DOCUMENT RESUME

ED 281 444 HE 020 348

AUTHOR Knight, Randall D.
TITLE Science, Space, and Scholarship: University Research and the Strategic Defense Initiative. ASHE 1987 Annual Meeting Paper.
PUB DATE Feb 87
NOTE 26p.; Paper presented at the Annual Meeting of the Association for the Study of Higher Education (San Diego, CA, February 13-17, 1987).
PUB TYPE Viewpoints (120) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Academic Freedom; Aerospace Technology; College Faculty; *Federal Aid; Government School Relationship; Higher Education; *Military Organizations; National Defense; *Public Policy; *Research and Development; *Research Universities; Scholarship; Scientific Research; Technology
IDENTIFIERS *ASHE Annual Meeting; Department Of Defense; Reagan Administration; *Strategic Defense Initiative

ABSTRACT

Issues concerning the federal role in financing research and development (R&D) and the impact of these policies on academic research are examined. Specific concerns are whether the Reagan Administration is militarizing research and implications of the Strategic Defense Initiative (SDI) program. National Science Foundation data are examined, including: the percentage of the Gross National Product devoted to R&D funding and nonmilitary R&D for the United States, West Germany, and Japan; the percent of federal expenditures for R&D since 1966, reported in 2-year intervals; the percentage and amount of expenditures for basic research allocated to universities, industry, and federal agencies; and federal obligations for university funding from various federal agencies. The federal investment in R&D has focused on military development, while spending for academic research has shown modest growth and has been targeted at the physical and mathematical sciences as well as selected areas of engineering. In addition, Department of Defense involvement in university research has substantially increased. Detailed attention is directed to SDI funding and implications for university research. (SW)

Science, Space, and Scholarship: University Research and the Strategic Defense Initiative

Randall D. Knight
Department of Physics
Ohio State University
Columbus, Ohio 43210

ASHE
ASSOCIATION
FOR THE
STUDY OF
HIGHER EDUCATION

The George Washington
University
One Dupont Circle, Suite 630
Washington, D.C. 20036-1183
(202) 296-2597

This paper was presented at the Annual Meeting of the Association for the Study of Higher Education held at the San Diego Hilton in San Diego, California, February 14-17, 1987. This paper was reviewed by ASHE and was judged to be of high quality and of interest to others concerned with the research of higher education. It has therefore been selected to be included in the ERIC collection of ASHE conference papers.

Annual Meeting • February 14-17, 1987
San Diego Hilton • San Diego, California

Life has never been peaceful for the academic researcher. A substantial portion of faculty time is absorbed not only with the actual writing of proposals, but also with following the shifting political fortunes of the various sources of research dollars. Universities spend 50% of the basic research dollars in this country, a figure which has shown no significant change in the last twenty years. The portion of that research financed by the federal government has, however, declined from 77% to 67% during this period. Perhaps more significantly, the drop to 67% occurred suddenly with the Reagan administration, after holding at a nearly constant 71% throughout the 1970's. Uncle Sam remains by far the largest contributor to university research, and federal spending policies are clearly of concern to the academic researcher.

Research looks quite different from the government's point of view. The importance of research to a vital economy and a strong defense is valued by all, but tradeoffs between research programs are day-to-day occurrences in the political arena. Legislators and administrators debate not only spending levels, but also the distribution of dollars among agencies and projects. While academics champion the virtues of "pure" research, the government is duly concerned with what it is buying for its dollars. This directly affects the types of research programs which are funded. In the late 1980's, Congress and the Administration must also weigh research spending against reducing the federal deficit. Both are alleged to be vital to the well being of future generations.

This paper will look at some of the issues surrounding the federal government's role in financing research and development and the impact that these policies have on academic research. A significant question circulating within the academic community is whether or not the Reagan administration is militatizing teseatch and, if so, what influence that will have on teseatch funding, academic fteedom, and telated issues. Among militaty teseatch ptogtams, the Sttategic Defense Initiative (SDI) has been singled out with vocal and latgely unptecedented opposition ftom academic scientists. I will examine these complex issues thtough an analysis of both the financial and political aspects of fedetal policies.

Let me state patt of my methodology and assumptions at the outset. The budget figutes I have used ate those compiled and tepotted by the National Science Foundation. As anyone who has evet delved into details of the fedetal budget knows, the motass of tables, chatts, and figutes can be overwhelming. To complicate mattets futthet, the "units" ate tately the same ftom one table to anothet (e.g. fedetal expenditutes in one vs. fedetal obligations in anothet), making compatisons tticky. Even tables which putpott to contain identical information often show diffetences, sometimes small but occasionally significant, when taken ftom diffetent NSF publications. One ftequently has the feeling of compating apples and otanges.

