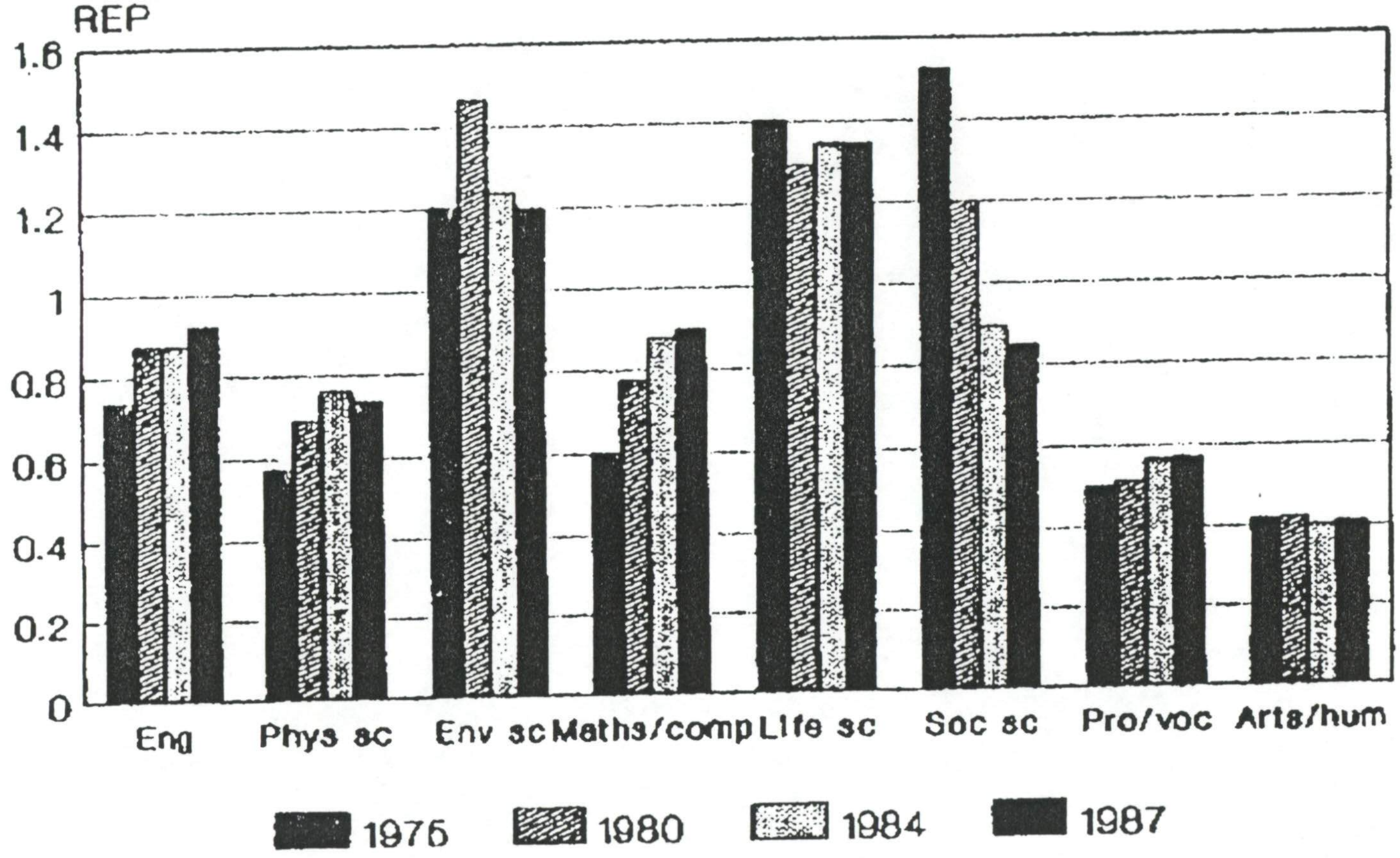

FIGURE 5 RELATIVE EUROPEAN FUNDING INDEX
Breakdown by Field in 1987

