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Colloquium Paper

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Trends and patterns in research and development expenditures in the United States

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ABSTRACT This paper is a review of recent trends in United States expenditures on research and development (R&D). Real expenditures by both the government and the private sector increased rapidly between the mid-1970s and the mid-1980s, and have since leveled off. This is true of both overall expenditures and expenditures on basic research, as well as funding of academic research. Preliminary estimates indicate that about $170 billion was spent on R&D in the United States in 1995, with ≈60% of that funding coming from the private sector and about 35% from the federal government. In comparison to other countries, we have historically spent more on R&D relative to our economy than other advanced economies, but this advantage appears to be disappearing. If defense-related R&D is excluded, our expenditures relative to the size of the economy are considerably smaller than those of other similar economies.

This paper is an overview of historic trends and current patterns of research and development (R&D) activity in the United States. Most of the information contained herein comes from the National Science Foundation (NSF) (1). (I am indebted to Alan Rappaport and John Jankowski of NSF for sharing with me preliminary, unpublished statistics from the 1996 edition of *Science and Engineering Indicators*, which had not been released when this paper was prepared.) The background is divided into three sections: (*i*) overall spending; (*ii*) basic and academic research; and (*iii*) international comparisons.

Overall R&D Spending

Total spending on R&D in the United States in 1994 was $169.6 billion, and is estimated to be $171 billion in 1995 (all numbers provided herein for 1994 are preliminary and for 1995 are preliminary estimates). The 1994 number is about 2.5% of Gross Domestic Product (GDP). For comparison, 1994 expenditure on gross private domestic investment was $1038 billion, of which $515 billion was new producers' durable equipment; state and local government spending on education was approximately $400 billion. Thus, among the major forms of social investment, R&D is the smallest; however, it is a nontrivial fraction of the total.

There are myriad ways to decompose this total spending, including: by source of funding; by performer of the research or development; by basic research, applied research and development; and by field of science and engineering.

All possible decompositions are beyond the scope of this paper; however, all can be found in some form in ref. 1. Fig. 1 represents an attempt to summarize the current data along the first two dimensions. The horizontal bars correspond to the four major performers of research: (*i*) private firms ("industry"), (*ii*) federal labs, including Federally Funded Research and Development Centers (FFRDCs), (*iii*) universities and colleges, and (*iv*) other nonprofits. The vertical divisions correspond to the three major sources of funding for R&D, with industry funds on the left, federal funds in the middle, and other funds (including state and local governments) on the right.

Overall, industry provides about 60% of all R&D funds, and the federal government provides about 35%. Industry performs about 70% of the R&D, federal labs and universities each perform about 13%, and other nonprofits perform about 3%. By far the biggest source-performer combination, with just shy of $100 billion, is industry-funded, industry-performed research. Federally funded research at private firms and the federal labs each account for about $22 billion.† Universities performed about another $22 billion; of this amount, about 60% was funded by the federal government, about a third was funded by universities' own funds, state and local governments, or other sources, and about 7% came from industry. Other nonprofits performed a total of about $6 billion, with the funding breakdown roughly similar to universities.

Fig. 2 provides the same breakdown for 1970 (the picture for 1953 is very similar to that for 1970). It shows a striking contrast, with a much larger share of funding provided by the federal government, both for the total and for each performer. In 1970, the federal government provided 57% of total funding, including 43% of industry-performed research. The biggest difference in the performance shares is between federal labs and universities; whereas the two now have about equal shares, in 1970 the labs performed about twice as much R&D as universities.

These changes in shares occurred in the context of large changes in the totals. These changes over time are shown in Fig. 3 (performers) and Fig. 4 (sources of funds). There is an overall reduction in total spending in the late 1960s, followed by very rapid increases in real spending between 1975 and 1985; this increase decelerated in the late 1980s, and total real spending has fallen slightly since 1991. Fig. 3 shows that the 1975–1985 increases occurred mostly in industry; universities then enjoyed a significant increase in performance share that still continues, with real university-performed R&D continuing to increase as the total pie shrank in the early 1990s.