I have elected to apptoach the information as a scientist. These tables teptesent "data," and in any expetiment the data contain a cettain amount of noise. My goal has been to seek out significant ttends in the data that cleatly stand out above the noise. Small diffetences between tables, small diffetences in the "units", etc. I have considdeted to be patt of the noise. As a consequence of this apptoach, the "tesults" I quote should be consideted to have some "expetimental uncertainty" associated with them. If I find spending in category X to have incteased by 3.5% while that in categoty Y has incteased by 3.8%, I will consideted them, fot my putposes, to be essentially the same. Putists will undoubtedly be offended, and I do not deny that the ptecision of my tesults could be imptoved with mote cateful ttacking down of the budget details. My assertion, however, is that I can clearly distinguish between a 3.5% growth and a 7% growth. Since my aim is to look for large-scale trends, the finer details are of less significance.

As a final note on the data, I have used the most recent information available. There is often a lag time of several years before this type of information is compiled, tabulated, and published. Consequently, some data are available only through 1983, whereas others are known up to the present fiscal year, 1987. Drawing inferences from this data, particularly with regard to apparent trends from early in the Reagan administration, is thus somewhat speculative. Further research is clearly needed to verify whether or not these trends are continuing.

The importance of research and development to our economic well-being can hardly be understated. For many years following World War II, the U.S. led the world in the percentage of the gross national product which was invested in R&D. One can argue convincingly that this investment paid handsomely with the unparalleled technological expansion and economic prosperity which has lasted until the present day but which now shows signs of faltering. A comparison with Japan and West Germany, those nations which seem to be overtaking us economically, is revealing (Fig. 1a). Over the past 15 years, the fraction of U.S. GNP devoted to R&D underwent first a significant decline and, more recently, a recovery. Japan and West Germany have been steadily increasing their investment in R&D throughout this period, and the once commanding U.S. lead has now become an essential parity between these advanced nations.

A closer look is yet more disturbing. A large fraction of U.S. research and development is devoted to military pursuits, while Japan and West Germany are, for the most part, investing directly in consumer-oriented technologies. Fig. 1b shows the percentage of GNP devoted to non-military R&D. The U.S. has always trailed in this category, and the gap is widening. This has become more accentuated during the Reagan administration, which has terminated the modest increase in non-military R&D of the Carter administration.

The Reagan administration frequently asserts its devotion to research and development. Indeed, the federal government's spending on research and development has increased from $33.4 billion in FY1981, the last Carter budget, to an estimated $55.2 billion in FY1986. (Hereafter, all years represent fiscal years.) After allowing for inflation, this represents 34% real growth in five years, or an average 6% per annum. Where has this money gone, and are university researchers realizing grant increases of this magnitude?

Figs. 1a and 1b suggest the answer. Starting in 1981, the rapid increase in total R&D seen in Fig. 1a is not matched by any increase in the non-military R&D of Fig. 1b. Other statistics are even clearer. Fig. 2 shows the percentage of federal R&D devoted to defense, to space, and to civilian activities. The trend through 1980 is clear: a shift from space to civilian R&D after the end of the Apollo program, with defense holding a nearly constant 50%. The slight downward drift in defense spending during the 1970's followed the Vietnam War.

Starting in 1981, a startling shift in policy is obvious: American research and development has militarized to an extent not seen in decades. Indeed, of the increase in research and development dollars spent thus far during the Reagan presidency (through 1986), fully 93.5% of them have gone to the Department of Defense.[1] When adjusted for inflation, Department of Defense R&D has experienced a real increase of 86% during this period, while non- defense R&D has undergone a real decrease of 12%. Furthermore, 96% of this major DoD increase has been in its development budget.

These policies bear directly on academic research. The general public and, to some extent, Congress as well make little distinction between research and development. Yet the distinction, from the perspective of academia, is crucial. For the past decade, university research and development spending has been structured approximately 95% research (67% basic, 28% applied) and only 5% development.[2] Prior to that, basic research was emphasized even more over applied research, but development spending has hovered in the 4 - 5% range at least since the early 1960's. Federal policies placing all of their emphasis on development, particularly military development, will by-pass the university.

This ia borne out if we focus on spending for basic research alone. Fig. 3a shows how all basic research (university, industry, and government) has been financed since 1965. This graph has been normalized to 1982 dollars in order to remove the effects of inflation. A small contribution from non-profit organizations (less than 6%) has been omitted. The well-known downturn of the early 1970's is apparent, followed by a modest increase during the Carter years and a more sustained increase during the Reagan administration. Fig. 3b renormalizes federal, industry, and university spending on a percentage basis. Here it becomes clear that the increase during the 1980's has been due not so much to federal policies as to increased industrial research. Indeed, the federal contribution to basic research has been steadily declining throughout the 1980's. The trend for applied research is even larger, with the federal share having dropped from 50% in 1976 to 40% by 1986.[3]

It is also revealing to compare these data to the growth of the gross national product. Such a normalization indicates whether or not research spending is keeping up with the general growth of the economy. A comparison of this type shows that federal spending for basic research has just about exactly matched the overall growth of the economy since the early 1970's (i.e. constant fraction of GNP devoted to basic research), and that research spending during this period has been a much smaller portion of the economy than during the late 1960's. A slight growth per GNP dollar seen since 1980 in the total expenditure is due almost entirely to industry-financed research.