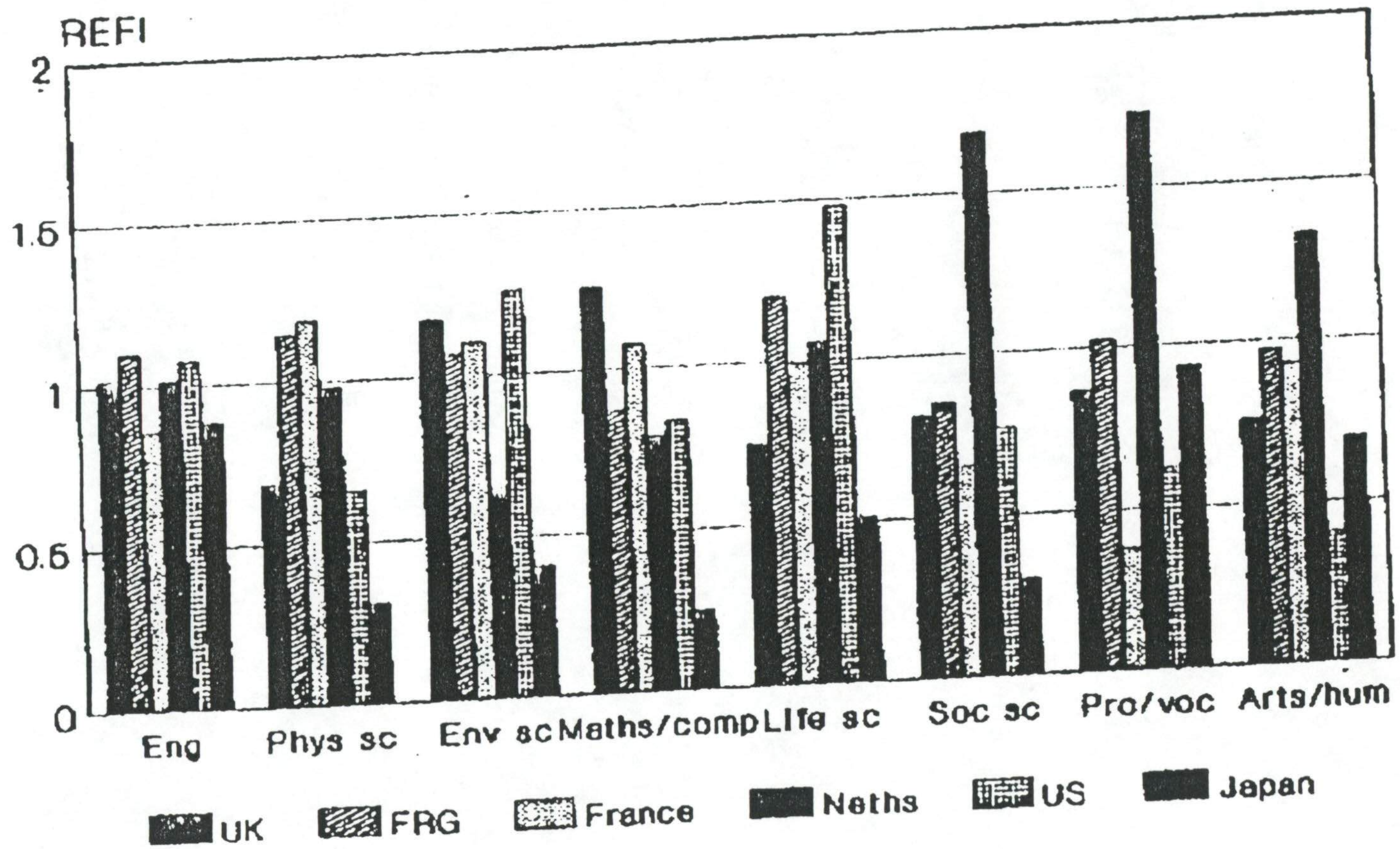

FIGURE 6. US EXPENDITURE COMPARED WITH 'EUROPE' (per capita based divergence)