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Abbreviations: R&D, research and development; GDP, Gross Domestic Product; FFRDC, Federally Funded Research and Development Center; NSF, National Science Foundation.

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†The preliminary 1995 data that I was able to get classify industry-operated FFRDCs (such as the Oak Ridge Lab in Tennessee) with federally funded industry research. Based on a break-out for this category in the 1993 Science Indicators, such facilities account for about $2 billion. Thus, a more realistic accounting would put federal labs at about $24 billion and federally funded industry research at about $20 billion.

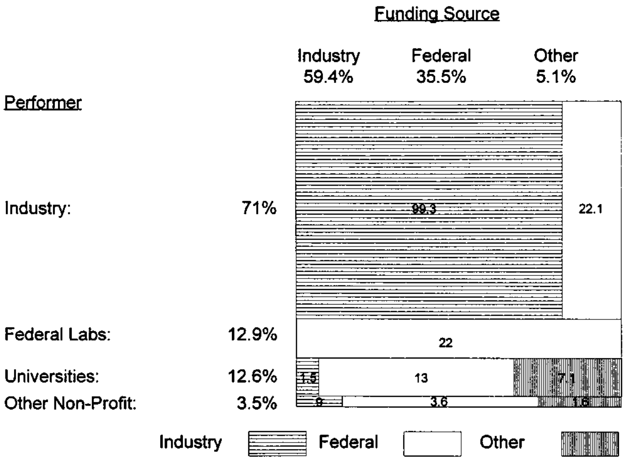

FIG. 1. United States R&D funding by performer and funding source; preliminary estimates for 1995 (in billions). "Federal Labs" includes intramural federal research and university-operated FFRDCs. Industry-operated FFRDCs are included under federal industry research. "Other" funding sources are state and local governments and institutions' own funds. Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

Fig. 4 shows that movements in the total over time have been driven by cycles in real federal funding combined with a rapid buildup in industry spending between 1975 and 1991. Real federal spending peaked at about $60 billion (in 1994 dollars) in 1967, fell to about $47 in 1975, rose to about $73 in 1987, and then fell back to about $61 billion in 1995. Hence, federal spending today is essentially the same as in 1967. (We will see below that the composition of this spending is different today than it was in 1967.) Industry funding increased steadily to about $36 billion in 1968, was essentially flat until 1975, and then increased dramatically, surpassing federal funding for the first time in 1981, increasing to about $80 billion in 1985–1986, and then increasing again to about $100 billion in 1991, where it has leveled off. One of the most interesting questions in the economics of R&D is exactly why industry went on an R&D spending "spree" (2) between 1975 and 1990, and whether or not the economy has yet or will ever enjoy the benefits thereof.

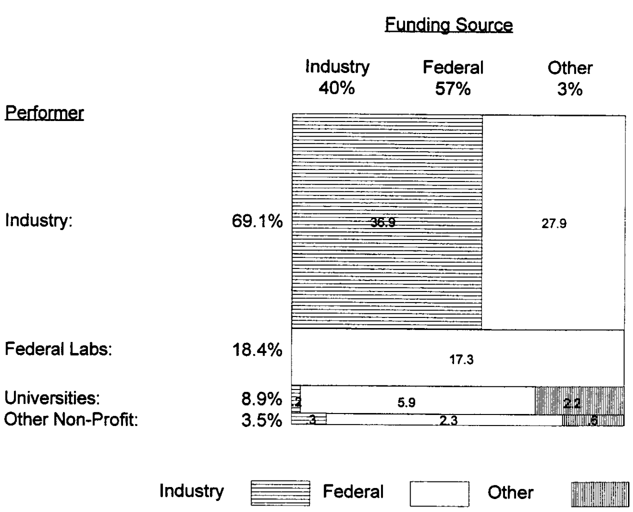

FIG. 2. United States R&D funding by performer and funding source for 1970 (in billions of 1994 dollars). Performers and funding sources are as in Fig. 1. Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