Fig. 4a focuses still more closely on the financing of university-performed basic research. The trend in total expenditures since 1965 is not particularly different than that for basic research in its entirety (Fig. 3). Normalization is again in 1982 dollars; normalization to GNP shows, as above, only very slight growth since the early 1970's. Since 1976, real growth has averaged 4.2% per annum, with no significant difference between the Carter years (3.8% growth) and Reagan's (4.5% growth). The federally-financed portion of university basic research experienced 3.3% per annum real growth under Carter and 3.5% real growth under Reagan, an even smaller difference. Note, however, that during this recent period of 3.5% annual real growth of federally sponsored university basic research, the federal investment in development moved ahead with 7.3% annual real growth.

Fig. 4b again puts these figures on a percentage basis and provides the basis for the statement, made in the introduction, that the portion of university basic research supported by the federal government has declined from 77% to 67% during the past twenty years. A decade long period of stability during the 1970's was punctured by a sudden drop, early in the Reagan administration, in the federal contribution.

One might expect that the apparent militarization of R&D under the Reagan administration would lead to an emphasis on the physical sciences. At least through 1984, the most recent year for which detailed budget breakdowns are available, this seems to be the case. For 1981-84, federal support for university mathematical and physical sciences experienced real growth of 4.2% per annum, as contrasted with only 1.2% per annum growth in federal support for university basic research as a whole during this period (the average 3.5% figure for 1981-86, noted above, depends on the significantly larger 8.3% growth during 1985-86). By comparison, federally supported university research in engineering and the life sciences each experienced only about 1% per annum real growth during 1981-84, while environmental research declined about 1% and social science research declined about 10% per annum.[4]

Further insight into federal research policies and how they affect the university community is gained by examining the distribution of funding by federal agencies. Fig. 5 shows federal obligations, normalized to 1982 dollars, for university R&D originating with various agencies which are instrumental in supporting the physical sciences; major agencies (e.g. National Institute of Health) which fund other disciplines are not shown here. The time evolution of the distribution is quite striking. Dates of particular interest are 1970, when the Mansfield Amendment placed restrictions on some types of research which had been DOD sponsored and likely contributed to the continuing decline in the DOD share, and 1973, when the NSF budget received a strong boost as part of the Nixon economic stimulus program. The slow decline of NASA as well as the rise of DOE following the 1973 oil boycott are apparent.

Of particular interest is the resurgence of DOD funding of university research starting in the late 1970's. For reasons not completely clear, the restrictions of the Mansfield Amendment were relegated to oblivion. The 1978 budget contained a significant increase in the DOD share, which then remained relatively constant throughout the remainder of the Carter years. The early years of the Reagan administration accelerated this trend, and DOD surpassed NSF in university research funding for the first time in a decade.

More recent data, from the Council on Economic Priorities, show that in the period from 1980 through 1986, DOD support for university research increased at a yearly rate nearly twice that of NSF and more than twice that of any other federal agency.[5] By 1986, more than 37% of all engineering research at universities was DOD supported. Some specialties are much higher, with electrical engineering 57% and astronautical engineering 81% DOD supported.

The implications of these statistics seem clear. The Reagan administration's investment in R&D, which has been substantial, has been focused almost exclusively on military development. Federal spending for academic research has shown only modest growth, and that has been narrowly targeted at the physical and mathematical sciences as well as selected areas of engineering; federal support in many other academic disciplines has declined. Finally, the present administration has accelerated the trend, begun under Carter, toward substantially increased DOD involvement in university research.

Where does the Strategic Defense Initiative fit into this, and what are its implications to the University? Since its inception in 1984, SDI has risen rapidly to command a $3.5 billion budget in FY87. This makes SDI the largest single program within DOD, and its budget comfortably exceeds that of the National Science Foundation. Much of that budget, of course, goes to development programs at government labs and to defense contractors. A sizable portion, though, finds its way to the University.

SDI is divided into six program sections. One of these, the Office of Innovative Science and Technology (IST), is directly concerned with "highly innovative, high-risk" ventures, and much of its budget is targeted toward the academic community. IST is slated to receive 5% of all SDI funding over the next five years, although its budget, which tripled from $28 million in 1985 to $92 million in 1986, has been running less than that. In addition, some portion of the budgets of the other five SDI programs is allocated to university research and development.

When the various SDI programs are combined, contracts to universities totaled $84.1 million in 1985 and exceeded $200 million in 1986.[6] Adjusted to our standard 1982 dollars, these figures become $75.2 million and $173 million. With reference to Fig. 5, which showed federal obligations for university R&D, we see that SDI sponsored university research has reached the level of NASA and is roughly a quarter that of NSF. Since substantial portions of the NSF budget are allocated to the biological and social sciences, SDI funding of university engineering and physical science research must already well exceed a quarter that of NSF. Further, Administration plans are for the SDI budget to continue growing at an enormous rate (60% increase requested for the next budget, FY88) while other funding sources hold roughly constant. Congress, of course, may view things differently.

