# INVESTING IN THE FUTURE: HOW MUCH GOVERNMENTS PAY FOR ACADEMIC RESEARCH

**In relation to its size and wealth, the US 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.**

John Irvine, Ben R. Martin and Phoebe Isard

It is conventional wisdom that scientific research is crucial to the wealth of nations. This view has influenced political thinking since Vannevar Bush, the MIT computer engineer who coordinated US defense research in World War II, first expounded it in his 1945 book, *Science, the Endless Frontier*.[1] In it he wrote: "New products and processes are founded on new principles and conceptions which, in turn, are developed by research in the purest realms of science." This has come to mean that the technological innovations so vital to economic competitiveness frequently depend upon scientific discoveries that usually emerge from the research base fixed firmly in universities, government laboratories and some large corporate organizations. Indeed, the connection of research and development with economic and social advancement is now a political maxim the world's great industrial nations (and those that aspire to greatness) have adopted, although sometimes more in principle than in practice.[2]

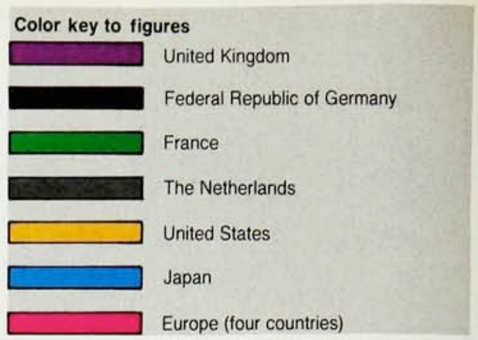
Maintaining a vibrant science base is increasingly expensive, and in recent years governments in most of the advanced countries have scrutinized their science budgets more closely to make sure that research programs accurately reflect currently perceived needs. Because the chancy, unforeseeable and long-term nature of much basic research invites questions about "value for money," the level of investment and the balance of research are gaining increasing attention in government circles.

What is happening is that elected politicians and agency officials are often confronting two key questions: First, how much should government invest in research performed at universities and related laboratories? Given the increasing global competition in science as well as in technology, funding agencies would like to know how their research outlays compare with expenditures in other nations, both in overall terms and for specific fields. Second, what funding procedures are most appropriate for supporting academic and related research? It is important to ask, then, what emphasis different countries give to institutional core funding in universities relative to peer-reviewed projects (or programs) supported by such national research-funding agencies as France's Centre National de la Recherche Scientifique, the Deutsche Forschungsgemeinschaft and the US National Science Foundation, compared with the intramural work conducted within laboratories operated by government units like Japan's Ministry of Education, Science and Culture (known as Monbusho) or the US Department of Energy.

By comparing national funding data for several leading industrial countries, we believe one can derive some insight into which funding arrangements work most effectively. Accordingly, we examined the main trends in government spending on academic and related research between 1975 and 1987, looking at the similarities and differences among the US and five other countries—namely, the United Kingdom, the Federal Republic of Germany, the Netherlands, France and Japan. This analysis draws upon the framework and findings of a study undertaken for NSF and the British Advisory Board for the Research Councils[3], which produced comparable figures on spending broken out into 9 fields and 40 subfields for each country. In our study, we also identified factors that underlie changes in the level and distribution of academic funding, based on information obtained from published reports and on interviews with government agency officials and science policy specialists.

Among the issues examined are the political priorities that nations assign to basic science in general and to specific fields as well as the pressures underlying the restructuring of research-support procedures in each country. One exceedingly important question outside the study's remit, however, relates to the changing balance between private and public financing of academic re-

**John Irvine** and **Ben R. Martin** are senior fellows of the Science Policy Research Unit at the University of Sussex, Brighton, England. **Phoebe Isard** is a research associate in the department of community medicine at the University of Edinburgh in Scotland. This article is adapted from their recently published book, *Investing in the Future: An International Comparison of Government Funding of Academic and Related Research*. No significance is implied by the order of the authors' names on this article.




search. 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 a certain amount of academic research is supported by nonprofit or charitable organizations, especially in the biomedical and health fields.

