Does Science Policy Exist, and If So, Does it Matter?: Some Observations on the U.S. R&D Budget

Discussion Paper for Earth Institute Science, Technology, and Global Development Seminar, April 8, 2003

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It is not only axiomatic but also true that federal science policy is largely played out as federal science *budget* policy. Public discourse related to the nation's S&T enterprise focuses obsessively on funding and budget numbers—especially each fiscal year's incremental change over the prior year. Science advocacy organizations such as the American Association for the Advancement of Science, the National Academy of Sciences, and various scientific societies carefully monitor the budget process and issue annual assessments; while issue-focused interest groups such as disease lobbies and environmental NGOs focus on agencies and programs of specific relevance to their constituencies. Overall, it is fair to say that marginal budgetary changes are treated by the S&T community (scientists, science bureaucrats and advocates, administrators of R&D institutions, etc.) as surrogates for the well-being of the science enterprise, whereas the interested public considers such changes to be surrogates for progress toward particular societal goals.

To get a feel for the depth of this worldview, consider the National Institutes of Health, whose budget doubled between 1998 and 2003, and whose FY 03 budget of $27.3 billion now accounts for more than half of federal nondefense R&D expenditures ($53.3 billion). Nevertheless, when the FY 04 budget debates began, NIH and its advocates in the research community managed to portray the situation as one of crisis arising from a sudden decline in the rate of budget increase.[1] In another notable example, the President-elect of the AAAS in 1990 surveyed some scientists and discovered that many were unhappy because they felt that they did not have enough funding. From this information he inferred a "crisis" in federal support for science.

Given the totemic importance of the federal R&D budget, and the centrality of the budget in S&T policy discourse, what can we learn about the U.S. science and technology enterprise from an examination of budgetary trends? The first thing to be said is that it depends on which trends one chooses to examine.

Certainly one of the most astonishing aspects of R&D budget-making over the past forty or so years is how closely R&D trends track overall trends for the entire U.S. discretionary budget. As shown in Figure 1, R&D spending has been extremely stable relative to the discretionary budget as a whole since at least the early 1970s, with nondefense R&D weighing in at about 11 percent of nondefense spending for almost 30 years, and total R&D fluctuating a bit more, but generally making up about 13 percent of total discretionary expenditures. This stability tells us, first of all, that marginal changes

[1] E.g., Weiss, Rick (2003), NIH Braces for Slower Funding Growth, *Washington Post*, February 2, p. A14

in the R&D budget are most directly responsive to overall budgetary climate—that they are tightly coupled to trends in the budget as a whole.

This stability is particularly amazing given the Balkanized manner in which science budgets are determined. The first thing to note here is that there is neither a capacity nor an intent to undertake centralized, strategic science policy planning in the U.S. The seat of American science policy in the Executive Branch is the Office of Science and Technology Policy, whose director is the President's science advisor. The influence of this power has waxed and waned with time (mostly waned), but it never exercised significant influence over budgetary planning. That influence came from the Office of Management and Budget (formerly the Bureau of the Budget), which solicits budgetary needs from the many Departments and Agencies that conduct R&D, and then combines them for reporting purposes into categories that could be considered to reflect a cumulative R&D budget—but the process is largely bottom-up.

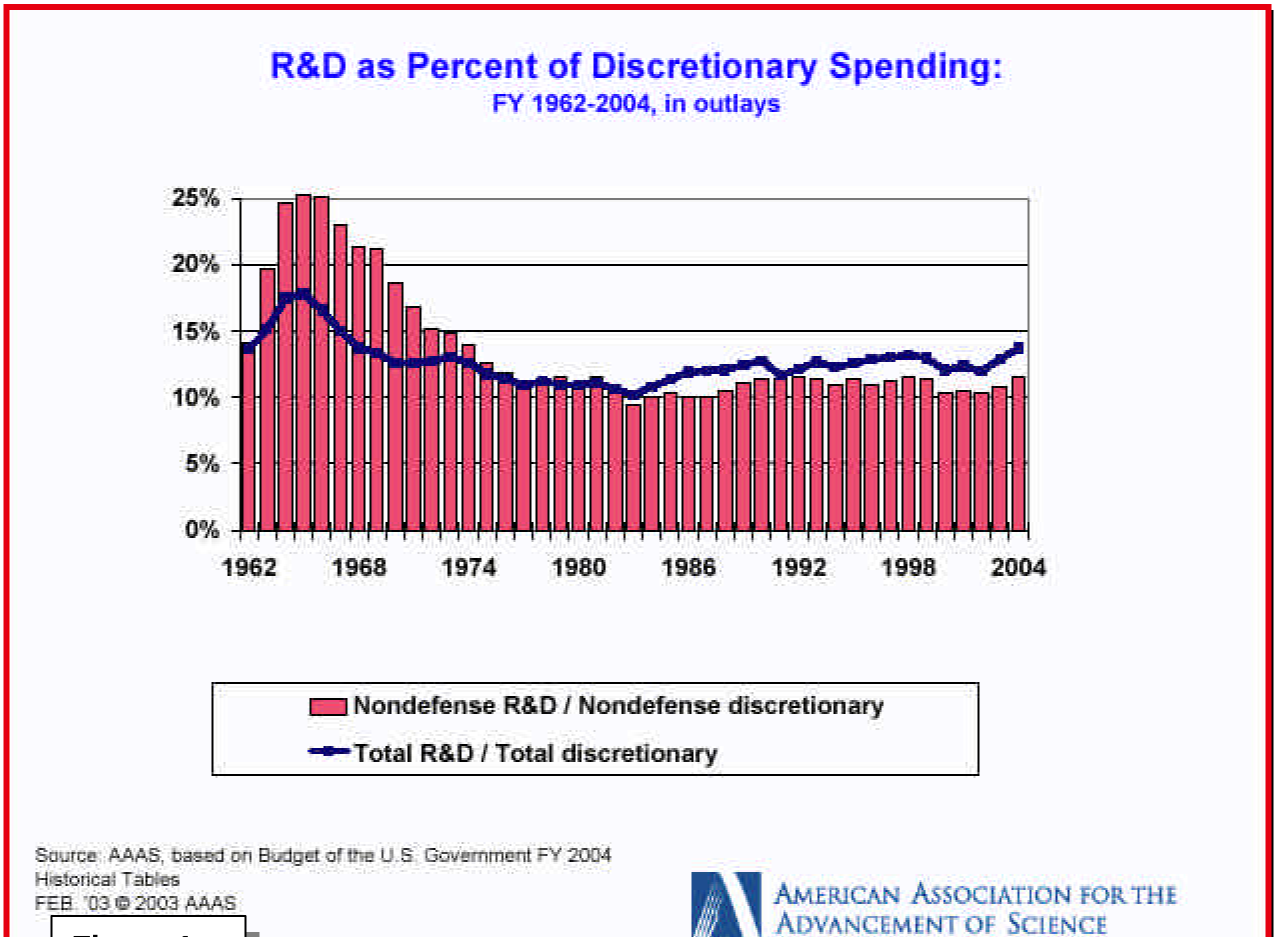

Figure 1

The situation in Congress is even more decentralized, with numerous authorizing and appropriations committees in the Senate and House each exercising jurisdiction over various pieces of the R&D enterprise. Moreover, the jurisdiction of the authorizing committees does not match that of the appropriations committees; nor does allocation of jurisdiction among Senate committees match those of the House. Finally, the appropriations process puts S&T agencies such as NSF and NASA in direct competitions with other agencies such as Veterans Affairs and Housing and Urban Development.