Much of the funding to date, it is true, has gone to off-campus research institutes, such as M.I.T.'s Lincoln Laboratory. Many of these labs were already performing similar military research that has now been shifted into SDI. This does not appreciably lessen the implication to the University. Faculty and graduate students often do their research in these off-campus institutes, and University risks finding itself beholden to a single agency for a substantial portion of its research dollars. This latter fact has political significance, as we will note later.

The fact is that in the space of only three years, SDI has come to control a not insignificant fraction of university research and development. Further, it is a fraction which will continue to grow rapidly if the present administration has its way. This raises serious questions about the future of university research, questions of legitimate concern to the academic researcher. In a time of deficit reduction, will SDI (or perhaps, more generally, DOD) crowd out other sources of funding? Will excessive dependence on SDI place limits on the types of research problems which can succeed in being funded? How will SDI (or again, more generally, DOD) affect the free flow of scientific knowledge? And in what fashion is the University being manipulated to provide political legitimacy for SDI?

Answers to these questions are, of course, speculative and will depend on the course adopted by Congress over the next few years. Although SDI is still a minor supporter of university research, it clearly has the potential, if it grows as expected, to alter the way in which university research is performed, and it is this threat which has helped galvanize the academic opposition to SDI. James Ionson, the Director of the Office of Innovative Science and Technology, has made clear the role which he wishes the University to play - namely, to unquestioningly serve as a resource for mission-oriented research and development. In his words:

> This is mission oriented basic science. The luxury to go off and sit in an ivory tower and do wonderful good science...that's a luxury that this country may not be able to afford for a while...That's not why we're here.[7]
>
> People go where the bucks are. There is a lot of money involved here. Even if someone is not an [SDI] advocate, there's still a lot to be gained - a lot of good science and the opportunity to perform that science. The only constraint is that it is mission-oriented.[8]

Nor is Ionson modest about SDI's relationship to and priority over other federal funding agencies. When asked, "How are bureaucratic relations developing here? After all, you're in a field that's crowded with many other agencies," Ionson replied:

> We just shove them out of the way. It's a Presidential Initiative, it's been given high priority in the eyes of the President...This is a very, very powerful organization because it's backed by the President.[9]

(space)→ In keeping with the mission-oriented approach, SDI contracts are designated DoD budget category 6.3, advanced development, not the more typical 6.1, basic research, or 6.2, exploratory research, under which most university contracts fall. Category 6.3 research is generally classified, thus bringing a whole other set of potential problems to the university. Although little of the university work contracted thus far is classified, SDI has been careful to leave the door ajar for future classification. Robert Hughey of DOE noted that "classification is going to be a problem," and that research begun openly might eventually be classified as it progresses.[10] Ionson has already expressed his desire that principal investigators obtain security clearance, so that they both can "steer their students" as well as receive briefings about SDI programs and goals.[11]

Even without strict classification, the growing role of DoD in university research is likely to restrict the free flow of information. This administration has previously make use of the Export Administration Act to control the presentation of DoD-supported but unclassified papers at meetings attended by foreign nationals. In 1985, the Pentagon intervened in the midst of a meeting of the Society of Photo-Optical Instrumentation Engineers and prevented the presentation of forty-three unclassified papers. Stricter guidelines, issued in the wake of scientific outcry over the SPIE meeting, have limited the government's ability to retroactively restrict dissemination of results, but there has, in exchange, been a growing tendency in some disciplines on sessions from which foreign nationals are excluded. The Adminstration continues to press this issue, most recently with a call for sweeping new restrictions on access to scientific databases. It seems likely that the re-emergence of DoD as a major supporter of academic research will lead to continued conflicts as the government attempts to restrict the exchange of and access to information heretofore considered free and open.

A significant related issue is the participation of foreign graduate students and foreign visitors in research supported by SDI or, more generally, DoD. Foreign graduate students comprise a third to a half of many science and engineering departments, including the best, and they have long been a major resource for research. The encroachment of classification or other restrictions into university laboratories will affect these students directly and will present faculty members with difficult and unwanted decisions. Do they curtail their research to only topics which can be funded by unrestricted funds (perhaps difficult to manage in many areas of engineering); do they refuse foreign students; or do they segregate their research group into two halves, Americans and foreigners, which are allowed only limited interaction with each other? These are difficult choices which will certainly affect the nature and productivity of university research.