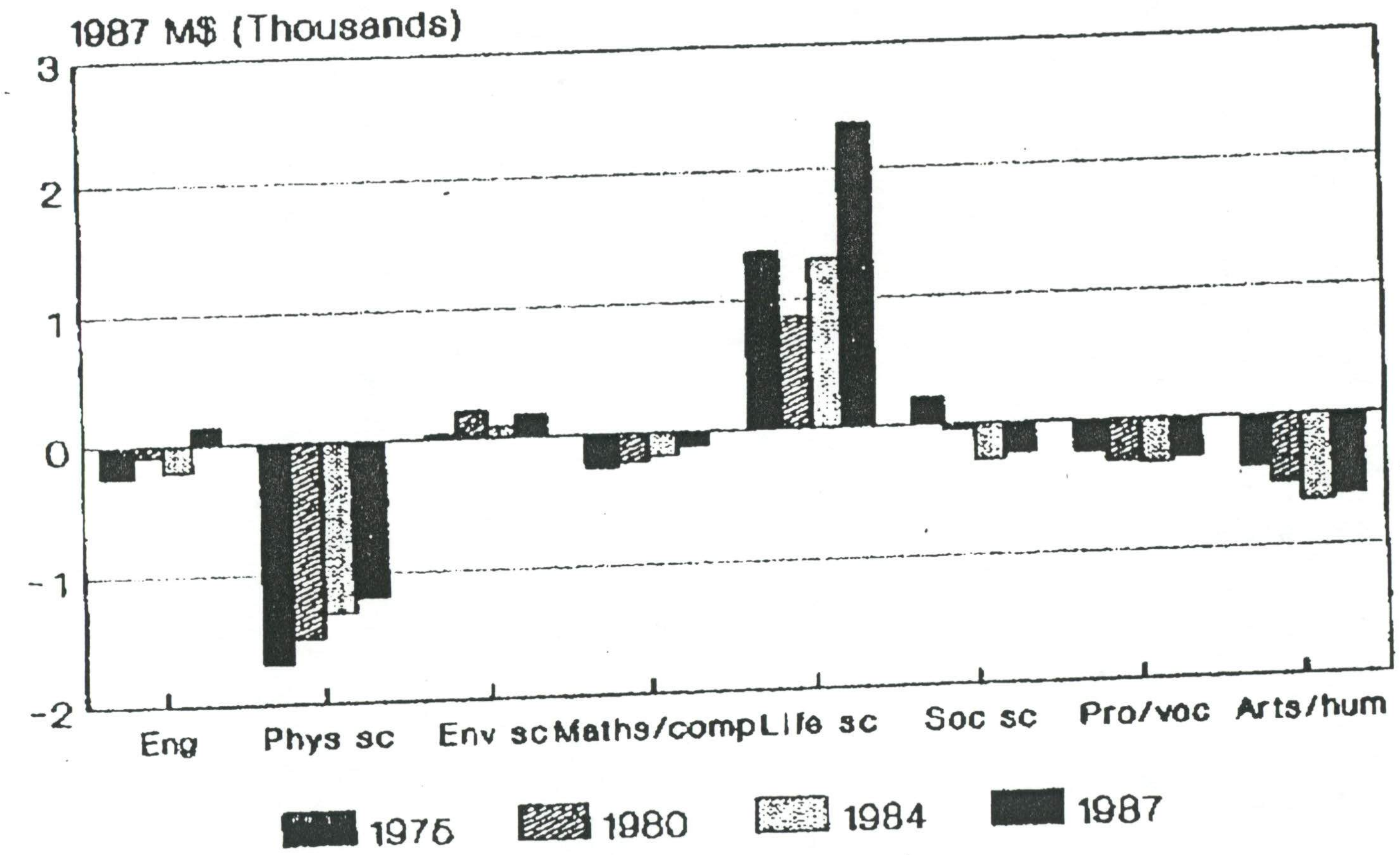

FIGURE 7. US EXPENDITURE COMPARED WITH 'EUROPE' (Divergence on GDP basis)