In total, the Balkanization of influence over S&T budgeting in the federal government precludes any strategic approach to priority setting and funding allocations. While a "Research and Development" budget can be—and is—constructed each year, this budget is an after-the-fact summation of numerous, independent actions taken by Congressional committees and Executive branch bodies. From this perspective, it can reasonably be asserted that there is no such thing as science policy in the United States.

In this light, the stability of R&D spending may appear even more befuddling. The likely explanation is that the political dynamics of budget-making result in a highly buffered system where given programs are protected by their advocates and entrenched interests, and the normal state of affairs is that annual changes in expenditure levels, whether for R&D programs or judges' salaries, are most likely to be a) very small changes over the previous year's expenditures and b) in line with overall trends in the budget. This interpretation suggests that federal support for S&T is subject to the same political processes and indignities as are other federal programs. While such a notion may offend the common claims of privilege on behalf of publicly funded science, on the other hand it offers evidence of a considerable embeddedness of S&T in the political process as a whole, an embeddedness that has offered and will likely continue to offer significant

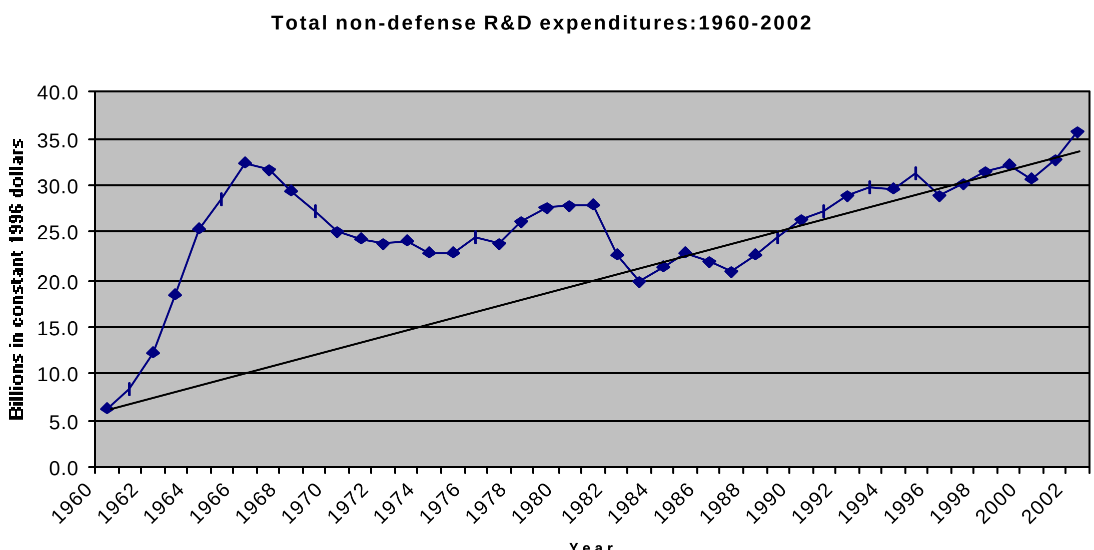

Figure 2
Source: Office of Management and Budget

protection against major disturbances in overall funding commitments for R&D activities.

II.

It will not have escaped the reader's notice that the 1960s do not fit in to the story I have told so far. R&D funding relative to discretionary spending increased markedly in the early sixties, peaked in 1965, and then declined to levels that were to characterize the next thirty years. This excursion can be explained in one word: Apollo.

Figure 2 shows nondefense R&D expenditures (all graphs use constant dollars) for the past 40 years. Here the Apollo/NASA bump shows up very conspicuously. President Kennedy's decision to send people to the moon is by far the most notable exception to the highly stable, buffered system that characterizes public funding for science. A second bump occurs in the late 1970s. This mostly represents the political response to the energy crisis during the Carter Administration: increased funding, especially in applied research and demonstration projects, for a variety of energy programs, and the creation of the Department of Energy as a central focus for such programs. It is worth noting that these two perturbations were driven largely by external geopolitical forces: the Cold War for Apollo, and the Arab oil embargo for energy R&D. This is not the internal logic of science making itself felt. If one eliminates these two features, then nondefense R&D can be seen to rise at a fairly consistent rate of about $1.5 billion per year since 1960—again, a remarkable consistency—but also a mirror of general budgetary growth as a whole, not some indication of a natural rate of expansion of the knowledge-producing enterprise.

R&D Outlays in Millions of Constant 2002 Dollars with Major Agency Breakdowns: 1960-2002

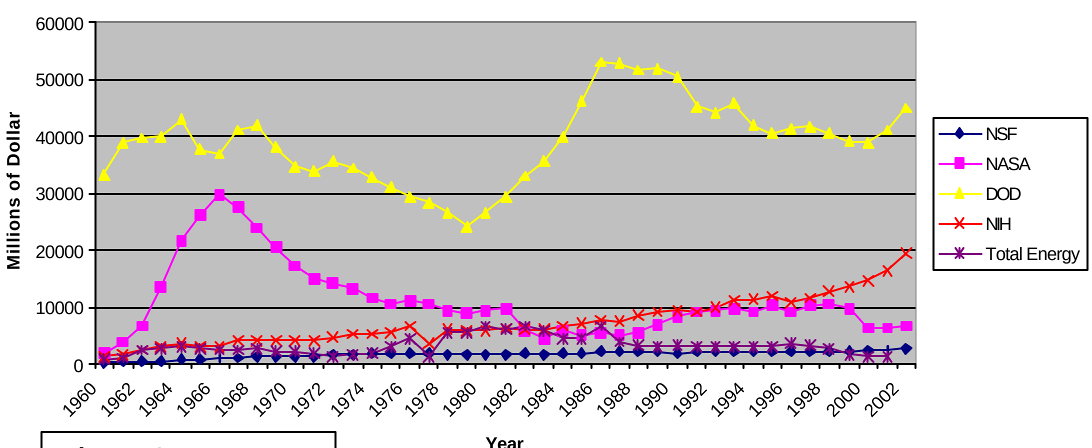

Figure 3
Source: Office of Management and Budget

More texture can be added to the story by viewing individual agency budgets, shown in Figure 3. Here again, NASA stands alone in its budgetary history. The decay curve from Apollo was very long; NIH and DOE S&T funding only caught up with NASA in the early 80s. NASA then got another boost in the 1990s from the space station. It is notable that, in the mid-1990s, budget-cutting fervor led to the demise of DOE's Superconducting Super Collider, while the space station, an order of magnitude more expensive, survived. It had a more broadly distributed constituency of subcontractors and public support.