## The methodology considered

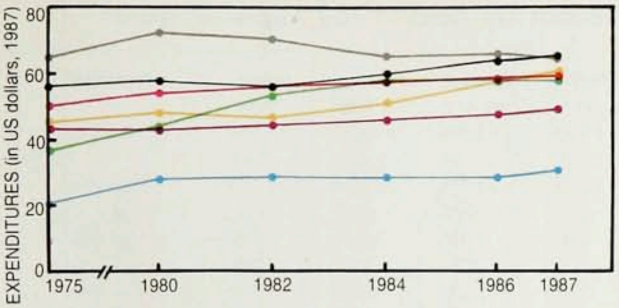
Disaggregated data were compiled for three categories of expenditures: (1) academic research financed through general university funds awarded to institutions by national or state governments; (2) separately budgeted academic research provided in the form of grants, contracts and other funding arrangements earmarked for specific research projects by public-sector funding agencies; and (3) academically related research undertaken outside universities, either by national or international laboratories operating central facilities for use by academic scientists, such as Fermilab, CERN and the National Optical Astronomy Observatories, or by institutes engaged in long-term basic research similar to the work at universities in other countries and financed primarily through government core funding, such as the intramural programs of the National Institutes of Health outside Washington, DC, or the Institute for Physical and Chemical Research (called Riken) located near Tokyo.

As the first category, general university funds represent an important method of support for academic research in Europe and Japan but one that is not so heavily used in the US. The category of separately

## Table 1. Government funding of academic and related research (millions of dollars)*

| | | 1975 | 1980 | 1982 | 1984 | 1986 | 1987 | Percentage change 1980–87 |
|---|---|---|---|---|---|---|---|---|
| General university funds | UK | 1 333 | 1 355 | 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 | 956 | 28 |
| | Netherlands | 624 | 685 | 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 | UK | 339 | 435 | 448 | 513 | 540 | 585 | 35 |
| | FRG | 577 | 589 | 575 | 591 | 689 | 730 | 24 |
| | France | 626 | 713 | 849 | 935 | 982 | 994 | 39 |
| | Netherlands | 102 | 144 | 141 | 152 | 177 | 191 | 33 |
| | 'Europe' subtotal | 1 645 | 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 | UK | 744 | 633 | 638 | 688 | 703 | 726 | 15 |
| | FRG | 859 | 934 | 954 | 1 077 | 1 185 | 1 182 | 27 |
| | France | 770 | 907 | 1 131 | 1 272 | 1 271 | 1 262 | 39 |
| | Netherlands | 158 | 190 | 162 | 166 | 170 | 176 | −7 |
| | 'Europe' subtotal | 2 531 | 2 663 | 2 885 | 3 203 | 3 329 | 3 345 | 26 |
| | US | 1 087 | 1 385 | 1 337 | 1 795 | 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 | 3 736 | 15 |

*Spending on national currencies was converted to US dollars using OECD purchasing power parities for 1987.




**Per capita spending** for academic research increased rapidly after 1982 in four of the six countries in the survey, with West Germany, the Netherlands and the US all in the range of $58 to $66 in 1987. Japan lagged with only $31 in 1987 because it concentrated research in government mission-oriented laboratories that are outside the study's definition of academic and related research. **Figure 1**

budgeted academic research covers a diversity of funding procedures, including all grants and contracts to universities from national, state and local governments. Academically related research can be viewed partly as a residual category that takes into account the funding of organizations that are formally outside university settings but are engaged nonetheless in academic types of research, thereby ensuring that the financial data for the six countries are truly comparable. This category includes research expenditures made by a wide range of institutions, including many US Federally funded R&D centers (generally known as FFRDCs), such as the National Center for Atmospheric Research, the Stanford Linear Accelerator Center and a majority of the programs at Lawrence Berkeley and Brookhaven laboratories. It also includes almost all the research done at West Germany's Max Planck Institutes and Japan's Monbusho-sponsored intramural institutes.

By organizing the information into these three categories we believe we have overcome the main discrepancies and limitations of higher-education R&D data reported and published by the Organization for Economic Cooperation and Development. While those data are widely used in international comparisons of academic research, they reflect the varying definitions and structures of research activities in higher education in different countries. For instance, OECD statistics cover only doctorate-granting universities in the Netherlands, while junior and technical colleges are included for Japan; moreover, US figures for higher-education R&D include such mission-oriented FFRDCs as the Los Alamos National Laboratory and Lincoln Laboratory, while in other countries such research centers are considered government R&D facilities.