With the aggressive tactics exhibited to date by SDI, it comes as no surprise that they have attempted to manipulate the University for political gains. These maneuvers have been designed to give SDI an apparent technological credibility and legitimacy. SDI has used the acceptance of contracts by individual academic researchers to imply an endorsement of the program by the university involved. Marvin Goldberger, President of California Institute of

Technology, has accused SDI officials of making "manifestly false" statements about his university's participation in research consortia.[12]

In another effort to build legitimacy, the Office of Innovative Science and Technology was "awarding" contracts for 1986 even before Congress approved the 1986 budget. When asked, IST Director Ionson commented:

> It's probably something that's never been done before, but this office is trying to sell something to Congress. If we can say that this fellow at MIT will get money to do such and such research, it's something real to sell. That in and of itself is innovative.[13]

At MIT's graduation ceremony, President Paul Gray criticized Ionson's claim:

> What I find particularly troublesome about the SDI funding is the effort to short circuit debate and use MIT and other universities as political instruments in an attempt to obtain implicit institutional endorsement. This university will not be so used.[14]

Yet deferring to the judgement of individual researchers does not remove the University from the political process. As noted by Vera Kistiakowsky, a professor of physics at MIT:

> By providing space and services for SDI research and taking overhead money, MIT becomes part of the process. That's why President Gray's statement that MIT "will not be used" is simply not accurate.[15]

Nonetheless, few, if any, universities are likely to take the step of outright banning of SDI research. The decisions, and the implications that flow from those decisions, to accept an increasing dependence upon SDI or other DoD funds will remain with individual professors.

This, perhaps, is at least a partial explanation of the unprecedented opposition to a government program by academic scientists and engineers. The "scientists' boycott," as it is called, has been endorsed by over 3700 professors and senior research scientists. Petition signers have pledged not to solicit or accept research funding from SDI. Support for the boycott has been particularly strong in physics departments, where sizable majorities have signed the petition in nearly every department where it has circulated. Engineering departments have been much less supportive. No doubt part of this difference is a matter of political beliefs, but an additional factor is purely practical: engineering is already heavily supported by DoD, physics less so. Given a choice between a lofty moral statement and continuing research grants, many have opted for the latter. Petition circulators uniformly report that the most common response from non-signers is, "I don't really think that SDI will ever work, but that's where the research dollars are. If I'm to continue my research, I don't want to close off the option of using some of that money."

Nor is lack of future funding the only consideration. Supporters of the boycott are perhaps risking the loss of non-SDI federal support for their research. Former Under Secretary of Defense Donald Hicks, in testimony to the Senate Armed Services Committee, expressed his views on any form of DoD support going to SDI critics: "I am not particularly interested in seeing department [i.e. Pentagon] money going to someplace where an individual is outspoken in his rejection of department aims, even for basic research."[16] In a later interview he elaborated further:

> If they want to get out and use their roles as professors to make statements, that's fine, it's a free country. [But] freedom works both ways. They're free to keep their mouths shut ... [and] I'm also free not to give the money... If he wants to get his money someplace else, that suits me fine. My money is overall specified to be given to people who feel the same kind of urgency that I feel.[17]

This attitude, from high officials within the Administration, has obvious implications for university research: professors exercising their right to disagree and to speak out risk government reprisal against their research programs. Yet these not-so-subtle threats, coupled with government actions already taken to curb foreign participation in and access to research, have so far prompted only minor objections from the universities. Thus the individual researcher is left to decide for himself or herself how federal policies are likely to affect the future course of their research.

SDI is not the main factor influencing university research, but it is nonetheless of growing significance and it cannot be lightly dismissed by the academic researcher. More significantly, SDI is just one piece of an expanding role which the Pentagon is now playing on campus. The issues of academic freedom, the dangers of the restriction of knowledge, and the implications of political manipulation of the University are still unresolved. The individual researcher has legitimate interest in these questions and just cause for speaking out. Life has never been peaceful for the academic researcher, and it certainly isn't getting any easier.

References

[1]National Science Foundation, National Patterns of Science and Technology Resources, 1986, (NSF 86-309), Tables 24, 25, and 34, (Washington, D.C., 1986).

[2]National Science Foundation, op.cit.,Tables 5 - 12.

[3]National Science Foundation, op. cit., Table 3.

[4]National Science Foundation, op. cit., Table 53 (adjusted for inflation).

[5]Council on Economic Priorities Newsletter, January, 1986.

[6]Union of Concerned Scientists, Empty Promise: The Growing Case Against Star Wars, p.37 (Beacon Press, Boston, 1986).

[7]Science and Government Report, April 15, 1985.

[8]Ibid.

[9]Ibid.

[10]Science 228, p.304 (April 19, 1985).

[11]Ibid.

[12]Council on Economic Priorities Newsletter, op. cit.

[13]Science, op. cit.

[14]Council on Economic Priorities Newsletter, op. cit.

[15]Union of Concerned Scientists, op. cit., p.54.

[16]Science 232, p.444 (April 25, 1986).

[17]Ibid.

[18]National Science Board, Science Indicators: The 1985 Report, Appendix Tables 1-2 and 1-4 (Supt. of Documents, U.S. Government Printing Office, Washington, D.C., 1985).

[19]National Science Foundation, op. cit., Table 22.

[20] Office of Management and Budget, "Special Analysis K," Budget of the U.S. Government, 1987, (Supt. of Documents, U.S. Government Printing Office, Washington, D.C., 1986).

[21] National Science Foundation, op. cit., Table 7.

[22] National Science Foundation, op. cit., Table 2 (adjusted for inflation).