Figure 4 gives more detail on another part of DOE—energy supply research--whose fortunes rose rapidly during the Carter Administration, and declined just as rapidly under President Reagan, never to recover. The overall point is that the R&D budget is a political construct.

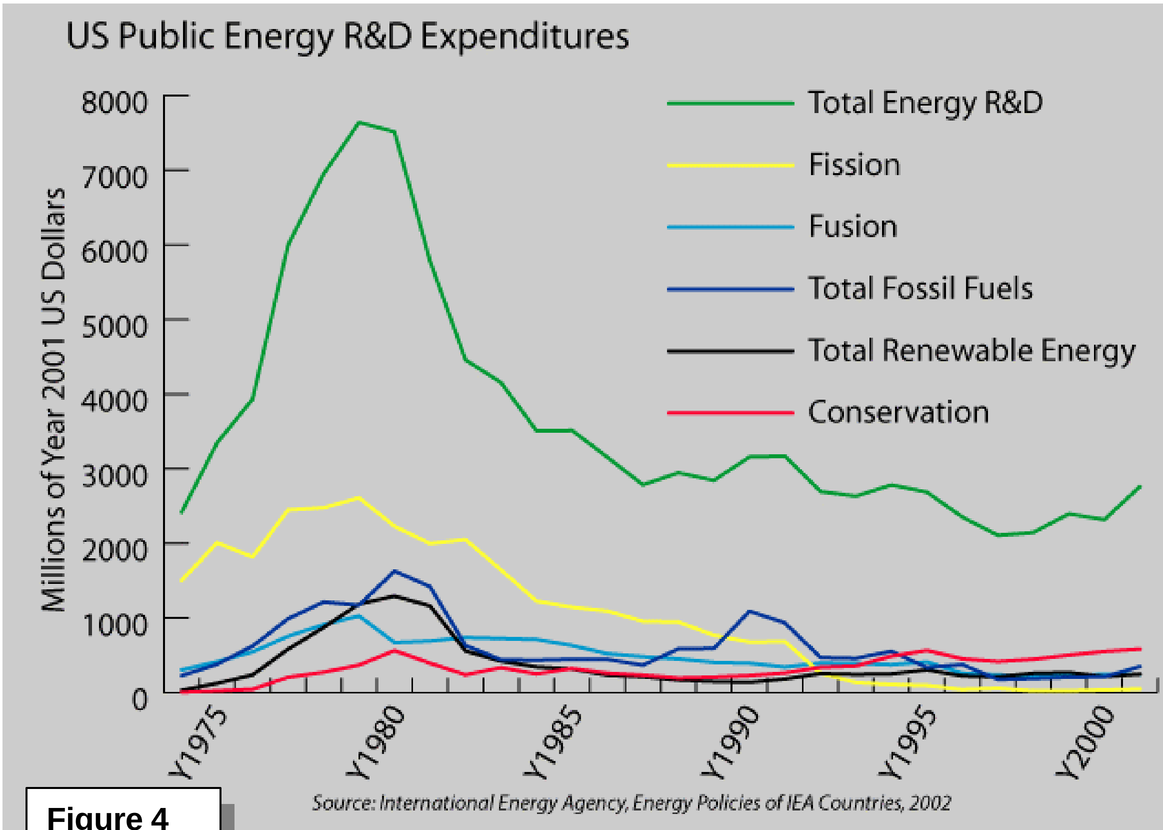

Figure 4

Defense R&D budgets exhibit behavior largely independent of nondefense spending (Figure 3). Defense R&D is mostly "D," of course—weapons systems development—but there has also been a critical component of basic research. The most conspicuous feature overall is the decline in defense R&D expenditures during the 70s, followed by a rapid increase in the late 70s under President Carter and then through much of the 80s under President Reagan. This is the era of Star Wars (SDI), among other things. Innovation scholars generally feel that the national investment in defense R&D in the 50s, 60s, and early 70s contributed significantly to the nation's overall innovation capacity, but that this contribution has fallen off significantly over the last 15 years or so. If this is the case, then the recent rise in defense R&D spending may add to the nation's S&T capacity only marginally—but, as we shall see, even if this is the case, the private sector has been taking up the slack.

Two other stories shown on Figure 3 are worth noting. The first is that the National Science Foundation has always been a relatively minor player in the federal R&D portfolio, despite its disproportionate significance for academic research. The second is the inexorably rise of the nation's commitment to health research through the National Institutes of Health.

Science policy discourse has been in the grip of a number of myths that seem utterly insensitive to the reality of this budgetary history. The first is that the nation's commitment to basic research is weak, and that basic science has been under continual assault by politicians who don't understand its value. A related myth is that the 1960s were the "Golden Age" of federal science funding in America, where basic scientists at universities were especially free to pursue their curiosity in any direction they desired with the full support of the government.

