How the US research effort compares with other countries

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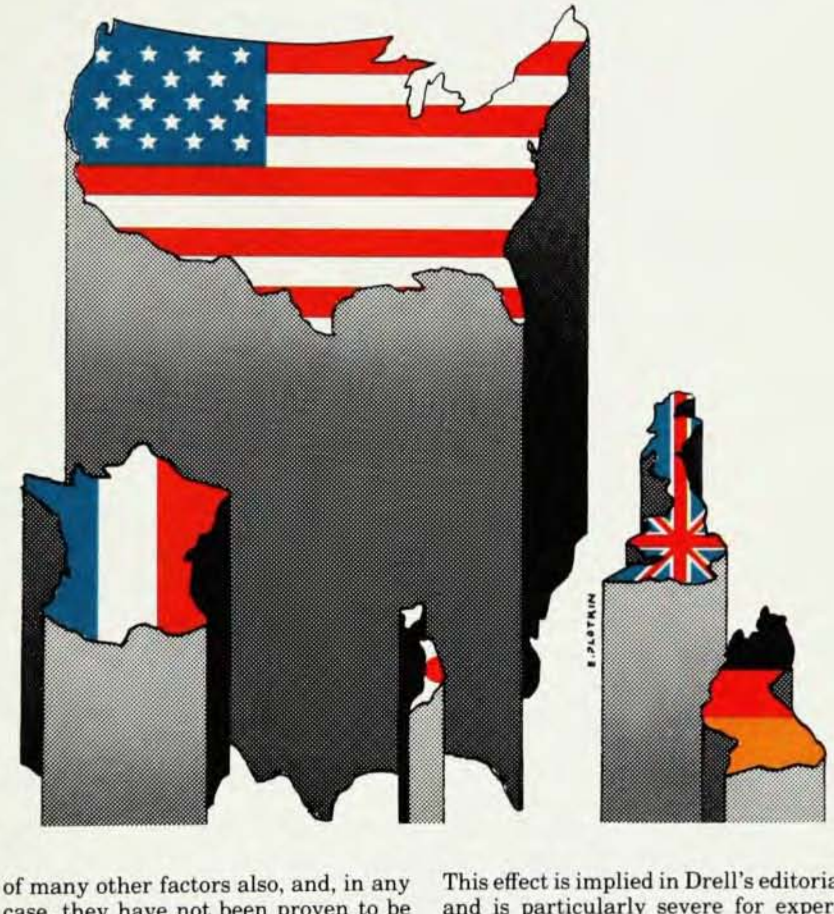
I want to supplement Sidney Drell's eloquent editorial (November, page 136) in favor of increased spending on basic research—high-energy physics in particular—and to identify some long-range trends, over the two decades up to 1982, in comparisons of the research efforts of some scientifically developed countries. A country's expenditure on research and development (R&D) is usually measured in terms of the percentage of the gross national product (GNP). For the US, this percentage was about 2.7% in 1961, it peaked at 3.0% in 1964, then gradually fell to 2.3% in 1978 and has since been rising to about 2.6% in 1982. If, however, we exclude military R&D, the share of which in the overall R&D expenditure has been decreasing considerably (from about $^1/_3$ to $^1/_4$ of the whole, during that time period), we get percentages for the civilian R&D which are 1.2% in 1961 and show an almost uninterrupted rise since, to the level of about 1.7% in 1982, not including space R&D.



How much of this R&D is spent on basic scientific research? There are some conceptual difficulties in distinguishing between "basic" and "applied" scientific research, but according to the definition used by at least one source, in 1961 about 9.6% of the total R&D expenditure of the US was spent on basic scientific research. This percentage gradually rose to about 13.6% in 1971, then gradually fell to 12.6% by 1981.

In a nutshell, therefore, one can say that compared to the early 1960s, the overall percentage spent on R&D is unchanged, the military R&D is down, the civilian R&D is up, and the fraction spent on basic research is up.

These figures by themselves lead to no definite conclusions as to the absolute numbers. There is no theory or empirical rule to tell us what the optimal amount is that a country should spend on R&D, or on basic scientific research. To be sure, spending roughly as much as we have been appears to produce good results, but they are simultaneously consequences of many other factors also, and, in any case, they have not been proven to be the best we can do.

One can judge better, therefore, by turning away from the absolute figures and looking at two other aspects: The change in the expenditures with time, and how the expenditures compare with other countries.