[23] National Science Foundation, Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, Fiscal Year 1983, (NSF 85-321), Table B-2 (adjusted for inflation), (Washington, D.C., 1985).

Figure Captions

Fig. 1. Fraction of the gross national product which is devoted to research and development. a) All R&D. b) Only non-military R&D. Reference 18.

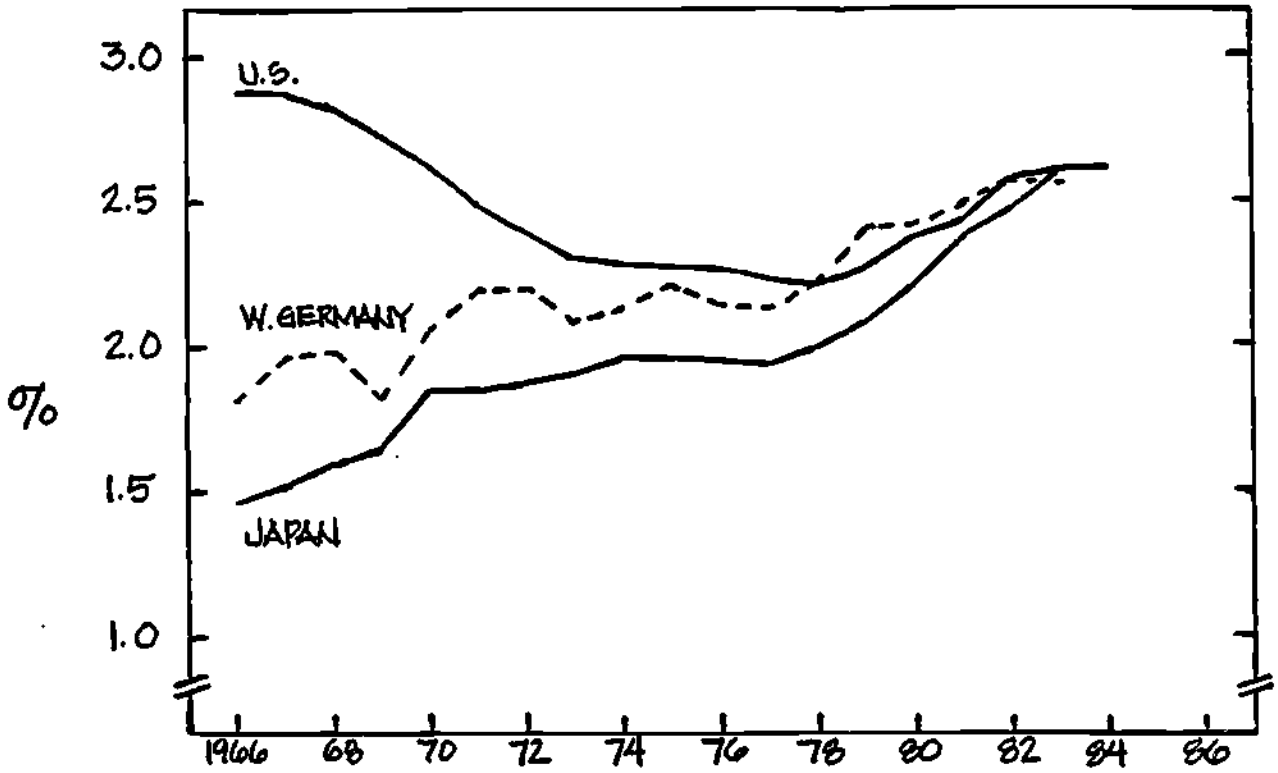
Fig. 2. Federal government expenditures for research and development. From 1973 on, the non-defense expenditures are subdivided into civilian and space categories. References 19 and 20.

Fig. 3. Sources of expenditures for basic research. a) In constant dollars (1982$). b) As a percentage of total expenditures. Reference 21.

Fig. 4. Sources of expenditures for university-performed basic research. a) In constant dollars (1982$). b) As a percentage of total expenditures. Reference 22.