Federal Obligations for Basic Research in Constant 2002 Dollars: 1970-1999

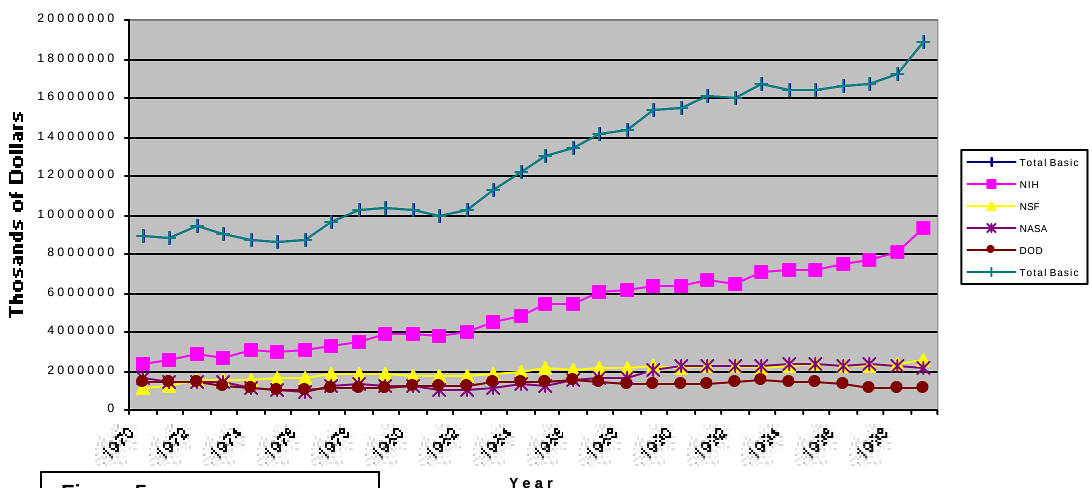

Figure 5
Source: National Science Foundation/ Division of Science Resource Statistics

The "Golden Age" myth almost certainly reflects the more favorable ratio of dollars to scientists in the 1950s and 60s rather than a deeper commitment to support of basic science. Exponential growth of the scientific community makes it virtually impossible to maintain per capita expenditure rates in the federal R&D budget. But in fact the record of public support for basic science has been strong. Figure 5 shows that funding for basic research was stagnant in the stagflation days of the 70s, but overall has grown quite robustly, most conspicuously at NIH but also at NSF, NASA, and DOE (not shown). The major exception, especially in recent years, has been DOD. Whereas DOD was the major funder of basic research, especially in the physical sciences, in the 50s and through much of the 60s, this is no longer the case. This may be a source of justifiable concern in that DOD, especially through DARPA and the Office of Naval Research, has been particularly willing and able to fund high risk research projects, since it has not been shackled to standard peer review mechanisms of project money allocation.

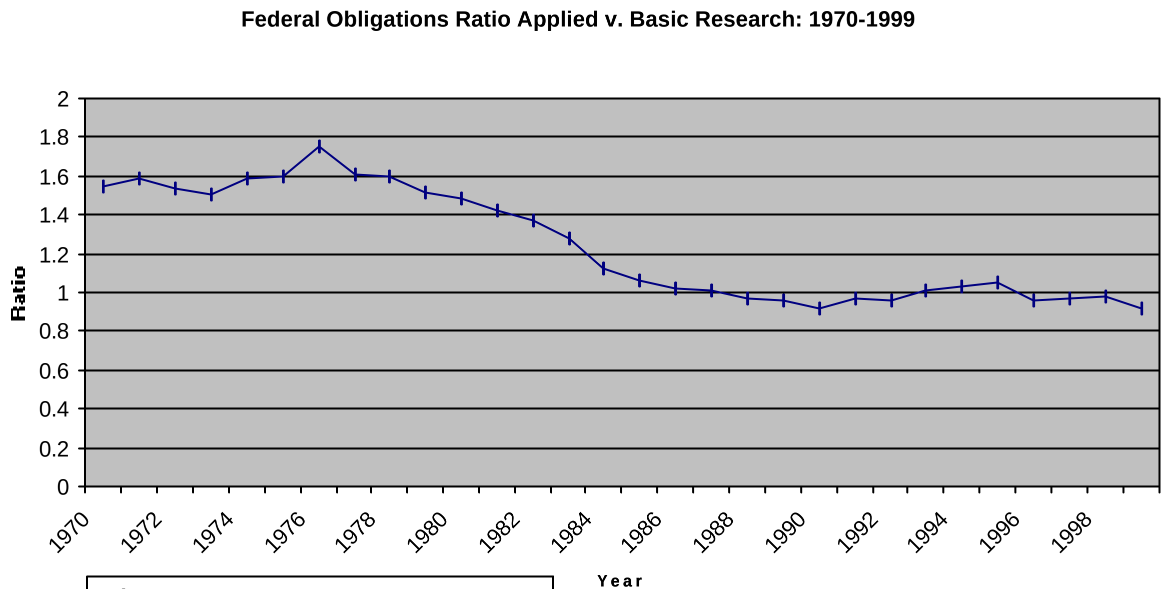

Figure 6
Source: National Science Foundation/ Division of Science Resource Statistics

In any case, what the persistent Sturm und Drang about basic research has failed to acknowledge is that not only has funding increased in a rather robust fashion for decades, but it has done so at the expense of applied research. Figure 6 shows the ratio of applied to basic research funding for the last 30 years; this has declined from about 1.6 in the early 70s, to stabilize at around 1:1 in the early 1990s. Moreover, total academic research