To compare funding trends in real terms in the 12-year period 1975–87, we converted all expenditures to 1987 prices, using OECD deflators for gross domestic product. Although we recognize that this action is likely to understate the true rate of inflation for the costs of research,[4] especially in fields where there has been a significant increase in the complexity and sophistication of experimental equipment and facilities, the lack of internationally comparable R&D deflators leaves us with no realistic alternative. We then converted the value of various national currencies into US dollars. Obviously, official exchange rates fluctuate and rarely represent actual domestic spending power or labor costs. Consequently, we relied mainly on the "purchasing power parities" worked out by OECD. However, because economists differ on whether this practice represents the best way to compare research expenditures, we also calculated some of the budget numbers using average official exchange rates by way of comparison. Finally, in presenting the results, we have frequently contrasted US spending with the outlays of the four European nations combined (which we term "Europe" in this article). Taken together, these four countries possess an aggregate population not dissimilar to that of the US.

## Trends in overall expenditures

Table 1 shows government funding data for 1975–87. US dollar values were calculated using OECD's purchasing power parities for the year 1987 in the three categories of general university funds, separately budgeted academic research and academically related research. Although general university funds grew by more than 50% in real terms in the US between 1980 and 1987 (largely as a result of increased institutional support from state governments), the expenditures still represented only 20% of total academic and related research in 1987, compared with around 45% for Europe and more than 65% for Japan. At the same time, Europe appears to have begun to move a little toward the US funding model by placing less emphasis on general university funds and more on project-based and other earmarked research support for universities—all four European countries witnessing large increases of 20% to 40% in separately budgeted research since 1980. Nevertheless, US expenditures for separately budgeted research, amounting to $9.9 billion in 1987, were still several times the combined total of $2.5 billion for the four European nations; by comparison, Japan lagged far behind with only $0.9 billion in 1987.

In contrast, Europe gave added emphasis to academically related research, providing $3.3 billion, compared with the $1.9 billion spent by the US, despite America's faster growth in this research category in recent years. For academic and related research combined, the total of $11.0 billion for the four European countries in 1987 was approximately three-quarters of the US figure of $14.9 billion. Japan's expenditures for academic and related research for that year came to $3.7 billion or about one-quarter of the US total. However, if official currency exchange rates are used, European expenditures rise to $13.3 billion—in other words, much closer to the US total. Likewise, when official exchange rates are used for Japan, its expenditures for academic and related research increase to $5.5 billion—more than one-third of the US total.

What do the statistics show when spending is adjusted for the differing size and economic strength of each country? One way to do this is to express the results in terms of expenditures per capita. Thus, figure 1 reveals that when academic and related research are combined, the US spending of $61 per capita in 1987 was roughly comparable to the $60 spent by the four European countries combined, once again calculated on the basis of OECD purchasing power parities. Although Japan's expenditure of $31 per capita seems relatively low by comparison with the other nations, it needs to be stressed that a considerable proportion of the country's government research support is concentrated in mission-oriented laboratories that fall outside our definition of academically related research. An example of research labs excluded

## Table 2. Government funding of academic research by field, 1987 (millions of dollars)*

| | UK | FRG | France | Neths | 'Europe' | US | Japan | Average† |
|---|---|---|---|---|---|---|---|---|
| Engineering | 436 | 505 | 359 | 112 | 1 412 | 1 966 | 809 | |
| | 15.6% | 12.5% | 11.2% | 11.7% | 12.8% | 13.2% | 21.6% | 14.3% |
| Physical sciences | 565 | 1 015 | 955 | 208 | 2 743 | 2 325 | 543 | |
| | 20.2% | 25.1% | 29.7% | 21.7% | 24.9% | 15.6% | 14.5% | 21.2% |
| Environmental sciences | 188 | 183 | 172 | 27 | 570 | 859 | 136 | |
| | 6.7% | 4.5% | 5.3% | 2.8% | 5.2% | 5.8% | 3.7% | 4.8% |
| Maths and computing | 209 | 156 | 175 | 34 | 574 | 596 | 88 | |
| | 7.5% | 3.9% | 5.4% | 3.5% | 5.2% | 4.0% | 2.3% | 4.4% |
| Life sciences | 864 | 1 483 | 1 116 | 313 | 3 776 | 7 285 | 1 261 | |
| | 30.9% | 36.7% | 34.7% | 32.7% | 34.3% | 48.9% | 33.7% | 36.3% |
| Social sciences (including psychology) | 187 | 210 | 146 | 99 | 642 | 754 | 145 | |
| | 6.7% | 5.2% | 4.6% | 10.4% | 5.8% | 5.1% | 3.9% | 6.0% |
| Professional and vocational | 161 | 203 | 67 | 82 | 513 | 490 | 369 | |
| | 5.7% | 5.0% | 2.1% | 8.5% | 4.7% | 3.3% | 9.9% | 5.8% |
| Arts and humanities | 184 | 251 | 218 | 83 | 736 | 411 | 358 | |
| | 6.6% | 6.2% | 6.8% | 8.6% | 6.7% | 2.8% | 9.6% | 6.8% |
| Multidisciplinary | 6 | 32 | 3 | 1 | 42 | 217 | 28 | |
| | 0.2% | 0.8% | 0.1% | 0.1% | 0.4% | 1.5% | 0.8% | 0.6% |
| Total | 2 798 | 4 037 | 3 212 | 958 | 11 005 | 14 904 | 3 736 | |
| | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