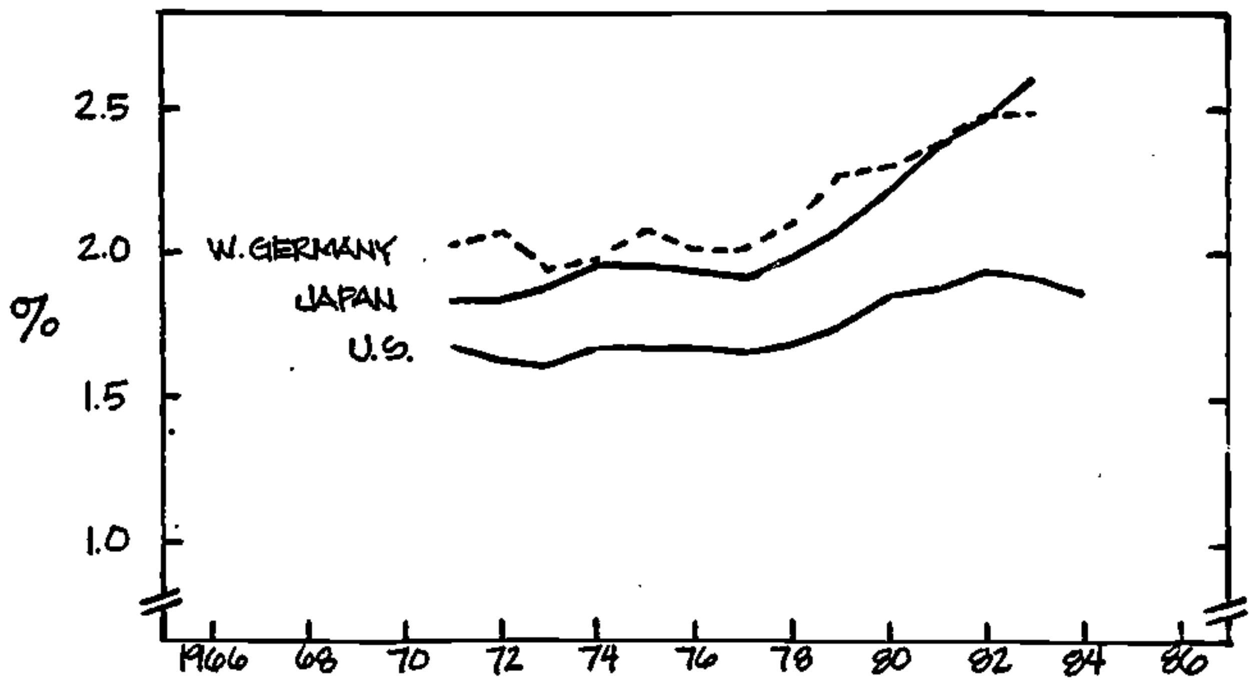
Fig. 5. Federal obligations, by selected agencies, for university-performed research and development. In constant dollars (1982$). Reference 23.

FRACTION OF GNP DEVOTED TO R&D



(a)

FRACTION OF GNP DEVOTED TO NON-MILITARY R&D



(b)