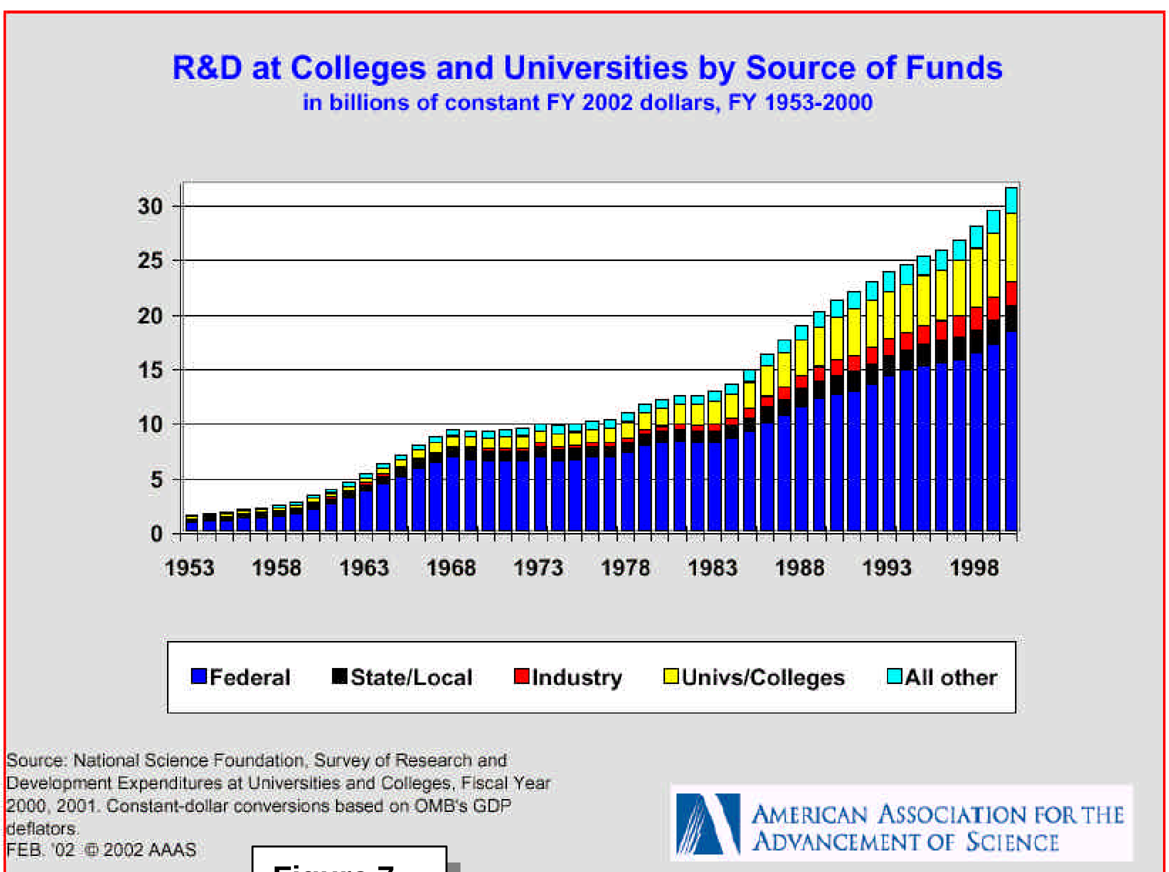

Figure 7

expenditures (basic and applied) have grown progressively over the past decades, led by health increases in the federal contribution (Figure 7). From another perspective, universities today perform about 25 percent of all federal R&D, up from nine percent in 1965.

Of course research that is "basic" is not necessarily irrelevant. Indeed, probably as much as 90 percent of the federal research categorized as "basic" is funded as part of a larger agency mission, NIH being the most obvious example, and NSF the most conspicuous exception (although this, too, is changing). This is another aspect of the "Golden Age" fantasy. Scientists in the 1950s and 60s may have felt particularly free from the guiding hand of political power, but the research administrators who were providing the funds—predominantly from DOD—often had some very specific long-range goals in mind (e.g., see Stuart Leslie's The Cold War and American Science, 1993).

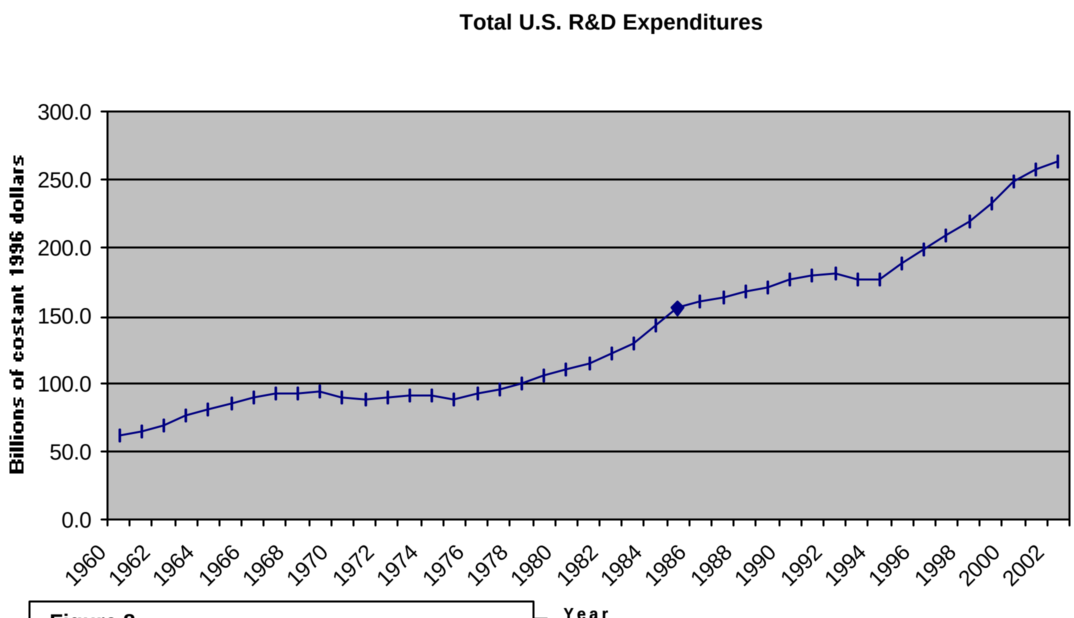

Figure 8
Source: The National Science Foundation/ Division of Science Resource Statistics

III.

What about total national expenditures, public and private? Figure 8 shows a picture of consistent growth over the past 40 years, with the steepest part of the growth curve during the past decade. Most of this growth has come in the private sector (Figure 9); indeed, the past 40 years show a progressive decline in the ratio of federal to private funding for R&D (Figure 10). I emphasize that this decline is a function of faster increases in private than public R&D investment, rather than absolute decline in public investment. From a simple market failure perspective, this trend may be interpreted as a great success: the private sector is taking on an increasing share of the knowledge creation burden of society.

Are we doing enough publicly funded research? From a scientific perspective, the answer to this question will always be "no." From a public policy perspective, the question is tougher to answer. In the mid-1990s the National Academy of Sciences issued a report which declared that the U.S. should be among the leaders in all fields of science and technology, and the undisputed leader in selected fields, yet this solipsistic