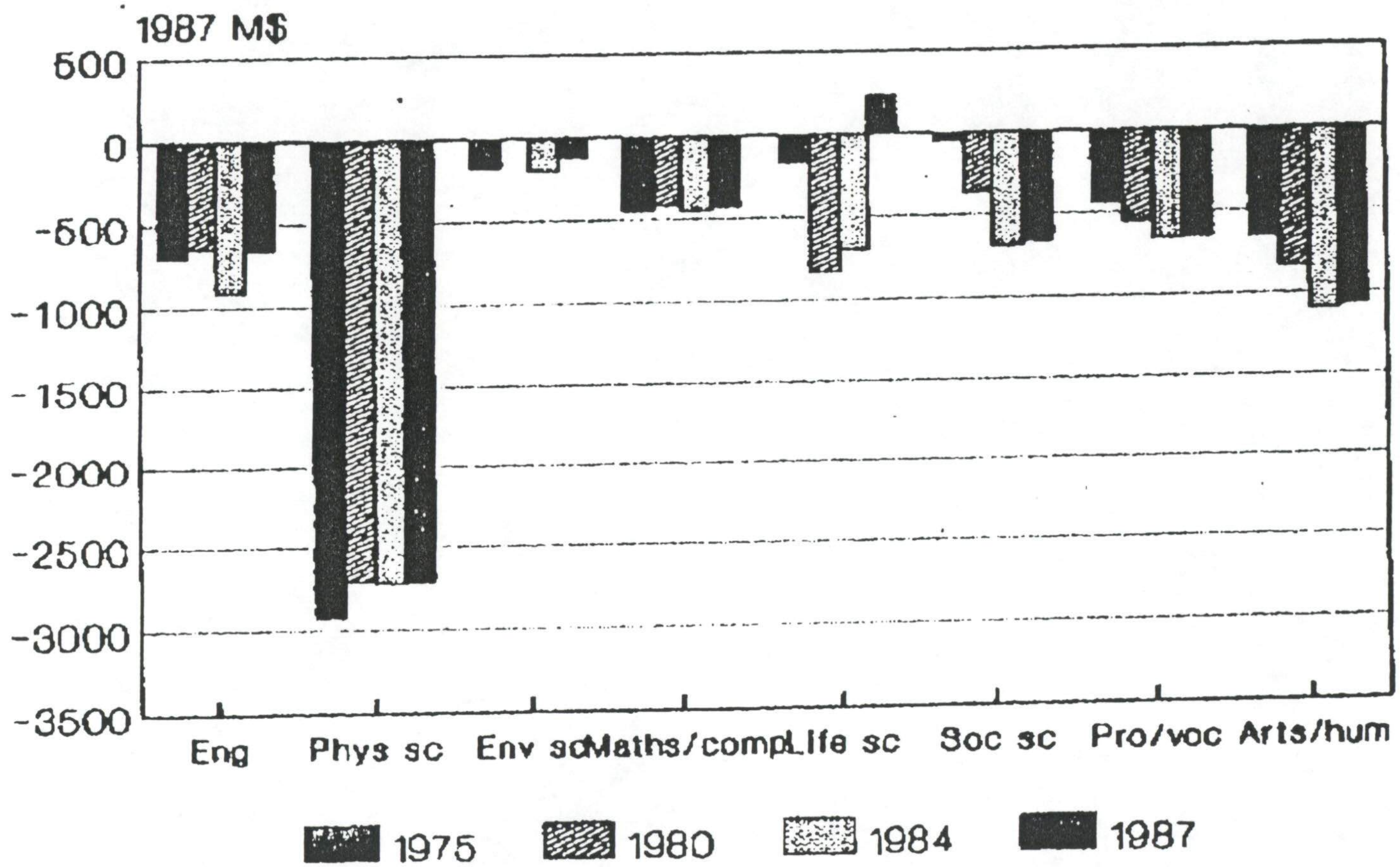

Table 1. Government funding of academic and related research (1987 $millions)