*Spending in national currencies was converted to US dollars using OECD purchasing power parities for 1987.
†Unweighted average for all six countries

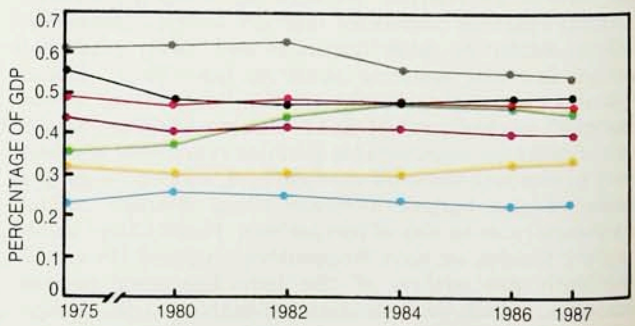
from the scope of this category is the group of R&D institutes under Japan's Ministry of International Trade and Industry. Furthermore, the apparent gap existing between Japan and the other nations narrows considerably when official exchange rates are used: Japan's expenditures rise from $31 to $45 per capita; at the same time the per capita average for the four European countries increases to $71—well above the unvarying US figure of $61.

The conventional approach to normalizing research expenditures for differences in the size of national economies is to express them as a proportion of gross domestic product. Figure 2 shows that in 1987 the US devoted 0.34% of its GDP to academic and related research—appreciably less than Europe's 0.47% of GDP. However, the US figure increased by 12% during the 1980s, while academic research in Europe remained constant and that in Japan dropped from 0.26% to 0.23%, mainly because research spending failed to keep pace with the country's rapid economic growth.

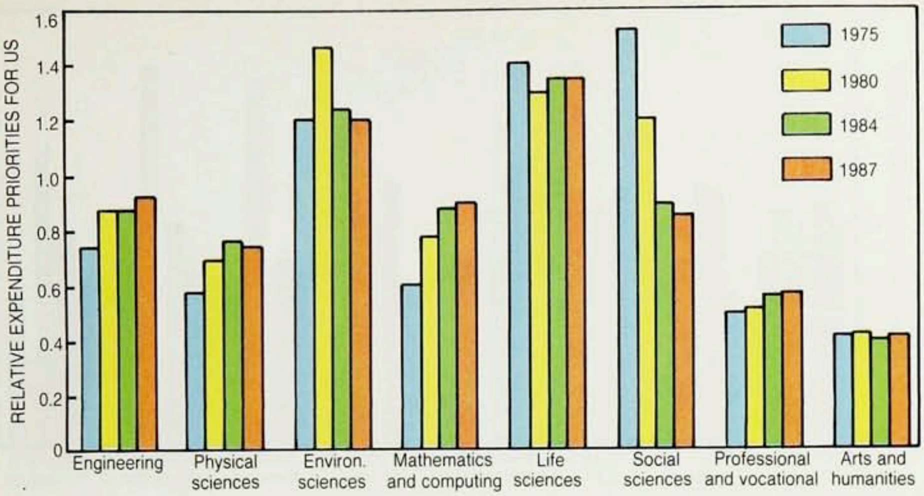
In short, allowing for variations in country size suggests that the US probably invested rather less than Europe in the category of academic and related research in 1987. Certainly, if one excludes the life sciences (biological, agricultural and medical research—areas where, as we show below, support has been much higher than in other scientific fields), then US expenditures emerge as appreciably lower than the European average, irrespective of whether these are expressed in per capita terms or as a percentage of GDP.