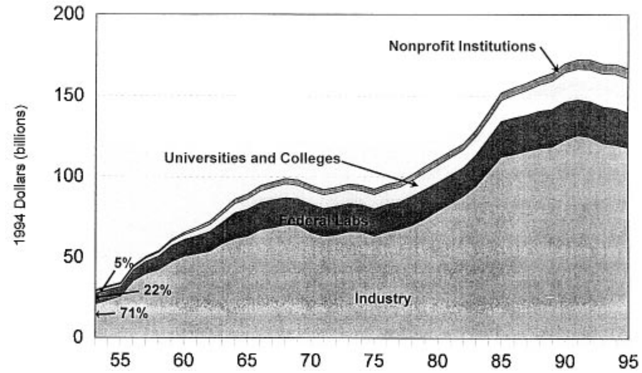

FIG. 3. Total United States R&D by performer, 1953–1995 (in billions of 1994 dollars). The 1994 numbers are preliminary; 1995 numbers are preliminary estimates. Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

[For an analysis of the effects of this large increase in spending on the private returns to R&D, see Hall (3).]

Basic, Academic, and Federal Lab Research

With respect to economic growth, the most important effect of R&D is that it generates "spillovers," i.e., economic benefits not captured by the party that funds or undertakes the research. Although there is relatively little concrete evidence regarding the relative potency of different forms of R&D in generating spillovers, theory suggests that the nature of the research and the research organization are likely to affect the extent of spillovers. Specifically, basic research, whose output is inherently intangible, unpredictable, and therefore difficult for the researcher to appropriate, and research performed at universities and federal labs, governed by social and cultural norms of wide dissemination of results, are likely to generate large spillovers. In my paper with Manuel Trajtenberg for this Colloquium (4), we provide evidence that universities and federal labs are, in fact, quite different on this score, with universities apparently creating more spillovers per unit of research output. In this section, I examine trends in basic research and in academic and federal lab research.

Figs. 5 and 6 are analogous to Figs. 3 and 4, but they refer to that portion of total R&D considered basic by NSF. They show a very rapid buildup in basic research in the Sputnik era of 1958 to 1968, mostly funded by the federal government. Like total federal R&D spending, federal basic research funding peaked in 1968 and declined through the mid-1970s. It then

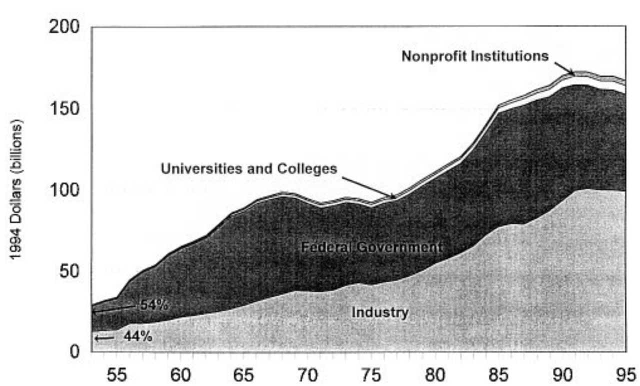

FIG. 4. United States R&D by source of funds, 1953–1995 (in billions of 1994 dollars). The 1994 numbers are preliminary; 1995 numbers are preliminary estimates. Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