As the specific cost of scientific research (measured in constant dollars) continuously increases due to the very nature of the problems we investigate, a budget for science that rises only as fast as the GNP places a severe constraint on the scientific community, especially if such a budget comes at a time when many people can still remember the times (never to recur) when over a period of some 25 years the percentage of the GNP spent on R&D rose ten-fold (from about 0.3% before World War II to about 3% after it). This effect is implied in Drell's editorial and is particularly severe for experimental high-energy physics.

Let us now look at comparisons with other countries. There has certainly been a change here even just during the decade 1969–1979. In 1969, five countries—France, West Germany, Japan, the United Kingdom and the US—spent a total of $37 billion on R&D, 70% of which was spent by the US. A decade later, the total rose to $111 billion, of which only 50% was spent by the US. Other data also confirm the relative rise of Europe and Japan during this period. Between 1965 and 1977 the number of scientists and engineers engaged in R&D per 10 000 labor force rose by a factor of two in Japan and in West Germany, while it remained the same in the US.

One could argue, however, that the

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faster growth in these countries simply reflects their catching up to the US. The total population of the above four countries (excluding the US) is about 25% larger than the population of the US, and yet, in *absolute* numbers, the aggregate of these four countries still lags behind the US in scientists and engineers per capita, and the expenditures are now only even, in spite of the larger population. So one could say that these countries are now just reaching their "due share" of the world's scientific effort.

In fact, the percentage of GNP spent on R&D by these four countries is also slightly lower than that of the US. If, however, we consider only civilian R&D (excluding also space R&D), both West Germany and Japan exceed the percentage figure for the US by a considerable amount. Those of France and the UK do not.

The comparative percentages for the share of basic research are not readily available, but from what is available one concludes that in the mid-1970s the figures for all four other countries were higher than that for the US—considerably higher in the case of France and West Germany, and a bit higher for Japan and Great Britain. If, however, we take as the base the total *civilian* R&D, the US percentages are more comparable to those of the other four countries.

So far we have looked only at input indicators. Output indicators are much more difficult to find. One commonly used is the share of the world's scientific literature produced in the country. In this respect, the US position has remained virtually unchanged, at least between 1973 and 1980. In the former year it was 38%, while in the latter 37%, both rounded out to the nearest percent. The share of US contribution in the world production changes from discipline to discipline; in physics, the change between 1973 and 1980 has been more significant, from 33% to 30%.

Even by using this output indicator, however, the *absolute* numbers continue to favor the US. The number of publishing authors in a given year, found in the compilation generated by the Institute of Scientific Information in Philadelphia, was almost twice as large in the US in 1978 than in the other four countries taken together. (There might, however, be some bias in the ISI data in favor of scientific literature published in English.)

To find the optimal *relative* scientific effort of a country compared to other countries is also an unsolved theoretical and practical problem in science policy. One can see from the two extremes that the optimum is somewhere in between the two. If a country has no scientific activity at all, it is overwhelmed by the scientifically developed countries. If, on the other hand, no country in the world except the US were engaged in scientific work, the US could not utilize "free" scientific knowledge generated elsewhere, science as a whole would make much slower progress and the US itself would also suffer. It is not even true that a country must be the pioneer in all research in a given field to be a leader in the derived technology. For example, the pioneering research and development in robotry was done mainly in the US, and yet the world leader in the manufacture and utilization of robots is Japan.

So far I have considered science only in its role as a basis for technology. But science also has two other broad roles. One is as a human aspiration in the 20th century and hence a source of pride, of high morale, of heightened self-image for a country, an institution, a group or an individual. I sensed a considerable amount of this motivation for doing science when Drell said in his editorial: "It saddens me greatly to see this nation giving that baton back without cause and reason after possessing it a mere fifty years." The other nontechnological role of science is in its impact on our view of the world and of our role in it. This is science as a cultural force. From this point of view also, being out front is effective.

It is possible to interpret the above figures in several ways. These are my own conclusions:

▶ It is difficult at this point to show conclusively that the relative rise of the other developed countries in scientific research and technological development has so far proven to be detrimental to the US.

▶ It is also difficult to argue conclusively that the present absolute level of scientific and technological efforts by the US spells a material disaster for the country.

▶ There is a strong indication that the altered absolute and relative position of the US in science and technology originates in a general lowering of morale, in a general loss of will power and in a fading interest in exploration, risk taking and pioneering in this country. If these factors are indeed in operation, they can in fact represent a nonmaterial crisis in this country and hence, eventually, also a material decline.

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All statistical data (except those specifically cited as coming from ISI) were taken from unpublished data from the Division of Science Resources of the National Science Foundation. I am grateful to the Division for providing me with the data. □