### Distribution across fields

Table 2 contains data on academic and related research expenditures in 1987 broken out by field. To take engineering research first, the US expenditure of $2.0 billion was 40% greater than that of the European countries and more than twice Japan's outlays. In percentage terms, however, the US and Europe committed 13% of their overall research funds to engineering (including materials research)—much less than the 22% figure for Japan. By contrast, the physical sciences (meaning physics, chemistry and astronomy) accounted for less than 15% of Japan's total—well below the six-country average of 21%. US funding of the physical sciences represented nearly 16% of its overall effort in academic research and was far lower than the 25% outlay of the four European nations in our survey. This is the only major scientific field where Europe outspent the US.




**As a percentage of GDP**, US expenditures on academic and related research increased 12% in 1984–87—more by far than any other country. France was unmatched in its support of academic science in 1975–84, with a 34% rise in outlays in relation to GDP. But during the entire period 1975–87 Japan's funding of academic research failed to keep pace with the nation's growing GDP. **Figure 2**




**US investment** in the physical sciences declined in relative spending priorities across fields in 1987. The nation's priorities increased for engineering research and for mathematics and computing. **Figure 3**

Other differences are also apparent. The government's share of funds devoted to the life sciences in the US, which came to 49% in 1987, was well above those in Europe and Japan (34% in both cases), reflecting the high level of funding for NIH. In addition, government support of the arts and humanities in the US ($0.4 billion) was considerably less than in Europe—this being the result of traditional differences in cultural priorities as well as greater emphasis on general core funding for universities in Western Europe. Indeed, in the US the arts and humanities are often regarded as not involving "real" research.

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 3. This is defined as follows:

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

Hence, for the physical sciences, where the US share of 15.6% was just under three-quarters of the six-country average in 1987, we obtained a relative expenditure priority of 0.74, which is less than the average for all six countries. [An index figure of 1.0 would signify a priority equal to that of the other countries.] After increasing between 1975 and 1984, this figure began to slip. Engineering gained in relative priority in the US over the same period, reaching an index value of 0.92 in 1987. The largest improvement was in mathematics and computer science, where the relative expenditure priority rose from 0.60 to 0.90. By contrast, appreciable declines were recorded in the environmental and social sciences. As might be expected, the field with the largest relative expenditure priority in the US is the life sciences, with a value of 1.35 in 1987, followed by the environmental sciences [which include 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 the leading US priorities for academic and related research in 1987 were aerospace engineering (with a relative expenditure priority 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 subfields 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). The point is obvious: In the US, the physical sciences get just over half the funding priority accorded the life sciences.

## Research support mechanisms

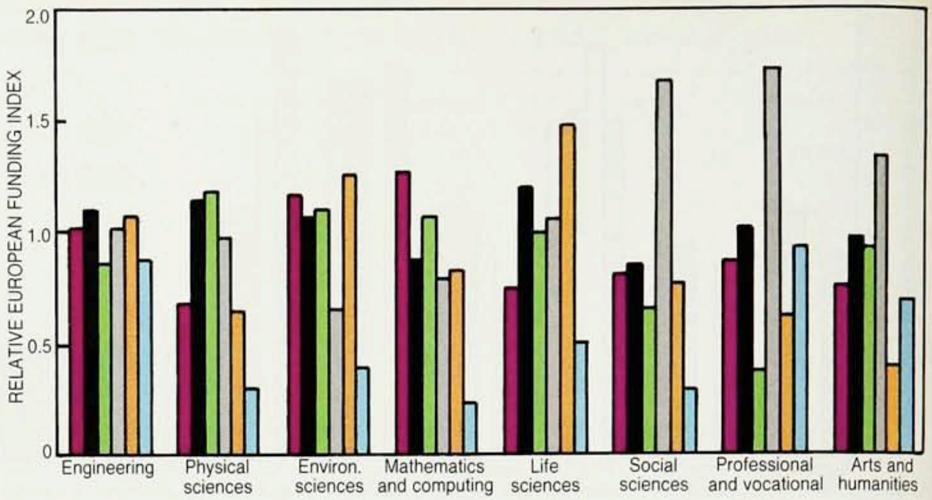
Let us now turn to certain policy issues concerning research-support mechanisms that have emerged in recent years. Within universities, a central concern in Europe and Japan has been the balance between general university funds provided to institutions relative to financial support for separately budgeted research. Table 3 shows how the proportion of academic research accounted for by separately budgeted grants has varied over time. Since general university funding 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 to meet 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, France's figure of 0.51 continues to be higher because much of the country's research is supported through CNRS. The US 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 as state governments begin to provide universities with increased core funding for facilities and infrastructure to help overcome problems associated with an overreliance on generally short-term project funding.