		1975	1980	1982	1984	1986	1987	% change 1980-87
General university funds (GUF)	UK	1,333	1,368	1,407	1,400	1,461	1,487	10%
	FRG	2,037	2,040	1,928	1,992	2,047	2,125	4%
	France	533	746	931	996	966	965	29%
	Netherlands	624	686	706	620	613	591	-14%
	'Europe' subtotal	4,527	4,824	4,972	5,008	5,088	5,158	7%
	US	1,775	2,056	2,184	2,509	2,872	3,097	51%
	Japan	1,606	2,180	2,322	2,306	2,329	2,512	15%
Academic separately budgeted research (ASBR)	UK	339	435	448	513	540	585	35%
	FRG	577	589	575	591	689	730	24%
	France	626	713	849	935	982	984	39%
	Netherlands	102	144	141	152	177	191	33%
	'Europe' subtotal	1,646	1,881	2,012	2,190	2,388	2,500	33%
	US	6,928	7,468	7,385	7,807	9,244	9,893	32%
	Japan	483	771	792	828	824	888	15%
Academically related research (ARR)	UK	744	633	638	688	703	726	15%
	FRG	889	934	954	1,077	1,165	1,182	27%
	France	770	907	1,131	1,272	1,271	1,262	39%
	Netherlands	158	190	162	165	170	175	-7%
	'Europe' subtotal	2,531	2,663	2,885	3,203	3,329	3,345	26%
	US	1,087	1,385	1,337	1,796	1,875	1,915	38%
	Japan	187	284	258	284	317	335	18%
Total	UK	2,417	2,422	2,493	2,601	2,704	2,797	16%
	FRG	3,473	3,563	3,456	3,661	3,921	4,037	13%
	France	1,929	2,365	2,911	3,203	3,219	3,212	36%
	Netherlands	884	1,018	1,008	937	960	958	-6%
	'Europe' subtotal	8,703	9,368	9,869	10,402	10,805	11,004	17%
	US	9,790	10,910	10,905	12,112	13,991	14,905	37%
	Japan	2,276	3,235	3,373	3,418	3,470	3,735	15%

* Spending in national currencies was converted to US dollars using OECD 'purchasing power parities' for 1987 calculated in early 1989.

Superseded by Figures 2 and 3

Table 2. Total government funding adjusted for country size

			1975	1980	1982	1984	1986	1987	% change 1980-87	
Expenditure per capita (1987 dollars)	PPP basis *	UK	43.0	43.0	44.3	46.0	47.6	49.1	14%	Replaced by Figure 2
		FRG	56.2	57.9	56.1	59.8	64.2	66.0	14%	
		France	36.6	43.9	53.4	58.3	58.1	57.7	32%	
		Netherlands	64.7	72.0	70.4	66.0	65.9	65.3	-9%	
		'Europe' ^	50.1	54.2	56.1	57.3	59.0	59.5	10%	
		US	46.3	47.9	46.9	51.1	57.9	61.1	28%	
		Japan	20.4	27.7	28.5	28.8	28.6	30.6	10%	
	OER basis +	UK	40.9	40.9	42.1	43.8	45.3	46.7	14%	
		FRG	77.1	79.4	76.9	82.1	88.1	90.5	14%	
		France	45.2	54.3	66.1	72.1	71.8	71.4	32%	Dropped
		Netherlands	76.5	85.1	83.3	76.8	77.9	77.2	-9%	
		'Europe' ^	59.9	64.9	67.1	68.7	70.8	71.5	10%	
		US	46.3	47.9	46.9	51.1	57.9	61.1	28%	
		Japan	30.1	40.9	42.1	42.1	42.2	45.2	10%	
Expenditure as a percentage of GDP		UK	0.439	0.405	0.418	0.413	0.402	0.398	-2%	Replaced by Figure 3
		FRG	0.556	0.484	0.472	0.479	0.490	0.496	2%	
		France	0.355	0.373	0.443	0.477	0.462	0.453	21%	
		Netherlands	0.611	0.618	0.625	0.556	0.543	0.532	-14%	
		'Europe' ^	0.490	0.470	0.489	0.481	0.474	0.470	0%	
		US	0.315	0.299	0.300	0.300	0.325	0.336	12%	
		Japan	0.233	0.260	0.254	0.238	0.225	0.232	-11%	

* Converted to US dollars using OECD 'purchasing power parities' (PPPs).
\+ Converted to US dollars using OECD official exchange rates (OERs).
^ Unweighted average for the four European countries.

2

Table ~~1~~. Breakdown of academic and related research by field, 1987 (1987 $M) *