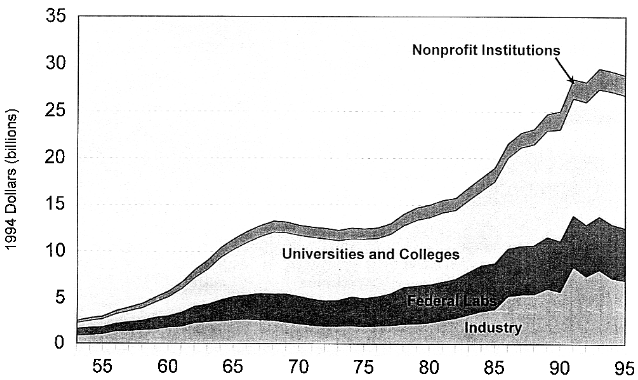

FIG. 5. United States basic research by performer, 1953–1995 (in billions of 1994 dollars). The 1994 numbers are preliminary; 1995 numbers are preliminary estimates. Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

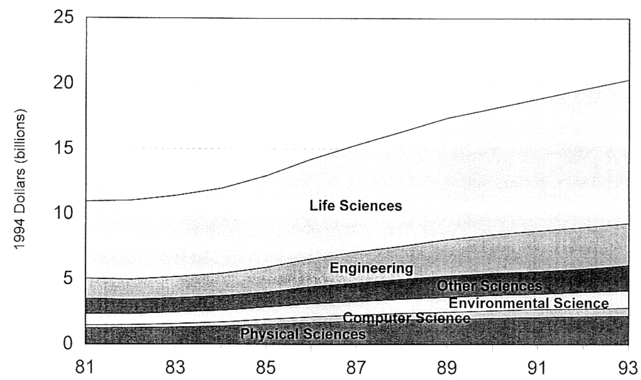

FIG. 7. Expenditures for academic R&D by discipline, 1981–1993 (in billions of 1994 dollars). Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

began a period of rapid increase, rising from about $8.5 billion in 1973 to $12.3 in 1985 and to about $17 billion today. Universities have been a prime beneficiary of the increase in federal basic research spending; basic research spending at universities increased about 50% in real terms between 1985 and 1995 (from about $9 billion to about $14 billion). Although industry does fund a small amount of basic research at universities and receives a small amount of federal funding for basic research, industry performance of basic research tracks industry spending on basic research very closely, increasing from just under $4 billion in 1985 to about $8 billion in 1993, and decreasing thereafter. Overall, basic research has fared relatively well in the 1990s, increasing its overall share of R&D spending (all sources, all performers) from 15% in 1990 to 17% in 1995.

Fig. 7 examines the distribution of academic R&D (for all sources of funding, and including basic and applied research and development) by science and the engineering field. There have not been dramatic shifts over this period in the overall field composition of academic research. Life sciences account for about 55% of the total, with medical research accounting for about half of life sciences. This apparently reflects a combination of the high cost of medical research, combined with a general social consensus as to the social value of improvements in health. (We will see below, however, that the United States is unique in devoting this large a share of public support of academic research to life sciences.) All of these major categories saw significant real increases in the last 15 years, although at a finer level of detail there has been more variation.

Fig. 8 suggests that this relative constancy by discipline masks some underlying changes in the funding from the federal government. Fig. 8 *Lower* shows that while all agencies have increased their funding of academic research over this period, the fraction of federal support of academic research accounted for by the National Institutes of Health increased from 37% in 1971 (data not shown) to 47% in 1980 and 53% in 1995. In the last few years, increases in National Institutes of Health funding (and smaller increases in NSF funding) have allowed total federal funding of academic research to continue to rise (albeit slowly) despite declines in funding from the Departments of Defense and Energy. The relatively small share of these two agencies in academic

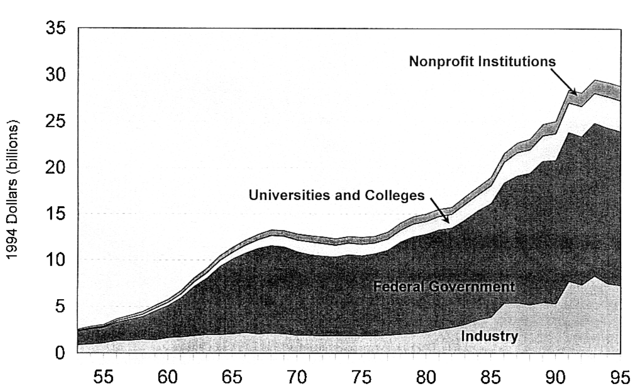

FIG. 6. United States basic research by source of funds, 1953–1995 (in billions of 1994 dollars). The 1994 numbers are preliminary; 1995 numbers are preliminary estimates. Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