For government funding agencies an equally important question during the 1980s was the balance between financing intramural laboratories and separately budgeted support for university research, particularly peer-reviewed grants to individual investigators. The lower section of table 3 relates to trends in the proportion of agency funds going to universities as academic separately budgeted research—that is, separately budgeted research divided by separately funded research plus academically related research. Since intramural funding is often linked to the support of permanent staff in laboratories while separately budgeted research mostly takes the form of shorter-term commitments, this ratio may again give an indication of the "flexibility" available to agencies to redeploy resources.

There has been a rapid increase in the British and particularly in the Dutch indices, bringing them up to the French level of approximately 0.5. In the US and Japan

Relative funding index by fields, based on OECD purchasing power parities for 1987, indicated that US and Japan invest less in physical sciences than other countries in the study. Nations adopted selective policies for fields they deem to be strategic to their interests. **Figure 4**




the ratio has been historically much higher—in fact, between 0.7 and 0.8. This is the case because government-supported research is generally conducted either on university campuses or in mission-oriented laboratories falling outside our definition of academically related research, such as work at the Los Alamos laboratory, Lawrence Livermore and the Jet Propulsion Laboratory.

## The question of a US expenditure gap

Given the earlier indications of a shortfall in US spending on academic and related research relative to the four countries of Europe included in this survey, 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 European nations—that is, in terms of the Relative European Funding Index (REFI) shown in figure 4. This is defined as follows:

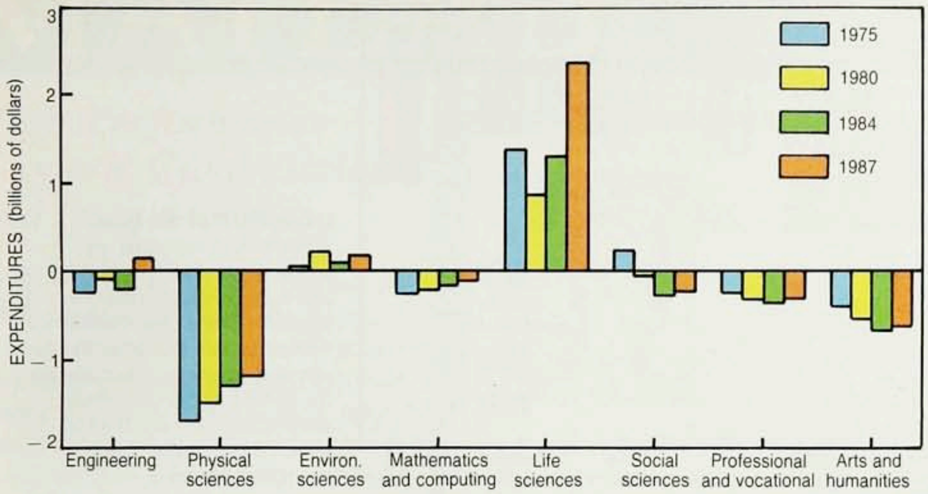
$$\text{REFI for field } A \text{ in country } X = \frac{\text{Spending on field } A \text{ in country } X}{\text{European average spending on field } A}$$

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

Given the wide range of relative European funding index values in figure 4, an obvious question is, How much more or less would the US have to invest to attain Europe's spending level? The results shown in figure 5 indicate that support for the life sciences in the US was no less than \$2.4 billion greater than the European average in 1987. This difference was apparently at the expense of the physical sciences, which registered a funding deficit of \$1.2

## Table 3. Changing emphasis on different research support mechanisms, 1975–87

| | | 1975 | 1980 | 1982 | 1984 | 1986 | 1987 | Percentage change 1980–87 |
|---|---|---|---|---|---|---|---|---|
| Ratio of academic separately budgeted research to general university funds | 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 | 0.141 | 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 | 0.254 | 0.264 | 0.261 | 0.261 | 0 |
| Ratio of academic separately budgeted research to academically related research | UK | 0.313 | 0.407 | 0.412 | 0.427 | 0.435 | 0.446 | 10 |
| | FRG | 0.402 | 0.387 | 0.376 | 0.354 | 0.368 | 0.382 | −1 |
| | France | 0.448 | 0.440 | 0.429 | 0.423 | 0.436 | 0.441 | 0 |
| | Netherlands | 0.393 | 0.431 | 0.465 | 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 | 0.838 | −1 |
| | Japan | 0.721 | 0.731 | 0.754 | 0.744 | 0.722 | 0.726 | −1 |




**Compared with Europe**, US spending, based on population, showed a large disparity between the physical sciences and life sciences. Chemistry and physics are fields most favored by France and the Federal Republic of Germany. **Figure 5**

billion. Worse, when all the main fields, with the exception of life sciences, are combined, there remains a net deficit of $2.0 billion compared with Europe's mean.