	UK	FRG	France	Neths	'Europe'	US	Japan	Average +
Engineering	436 15.6%	505 12.5%	369 11.5%	112 11.7%	1,412 12.8%	1,966 13.2%	809 21.6%	14.3%
Physical sciences	565 20.2%	1,015 25.1%	955 29.7%	208 21.7%	2,743 24.9%	2,325 15.6%	543 14.5%	21.2%
Environmental sciences	188 6.7%	183 4.5%	172 5.3%	27 2.8%	570 5.2%	869 5.8%	136 3.7%	4.8%
Maths and computing	209 7.5%	156 3.9%	175 5.4%	34 3.5%	574 5.2%	596 4.0%	88 2.3%	4.4%
Life sciences	864 30.9%	1,483 36.7%	1,116 34.7%	313 32.7%	3,776 34.3%	7,285 48.9%	1,261 33.7%	36.3%
Social sciences (and psychology)	187 6.7%	210 5.2%	146 4.6%	99 10.4%	642 5.8%	754 5.1%	146 3.9%	6.0%
Professional and vocational	161 5.7%	203 5.0%	67 2.1%	82 8.5%	513 4.7%	490 3.3%	369 9.9%	5.8%
Arts and humanities	184 6.6%	251 6.2%	218 6.8%	83 8.6%	736 6.7%	411 2.8%	358 9.6%	6.8%
Multidisciplinary	6 0.2%	32 0.8%	3 0.1%	1 0.1%	42 0.4%	217 1.5%	28 0.8%	0.6%
Total	2,798 100%	4,037 100%	3,212 100%	968 100%	11,005 100%	14,904 100%	3,735 100%	100%

* Converted US dollars using OECD 'purchasing power parities'.
\+ Unweighted average for the six countries.

Replaced by Figure 4

Table 4. Trends in relative expenditure priorities for the United States, 1975-87 *

	1975	1980	1982	1984	1986	1987	% change 1980-87
Engineering	0.74	0.87	0.91	0.87	0.91	0.92	6%
Physical sciences	0.58	0.69	0.70	0.76	0.75	0.74	7%
Environmental sciences	1.21	1.47	1.25	1.24	1.24	1.20	-18%
Maths/computer science	0.60	0.78	0.80	0.88	0.91	0.90	16%
Life sciences	1.40	1.30	1.32	1.35	1.35	1.35	4%
Social sci and psychology	1.52	1.20	1.01	0.89	0.86	0.85	-29%
Professional/vocational	0.50	0.51	0.52	0.57	0.55	0.57	11%
Arts and humanities	0.42	0.42	0.43	0.40	0.40	0.41	-3%

Figures used in Figure 4

* The relative expenditure priority for field A in country X is defined as the percentage share of spending by country X on field A divided by the average share of spending by all six countries on field A.

X

Table ~~5~~ 3. Changing emphasis on different research support mechanisms, 1975-87

		1975	1980	1982	1984	1986	1987	% change 1980-87
ASBR/GUF index ASBR/(ASBR+GUF)	UK	0.203	0.243	0.241	0.268	0.270	0.282	16%
	FRG	0.221	0.224	0.230	0.229	0.252	0.256	14%
	France	0.540	0.489	0.477	0.484	0.504	0.510	4%
	Netherlands	0.161	0.173	0.166	0.197	0.224	0.244	41%
	'Europe'	0.267	0.280	0.288	0.304	0.319	0.327	16%
	US	0.796	0.784	0.772	0.757	0.763	0.762	-3%
	Japan	0.231	0.261	0.294	0.264	0.251	0.261	0%
ASBR/ARR index ASBR/(ASBR+ARR)	UK	0.313	0.407	0.412	0.427	0.435	0.446	10%
	FRG	0.402	0.387	0.376	0.364	0.358	0.382	-1%
	France	0.448	0.440	0.429	0.423	0.436	0.441	0%
	Netherlands	0.393	0.431	0.468	0.478	0.509	0.521	21%
	'Europe'	0.394	0.414	0.411	0.406	0.418	0.428	3%
	US	0.864	0.844	0.847	0.813	0.831	0.836	-1%
	Japan	0.721	0.731	0.754	0.744	0.722	0.726	-1%

Replaced by Figure 5

Table 6. Indicators of divergence in national research expenditures in 1987 derived from Relative European Funding Index (on a per capita and PPP basis) *

Dropped

Expenditure (1987 $ per capita)	UK	FRG	France	Neths	US	Japan	'European' average +
Engineering	7.7	8.2	6.5	7.6	8.1	6.6	7.5
Physical sciences	9.9	16.6	17.2	14.2	9.5	4.4	14.5
Environmental sciences	3.3	3.0	3.1	1.8	3.5	1.1	2.8
Maths and computing	3.7	2.5	3.1	2.3	2.4	0.7	2.9
Life sciences	15.2	24.2	20.1	21.4	29.9	10.3	20.2
Social sci and psychology	3.3	3.4	2.6	6.8	3.1	1.2	4.0
Professional/vocational	2.8	3.3	1.2	5.5	2.0	3.0	3.2
Arts and humanities	3.2	4.1	3.9	5.6	1.7	2.9	4.2
Multidisciplinary	0.1	0.5	0.1	0.0	0.9	0.2	0.2
Total	49.1	66.0	57.7	65.3	61.1	30.6	59.5