Federal and Private R&D Expenditures in Constant 2002 Dollars: 1960-2000

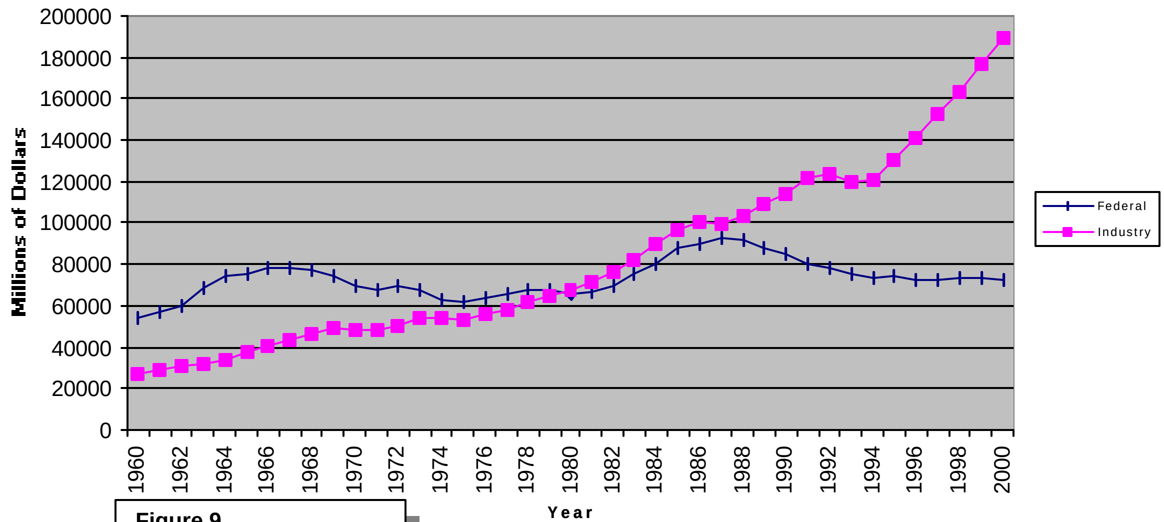

Figure 9
Source: Office of Management and Budget

perspective offers little help if one's concern is good governance. One must first ask what the public goals of publicly funded science are, and then one would have to figure out what level of investment was necessary to create a reasonably probability of reaching those goals. As I've already suggested, there is simply no mechanism for systematically

Ratio Federal:Industry: 1960-2000

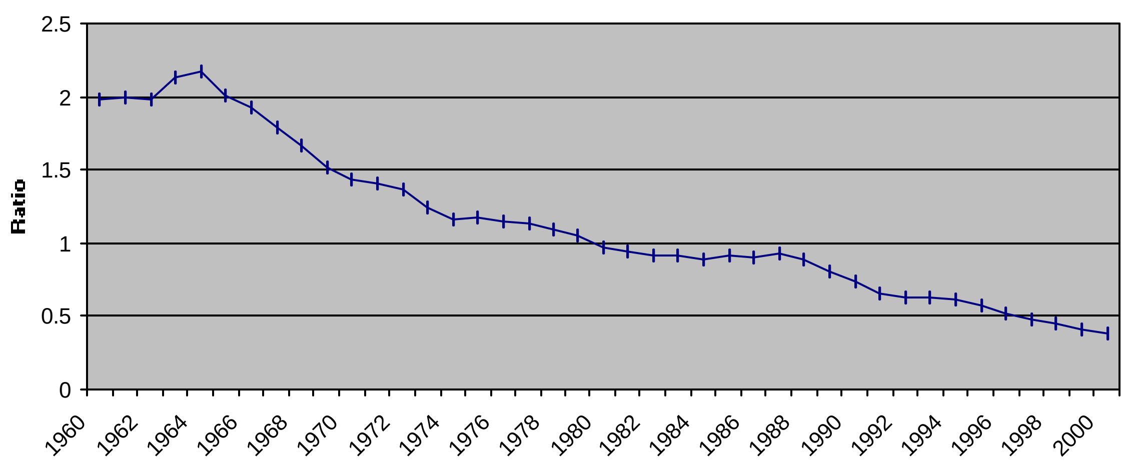

Figure 10
Source: Office of Management and Budget

R&D expenditures as a percentage of GDP including federal and non-federal:1960-2002

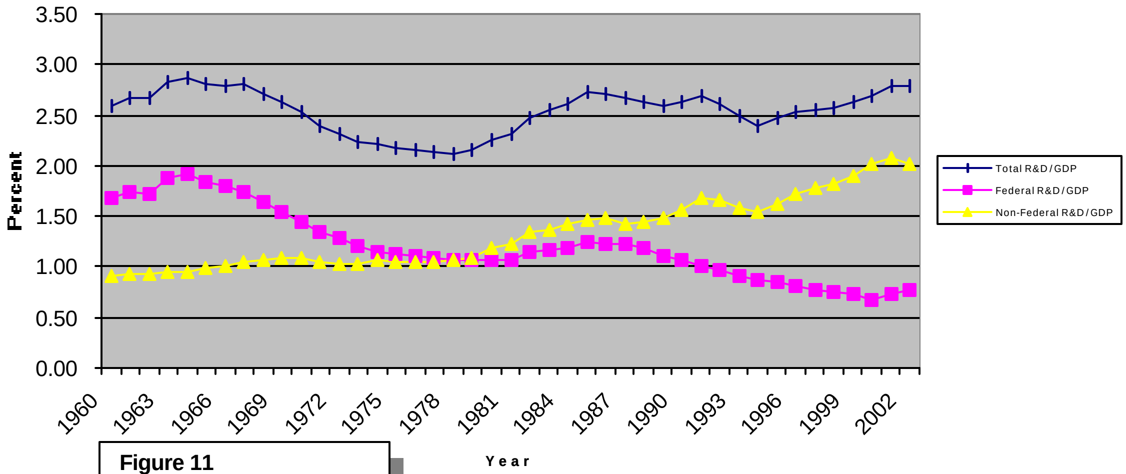

Figure 11
Source: Office of Management and Budget

asking such questions in the U.S.

Those who want to argue that the U.S. underinvests in science invariably point to normalized measures of R&D spending, especially investment as a percentage of GDP (Figure 11). Here the U.S. has consistently hovered around 2.5 percent (public and private), which is comparable to other major industrialized nations. If you strip out defense R&D (which may or may not be a reasonable thing to do), then the normalized U.S. investment in R&D is considerably less than countries such as Japan and Germany. Moreover, public investment has declined relative to GDP over the past decade or so.

Total Nondefense Expenditures by Selected Countries in Constant 1996 Dollars: 1981-1999

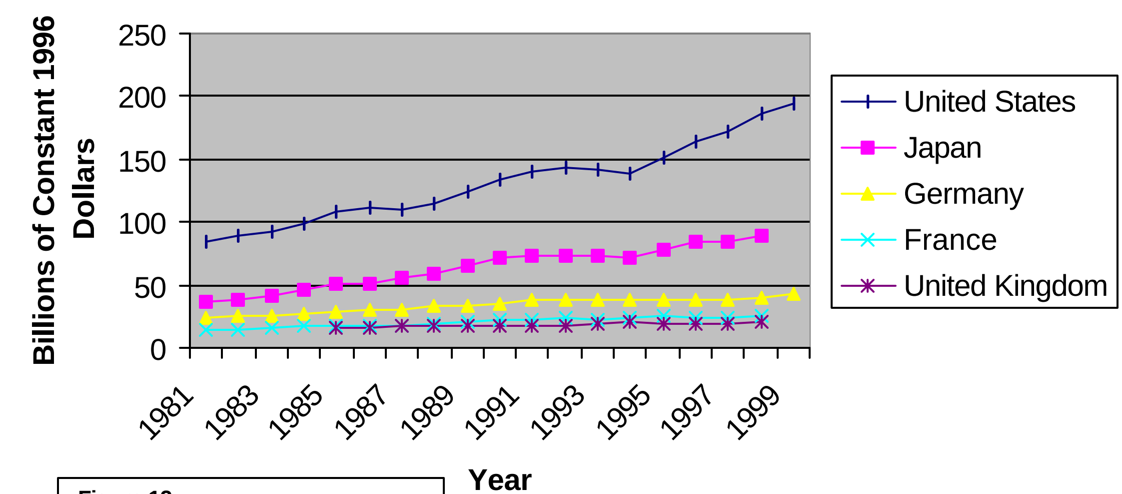

Figure 12
Source: Organisation for Economic Co-operation and Development (OECD)