Similar calculations suggest that Japan would also need to spend vastly greater sums to bring it up to the European four-country average—perhaps of the order of $3.5 billion per annum, according to this indicator. The largest increases would need to be in the physical sciences and life sciences.

How has the gap between the US and Europe changed over the years? As regards the funding for all fields combined, after worsening between 1975 and 1982, the situation improved over the following five years. However, if we break out the whole field, it is apparent that the turnaround stems largely from increased US funding for the life sciences. In contrast, the relative situation of the least well-endowed area—the physical sciences—has scarcely changed since 1984. Figure 5 also reveals a sharp 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 US) from another (for the European average) should be recognized. Nevertheless, the example of the statistics used for determining gaps in the balance-of-payments in the field of economics illustrates that there is sometimes little alternative to employing imperfect indicators of this sort in policy making. In such circumstances the best that one can do to minimize the uncertainties is to explore a range of indicators. The preference of certain politicians for viewing expenditures on academic research as a consumption item—that is, a cultural luxury that can best be afforded by more affluent nations—rather than as an investment in the future is another reason why one needs to consider parallel statistics on funding differences calculated from comparisons of spending expressed as a percentage of GDP.

Figure 6 illustrates how important it is not to rely on a single indicator in assessing the relative level of spending by the US. For all fields combined, the adoption of a GDP-based approach points to a US gap of $5.9 billion compared with Europe in 1987—a funding difference considerably larger than the per-capita-based number. This is much the same irrespective of whether the life sciences are excluded, and compares with the shortfall of $2.0 billion, leaving out the life sciences, suggested by the per capita figures shown in figure 5. It is significant that both sets of indicators show deficits in five of the eight fields.

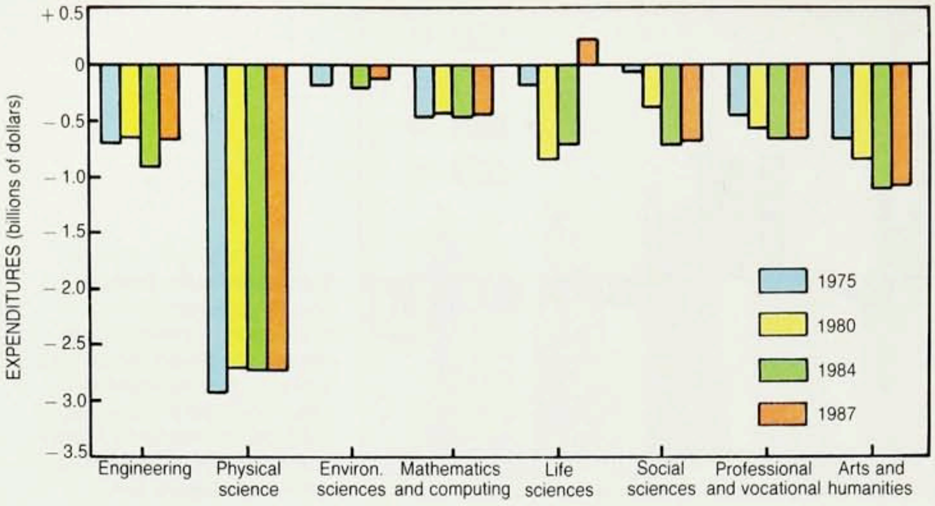
Overall, it appears that the US invests proportionately less than Europe in a wide range of academic research—though the life sciences are relatively well funded. Indeed, there seems little doubt that the amount by which US spending lags behind that of Europe is considerable for the physical sciences—with estimates ranging from $1.2 billion to $2.7 billion in 1987.

## Conclusions of the study

Before summarizing our main findings, we must again emphasize the intrinsic uncertainties involved in comparing spending levels across countries with rather different systems for organizing and financing research. Any attempt to assess the "adequacy" of US funding relative to Europe must therefore allow for the absence of increasing amounts of support for research at universities from commercial corporations and charitable foundations. Decisions on funding policy also need to take into account other measures of scientific activity such as the number of researchers. Furthermore, indicators of research output (for instance, publication data) and of scientific impact (citation statistics) are often at least as important for policy purposes as those relating to inputs.