Figures used in Figure 5

Relative European Funding Index (REFI)	UK	FRG	France	Neths	US	Japan	'European' average +
Engineering	1.02	1.10	0.86	1.02	1.08	0.88	
Physical sciences	0.69	1.15	1.19	0.98	0.66	0.31	
Environmental sciences	1.18	1.07	1.10	0.65	1.26	0.40	
Maths and computing	1.26	0.87	1.08	0.79	0.84	0.25	
Life sciences	0.75	1.20	0.99	1.06	1.48	0.51	
Social sci and psychology	0.81	0.86	0.65	1.68	0.77	0.29	
Professional/vocational	0.87	1.03	0.37	1.73	0.62	0.94	
Arts and humanities	0.77	0.97	0.93	1.33	0.40	0.69	
Multidisciplinary	0.55	2.89	0.34	0.22	4.92	1.28	
Total	0.83	1.11	0.97	1.10	1.03	0.51	

Dropped

Divergence from expected expenditure (1987 M$)	UK	FRG	France	Neths	US	Japan	'European' average +
Engineering	10	50	-60	0	140	-110	
Physical sciences	-260	130	150	0	-1200	-1220	
Environmental sciences	30	10	20	-10	180	-210	
Maths and computing	40	-20	10	-10	-110	-270	
Life sciences	-290	250	-10	20	2360	-1210	
Social sci and psychology	-40	-40	-80	40	-230	-350	
Professional/vocational	-20	0	-110	30	-300	-30	
Arts and humanities	-60	-10	-20	20	-620	-160	
Multidisciplinary	0	20	-10	0	170	10	
Total ^	-590	390	-100	80	380	-3530	

* Converted to US dollars using OECD 'purchasing power parities'.
\+ Unweighted average for the four European countries.
^ Because of rounding to the nearest $10 million, details may not sum to totals.

Replaced by Figures 6 and 7

Table 7. Indicators of divergence in US research expenditure for 1975-87 derived from 'Relative European Funding Index' *

		1975	1980	1982	1984	1986	1987	Change Since 1975
Calculated on a per capita basis using PPPs +	Engineering	-240	-90	-150	-200	10	140	230
	Physical sciences	-1700	-1500	-1880	-1310	-1220	-1200	300
	Environmental sciences	40	220	110	90	170	180	-40
	Maths and computing	-260	-220	-220	-180	-130	-110	110
	Life sciences	1380	870	730	1310	2000	2360	1490
	Social sci and psychology	220	-40	-240	-280	-260	-230	-190
	Professional/vocational	-240	-320	-380	-340	-330	-300	20
	Arts and humanities	-390	-520	-610	-660	-640	-620	-100
	Multidisciplinary	150	170	170	100	140	170	0
	Total divergence ^	-1030	-1430	-2130	-1470	-260	380	1810
Calculated on a % of GDP basis	Engineering	-700	-640	-700	-910	-770	-860	-20
	Physical sciences	-2930	-2710	-2700	-2720	-2690	-2720	-10
	Environmental sciences	-180	0	-100	-200	-120	-120	-120
	Maths and computing	-450	-420	-420	-450	-440	-430	-10
	Life sciences	-170	-830	-960	-700	-100	230	1050
	Social sci and psychology	-50	-370	-890	-690	-690	-670	-300
	Professional/vocational	-440	-550	-600	-650	-680	-650	-90
	Arts and humanities	-650	-840	-950	-1100	-1090	-1070	-230
	Multidisciplinary	140	150	160	80	120	160	10
	Total divergence ^	-5440	-6220	-6860	-7340	-6460	-6930	290

Figures used in Figure 6

Figure 7

* Expected expenditures were calculated using unweighted averages (i.e. not adjusted to take into account the differing sizes of countries).
\+ National currencies were converted to US dollars using OECD 'purchasing power parities'.
^ Because of rounding to the nearest $10 million, details may not sum to totals.