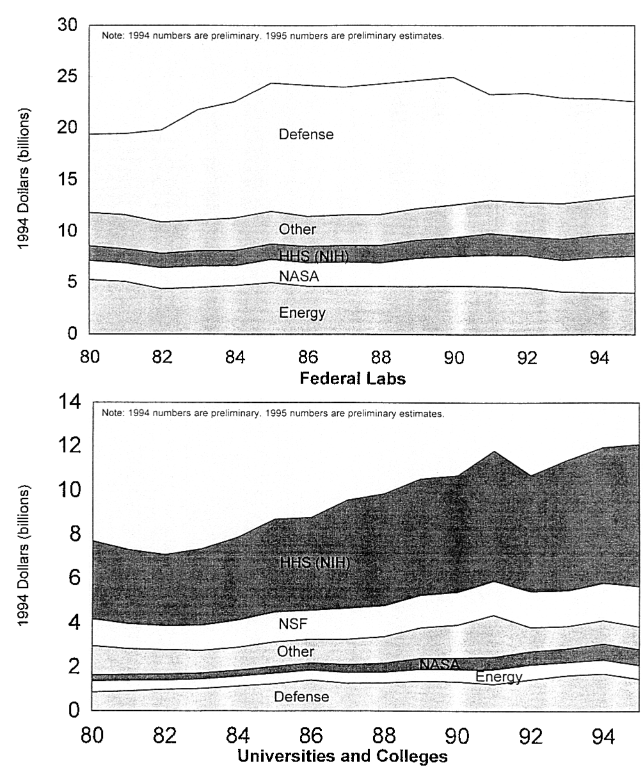

FIG. 8. Federal lab and federal university funding by funding agency. The 1994 numbers are preliminary; 1995 numbers are preliminary estimates. Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

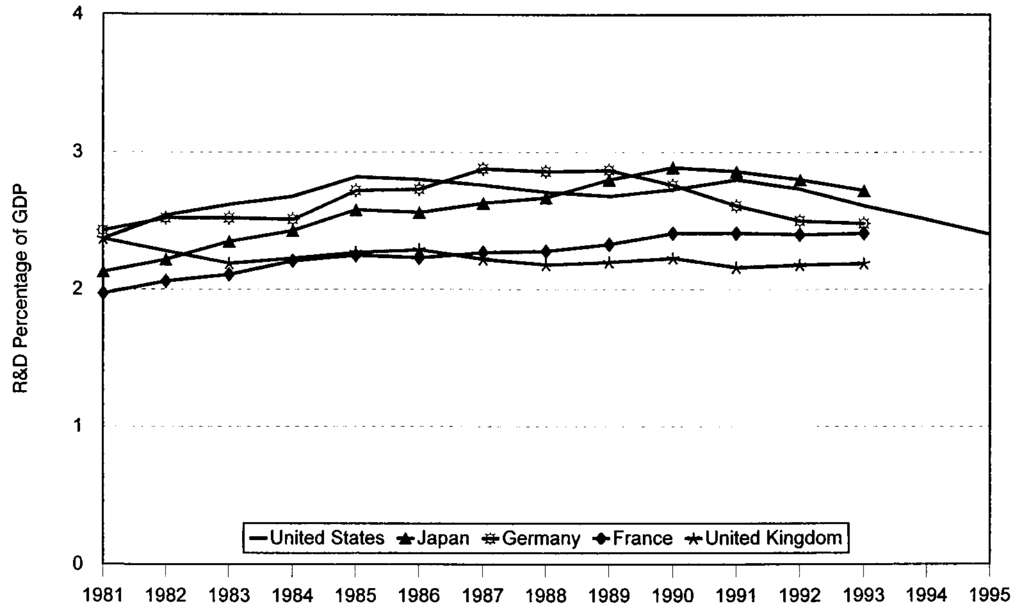

FIG. 9. International R&D expenditures as percentage of GDP, 1981–1995. Germany's data for 1981–1990 are for West Germany. The 1994 numbers are preliminary; 1995 numbers are preliminary estimates. Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