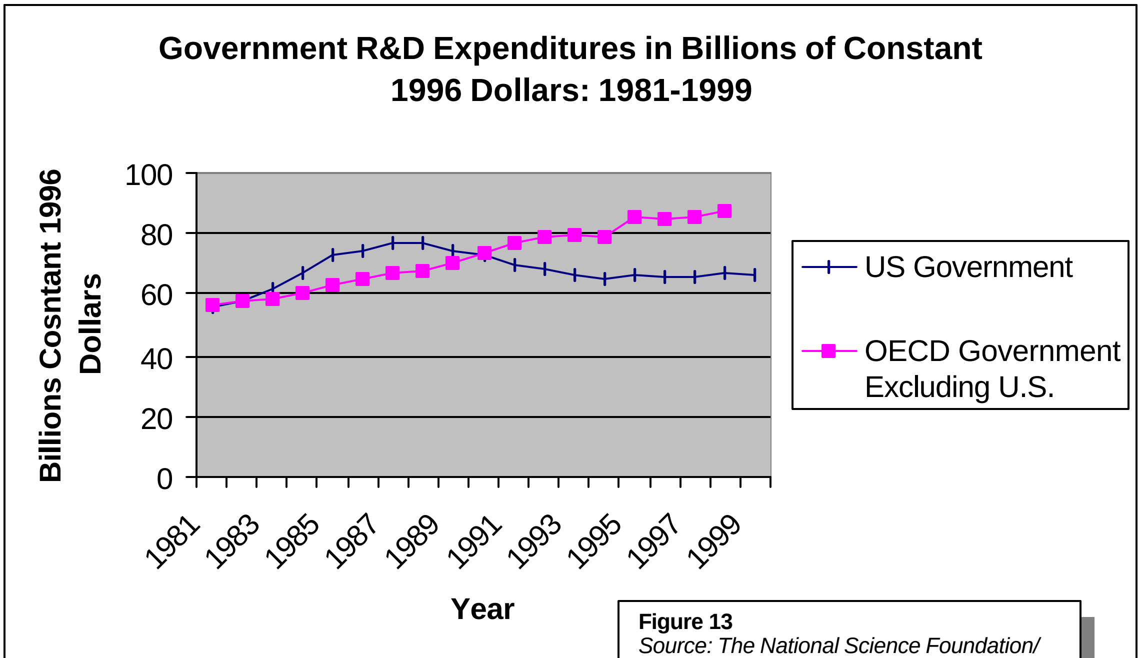

Figure 13
Source: The National Science Foundation/ Division of Science Resource Statistics

Some interpret these trends as reasons for anguish.

Whether this is a useful way to think about national R&D investments is unclear. In absolute terms, the U.S. investment in R&D, both public and private, dwarfs that of any other nation, even if one ignores defense expenditures (Figure 12). Public funding for U.S. R&D is comparable to that of all other OECD nations combined (Figure 13); the same can be said for private funding (Figure 14). The absolute scale of magnitude of the U.S. enterprise must be significant; it, again, points to the overall robustness of the enterprise.

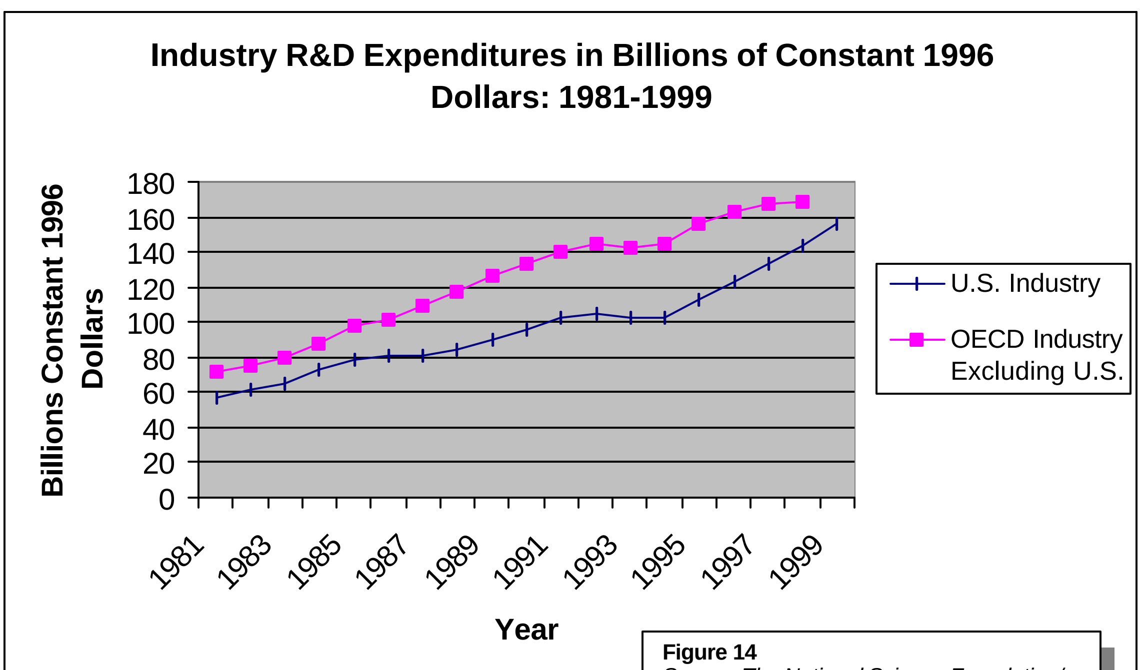

Figure 14
Source: The National Science Foundation/ Division of Science Resource Statistics

A Conclusion

R&D policies, and the resulting structures of national R&D enterprises, vary significantly from nation to nation. For example, ratios of public to private funding vary from 1:5 in Japan, to 2:3 in France. At a somewhat finer scale, differences are still more apparent. The most obvious illustration of this diversity is biomedical science, which in the U.S., as we've seen, commands more than 50 percent of the total federal nondefense R&D budget, compared to four percent in Japan and Germany, seven percent in France, and 24 percent in the U.K. Similarly, Japan devotes more than 20 percent of its civilian R&D to energy, while the U.S. spends about three percent, Germany four, France around seven; UK one. The U.S. spends 24 percent of its civilian R&D on space; France, 15; Germany five; etc.