With these provisos in mind, let us turn to the conclusions to be drawn from our study. First of all, in terms of absolute spending, US government support for academic and related research in 1987 ($14.9 billion) was very similar to the combined expenditures of Japan and the four European nations ($14.7 billion). Hence, the US is still by far the dominant world player in the realm of academic research. However, if the life sciences are excluded, or if expenditures are normalized for differences in population, then the US compares less favorably 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 has happened despite the government's expressed intention to strengthen fundamental science in response to criticisms that Japan has been hitching a "free-ride" on the scientific




**Using GDP as the base,** disparities in spending for academic research by the US and four European countries suggest a whopping shortfall in America's investment in the physical sciences. To make up the difference the US would need to invest more than $2 billion more in physical sciences. **Figure 6**

efforts of the US and Western Europe. Instead of contributing its "fair share" of resources to basic research, the argument runs, Japan has been a scientific freeloader.

At the field level, the picture is more complicated as a result of the dominance of US expenditures on the life sciences, with the 1987 outlay of $7.3 billion amounting to 45% more than the total spent by the other five nations combined. Nevertheless, the effect of NSF's expansion of support for engineering is evident in the gradual increase of the relative expenditure priority index for the field, although it was still only 0.92 in 1987. American investment in environmental sciences remained at a level 20% higher than the international average in 1987, despite the decline in the field's relative priority in the US compared with other countries.

While the low priority in the US for social sciences, professional and vocational studies and art and humanities is perhaps predictable, the relative funding situation of the physical sciences may give rise to 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—only slightly 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 relative expenditure priority index for the physical sciences in the US rose between 1980 and 1984, it has since begun to fall.

At the subfield level, US spending 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 relative expenditure priorities.

As regards procedures for financing research, the US relies predominantly on separately budgeted grants, whereas Europe's dual-support system (consisting of general university funding together with separately budgeted academic research) results in academic research receiving two-thirds of its money 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. During the 1980s, however, 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. This has been done in part with the intention that academic research should become more responsive to changing scientific and societal needs.

Finally, our analysis of differences in government funding across countries suggests that overall spending by the US matched that of the four European countries in 1987, at best, while, at worst, there was a sizable funding gap. Although the life sciences were supported reasonably well, the indications are that physical sciences were less favored than other disciplines—in fact by some $1 billion to $2 billion less per annum than the European average.

To be sure, there is no reason why exactly the same science priorities should be adopted in the US as in other countries. However, the magnitude of the difference suggests that US policymakers should at the very least reconsider whether present priorities in the physical sciences in particular are in line with current and future national needs and opportunities.

It is possible, of course, that a reassessment of priorities would lead to the conclusion that most of the exciting scientific advances in the next decades are likely to occur in new areas of the life sciences. Such a finding would suggest that Western Europe is placing too much faith in the physical sciences, having failed to recognize that the rapid rate of advance in that field during the postwar era is now slowing. However, an alternative conclusion could be that the high political visibility of health research in the US is the key factor responsible for NIH being favored by both the White House and Congress with an operating budget several times that of NSF, even though the foundation is responsible for supporting whole subfields of natural science, engineering and social science. If so, a dispassionate and systematic evaluation of the country's social and economic needs might well indicate that the present balance of effort between the physical sciences and life sciences needs to be readjusted.

• • •

*The authors gratefully acknowledge financial support from NSF (under Grant No. SRS 8709101), the British Advisory Board for the Research Councils and the UK Economic and Social Research Council. The conclusions are those of the authors alone and no endorsement of the findings by any of the sponsors is implied.*

## References


1. V. Bush, *Science, the Endless Frontier*, US Office of Scientific Research and Development, Washington, D. C. (1945); reprint ed., National Science Foundation (1960).
2. B. R. Martin, J. Irvine, *Research Foresight: Priority-Setting in Science*, Pinter, London (1989).
3. J. Irvine, B. R. Martin, P. A. Isard, *Investing in the Future: An International Comparison of Government Funding of Academic and Related Research*, Edward Elgar, Brookfield, Vt. (1990).
4. E. Mansfield, A. Romeo, L. Switzer, Res. Policy **12**, 105 (1983). ■