research funding explains why universities have fared relatively better than the federal labs in the last few years. Fig. 8 *Upper* shows that declines in funding from the Departments of Energy and Defense have led to reductions in the total level of real research spending at the federal labs since 1990. Note that the scales of the two graphs are quite different; the federal government still spends almost twice as much at the labs as it does at universities, and the Department of Defense is still the largest overall funder of research in the combined lab-university sector.

International Comparisons

It is very difficult to know in any absolute sense whether society should be spending more or less than we do on R&D, in total or for any particular component. We generally believe that R&D is a good thing, but many other good things compete for society's scarce resources, and a belief that the average product of these investments is high does not necessarily mean that the marginal product is high, in general or with respect to specific categories of investments. While other countries in the world are not necessarily any better than we are at making these choices, it is interesting to see how we compare, and to note in particular ways in which our activities in these areas differ from those of other countries.

Fig. 9 shows overall R&D expenditures, as a percent of GDP, for the G-5 countries (United States, Japan, Germany, France, and the United Kingdom). In general, R&D as a percent of GDP rose in the G-5 over the 1980s and has declined somewhat since. The United States is near the top of the group,

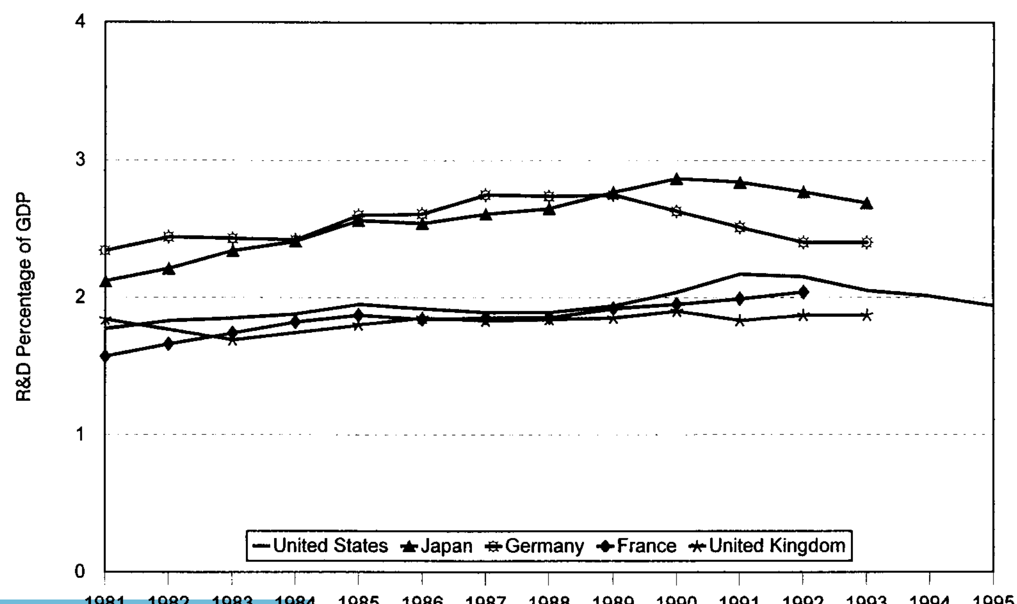

FIG. 10. International nondefense R&D expenditures as percentage of GDP, 1981–1995. Germany's data for 1981–1990 are for West Germany. The 1994 numbers are preliminary; 1995 numbers are preliminary estimates. Source: Ref. 1 and A. Rappaport and J. Jankowski, personal communication (Division of Science Resource Studies, National Science Foundation).