In fact, such numbers don't tell the whole story, because European nations and Japan distribute large chunks of their federal R&D dollars in the form of block grants to universities, which then have great discretion in allocating among various programs. Thus, both within and between nations there is an enormous diversity of policy models used to determine meso-scale R&D priorities and to translate those priorities into actual expenditures. In some ways the U.S. is more decentralized and more diverse than most other affluent nations, with its Balkanized budgetary authority. At the same time, in the U.S., there is a tighter linkage between specific agency missions and funding allocation to research performers than in many other OECD nations. And of course the decision processes for disbursement of funds in universities and national laboratories (as well as the relative roles of different types of R&D performing institutions) varies greatly from nation to nation and within nations. The role of peer review, smart managers, earmarks, block grants, equity policies (e.g., NSF's EPSCOR program; German efforts to support institutions in the east); are all highly variable and reflect different institutional and national histories, politics, and cultures. Human resources are also variable, with the proportion of scientists and engineers at over nine per 1000 in Japan, eight in the U.S., six in France and Germany, and five in the U.K. And of course the role of public R&D in "industrial policies" has varied greatly over time and varies greatly between nations and between sectors. The 1991 OTA report *Federally Funded Research: Decisions for a Decade* summed up the situation: "While there may be certain universality in science, this does not carry over to science policy."

Of course it is these very details that make up the nuts and bolts of what science and technology policy is all about, and much emotion and energy is invested in promoting policies that favor one approach, priority, or program over another. But given the great diversity in meso- and micro-scale science policies both within and between affluent nations, and given the relative similarity of macroeconomic and socioeconomic profiles of these same nations, I can see no reason to believe that there is a strong linkage between specific national science policies and general national scale socioeconomic characteristics. Of course the U.S. has a strong aerospace industry and a strong pharmaceutical industry, in part because of R&D policy priorities over the past fifty years, but the U.S. still has a 20 percent pre-tax poverty rate, average life expectancy in the mid-70s, GDP per capita above $20,000, Human Development Index above 0.9, etc. etc., just like other affluent nations. So, while federally sponsored science and technology are obviously causal contributors to public welfare, and while science and technology policies of some sort are necessary to ensure such contributions in the future, there is little reason to imagine that particular policy models and choices make much of a difference to broad socioeconomic outcomes—there seems to be a diverse range of options that work well—indeed, this diversity may itself be a component of success.

Standard debates about R&D budgets are important in that they keep the policy process focused on the value of science, and they allow for various policy options to be exercised and tested repeatedly over time. But particular decisions about levels and priorities for funding, and institutional arrangements for disbursing funds, seem not to be very important determinants of the socioeconomic characteristics of affluent nations. From this perspective, the machinations of science policy—the constant stream of conferences and reports; the dozens of committees and working groups; the lobbying and legislation—are best viewed as metabolic byproducts of an ongoing struggle for influence and funding among various political actors such as members of Congress, Administration bureaucrats, corporate lobbyists, college presidents, and practicing scientists. The significance of this struggle is largely political and internal to the R&D enterprise—it is not a debate over the future of the nation, despite continual grandiose claims to the contrary. We are largely engaged in science politics, not science policy. Or, to adopt a Kuhnian perspective, this is normal science policy.

This is not to say, however, that important issues are not at stake—only that these issues tend not to receive much attention. Consider, for example, the close coupling between private (corporate) and public (government) research agendas, which has been well documented by science policy scholars. As the ratio of public to private science in the U.S. continues to decline, what effect might this have on the capacity of the federal science enterprise to respond to societal needs that are not well expressed in the marketplace? The recent doubling of the NIH budget is a case in point. This doubling occurred without any national dialogue about what it might achieve or about alternative paths toward better national and global health. In large part because of the close coupling between NIH and the biomedical industry, high technology intervention (often at high cost, as well) has been adopted as the national strategy for improved health, with no serious consideration of other possible strategies for health research investment (e.g., public health approaches) that are not likely to be sources of significant profitability.

A second concern verges on the metaphysical. Traditionally, science policy has proceeded with a tacit, sometimes an explicit, assumption that everyone is made better off by investments in science. With that logic, the most important question, naturally, is "how much science can we afford?"—hence the obsession with budgets. But if one assumes that both the positive and negative impacts of science are unevenly distributed, it becomes important to pay more attention to the value bases of science and its outcomes, and to questions of who benefits.

The problem, of course, is that few people (perhaps none) have the breadth of understanding to even begin to provide a valid account of what will happen as a result of a five percent decrease or increase in, say, chemistry, or a 100 percent increase in cancer research. Thus, the change number becomes a conveniently available surrogate for knowledge about how science supports public values.

It is easy to criticize the annual numbers ritual but more difficult to identify any means of moving from "How much?" to "Why?" This is a general problem in federal budgeting but is especially acute in science policy. Some government officials are on the right track. When agency heads and their budget officers are asked to report on what they expect to accomplish with an increment of 10% as opposed to a decrement of 10% there is sure to be a great deal of smoke and mirrors, but at least there is some chance that a bit of truth will be reflected. An even better means of ensuring some increased focus on outcomes is to actually become serious about examining previous outcomes. Almost all government reforms pay some lip service to doing this, but there is limited staff, method, and will to follow through. Thus, the real answer may lie in political leadership.

If policy-makers can, in a more sophisticated manner, articulate a vision for what is to be accomplished, science funding agencies, and ultimately scientists, often prove a remarkably malleable and effective means of achieving a vision. The problem, however, is that political vision usually results in ungovernable and highly ineffective windfalls such as the War on Cancer or the synfuels program, or impossible, immeasurable demands, such as a Congressional requirement that the National Science Foundation use 60% of its funding for science that will have a social impact.

Some hope of moving from "how much" to "why," may be found in the same sort of broadly constituted panels that have been employed in such projects as *Healthy People 2010* (U.S. Public Health Service) in which problem-focused experts and stakeholders identified policy-making priorities to address social (health) needs. The example is instructive not only as an effective approach to identifying problems, research priorities, and possible solutions, but because of its limited influence on science policy and the near invisibility of the work among medical researchers or research advocates. Going from "how much?" to "what?" will not be easy, but it is the frontier of science policy.