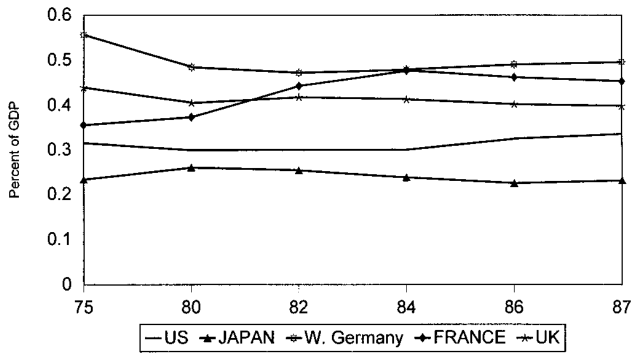

FIG. 11. Government-funded academic research as a fraction of GDP for G-5 nations. Source: Ref. 7.

exceeded only by Japan (since 1989) and by Germany (between 1987 and 1990). While we do not have estimates for the other countries in the last 2 years, the trend would indicate that our recent and apparently continuing reductions in the R&D/GDP ratio may be moving us to the "middle of the pack" from our historic position near the top. A different view of these comparisons is provided by Fig. 10, which excludes defense-related R&D from the R&D/GDP ratio. The argument in support of this alternative formulation is that defense R&D is likely to have fewer economic benefits, direct and indirect, than nondefense research, so our relatively high position in Fig. 9 could be misleading. Excluding defense R&D, our R&D/GDP ratio is very similar to that of France and the United Kingdom, but is consistently exceeded by Japan and Germany. On the other hand, since much of the recent decrease has been in the defense area, the downward trend is less pronounced when defense is excluded.

Of course, even if we accept that defense R&D has less economic benefit, Fig. 10 is not the right picture either, unless defense R&D is economically useless. The right picture is presumably somewhere between Figs. 9 and 10, suggesting that historically our investment in economically relevant R&D has been comparable to other countries as a fraction of GDP, but that we appear to be on a downward trend, while other nations have not, as yet at least, evidenced such a trend.

One could argue that the absolute level of R&D, rather than the R&D/GDP ratio, is the right measure of the scale of our investment; from this perspective, the United States would have far and away the strongest research position. This would be right if R&D were a pure public good, whose benefits or impact was freely reproducible and hence applicable to any amount of economic activity. [See Griliches (5). For evidence that the ratio of R&D to economic activity is a better indicator of the significance of spillovers, see Adams and Jaffe (6).]

The defense/nondefense split is any extremely coarse way of distinguishing forms of R&D that might have the most important spillover effects. An alternative approach is to look at academic research. This is much harder to do, because the nature of academic-like institutions varies greatly across countries. Irvine *et al.* (7) attempted to make overall comparisons of government support for academic research in a number of countries. Fig. 11 shows their numbers for 1975–1987. Here the United States is again near the bottom of the pack, exceeding only Japan in its support for academic research as a fraction of GDP. To the extent that academic R&D comes closer to being a "pure" public good than private research, however, then the view that it is the total and not the ratio that counts may apply. If so, then Fig. 11 is irrelevant, and what matters is that we spend far more on academic research than any other country. [Of course, if academic research is a pure public good, then it is not clear why it matters which country does it; we can all benefit. Hence the relevant questions are how far–in geographic, technological and institutional space–can R&D be spread. See Adams and Jaffe (6) and Jaffe and Trajtenberg (4).]

Finally, Irvine and his colleagues (7) tabulated government support for academic research by academic field. The

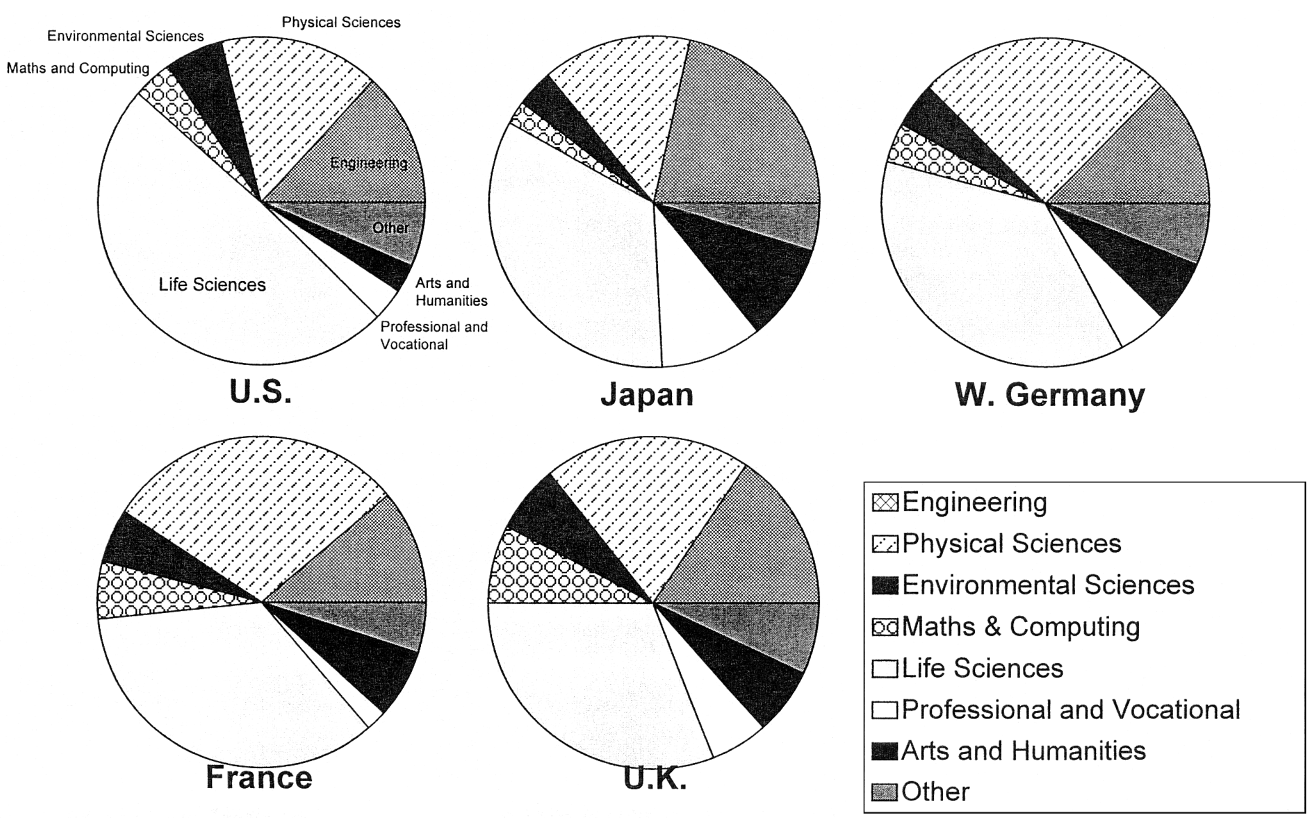

FIG. 12. Distribution of government-funded academic research by field in 1987 for the G-5 nations. Source: Ref. 7.

proportions are shown in Fig. 12. What stands out is that while the United States spends about half of its government support of academic research on life sciences, the other countries all spend more like one-third. Interestingly, the other countries differ in where else the money is spent. Relative to the United States, Japan spends more in engineering, and professional and vocational fields; Germany and France spend more on physical sciences, and the United Kingdom spends more on everything but life sciences (all as shares of the country totals).

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