Fig. 1

FEDERAL EXPENDITURES FOR RESEARCH AND DEVELOPMENT

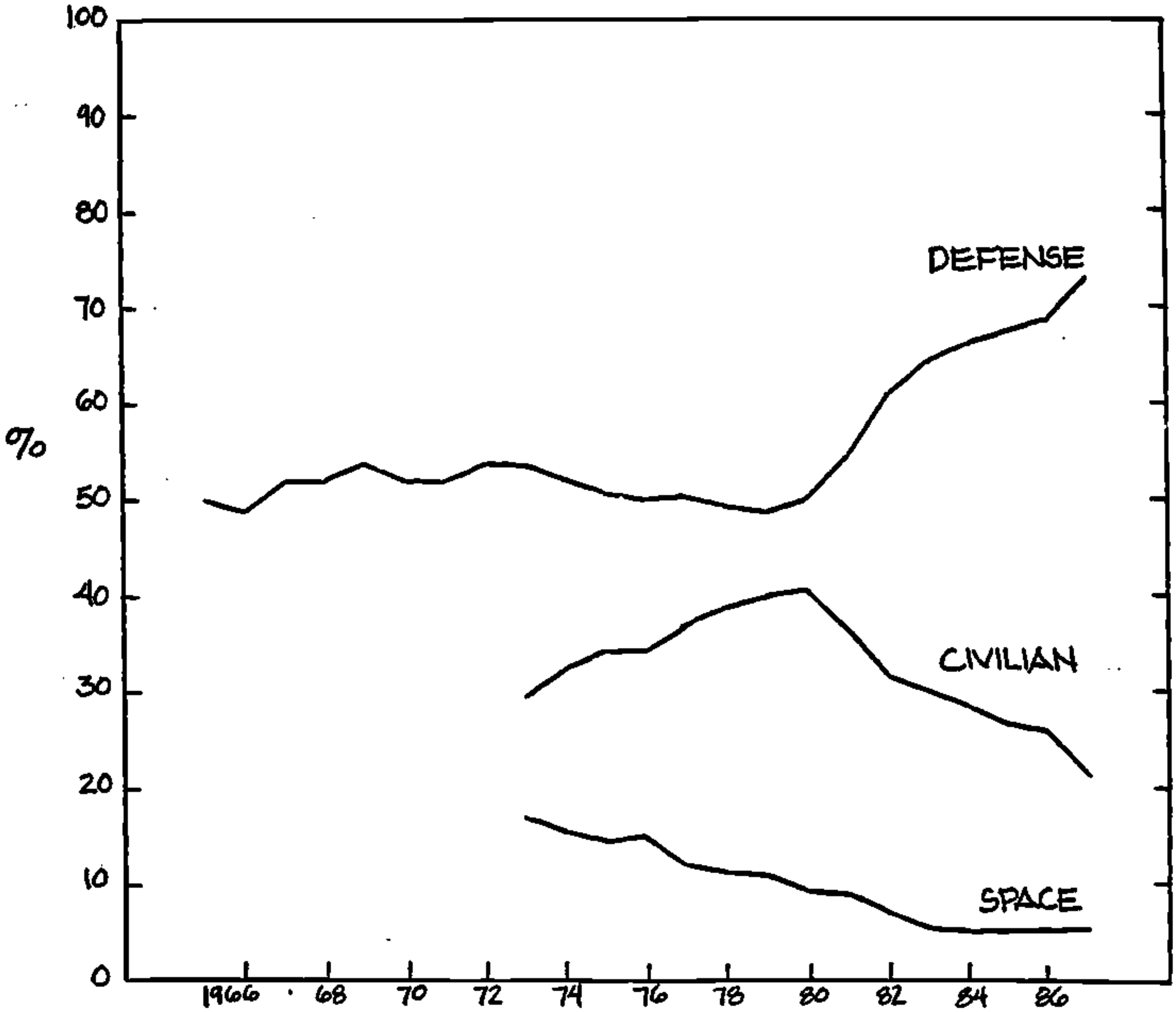
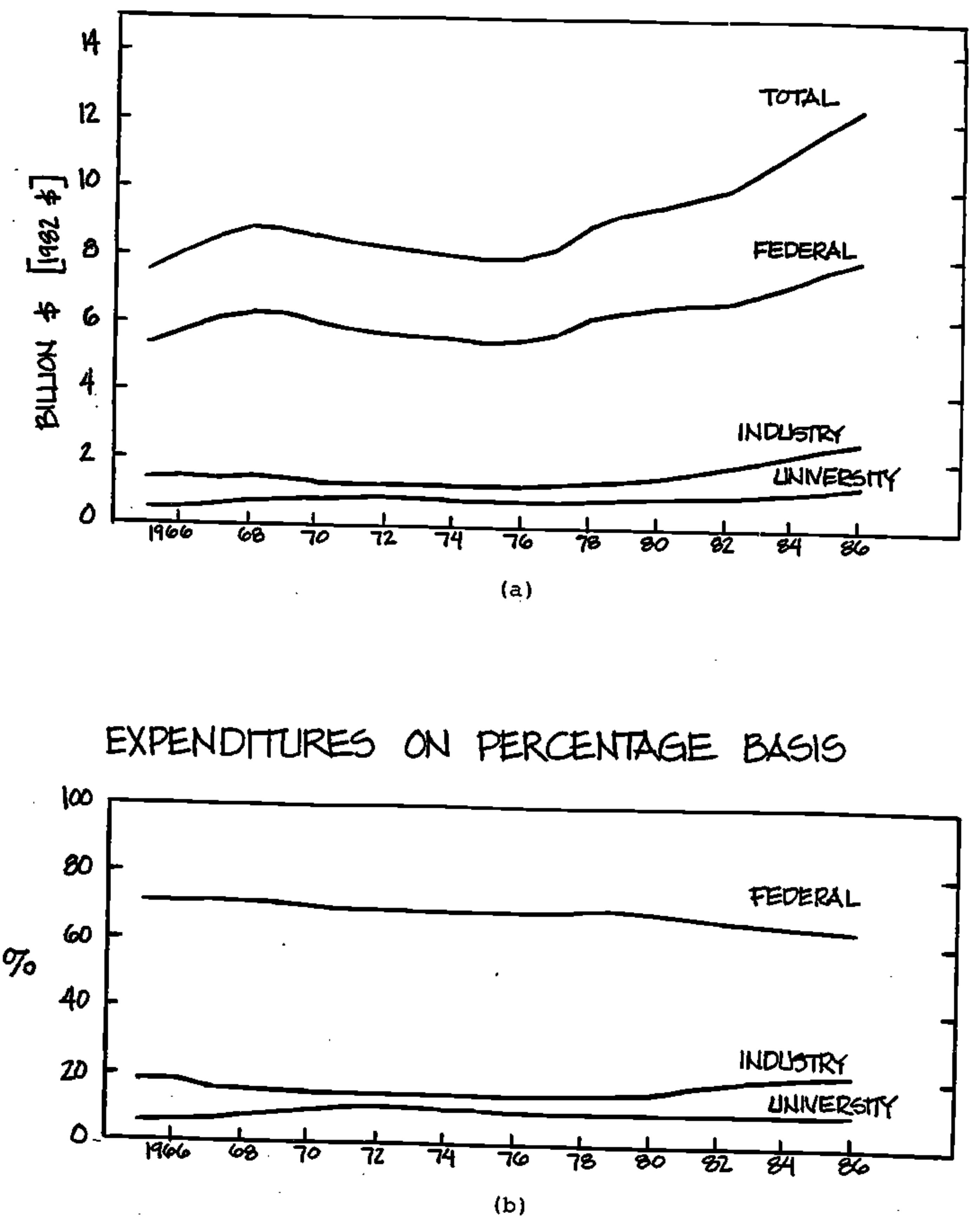


Fig. 2

EXPENDITURES FOR BASIC RESEARCH



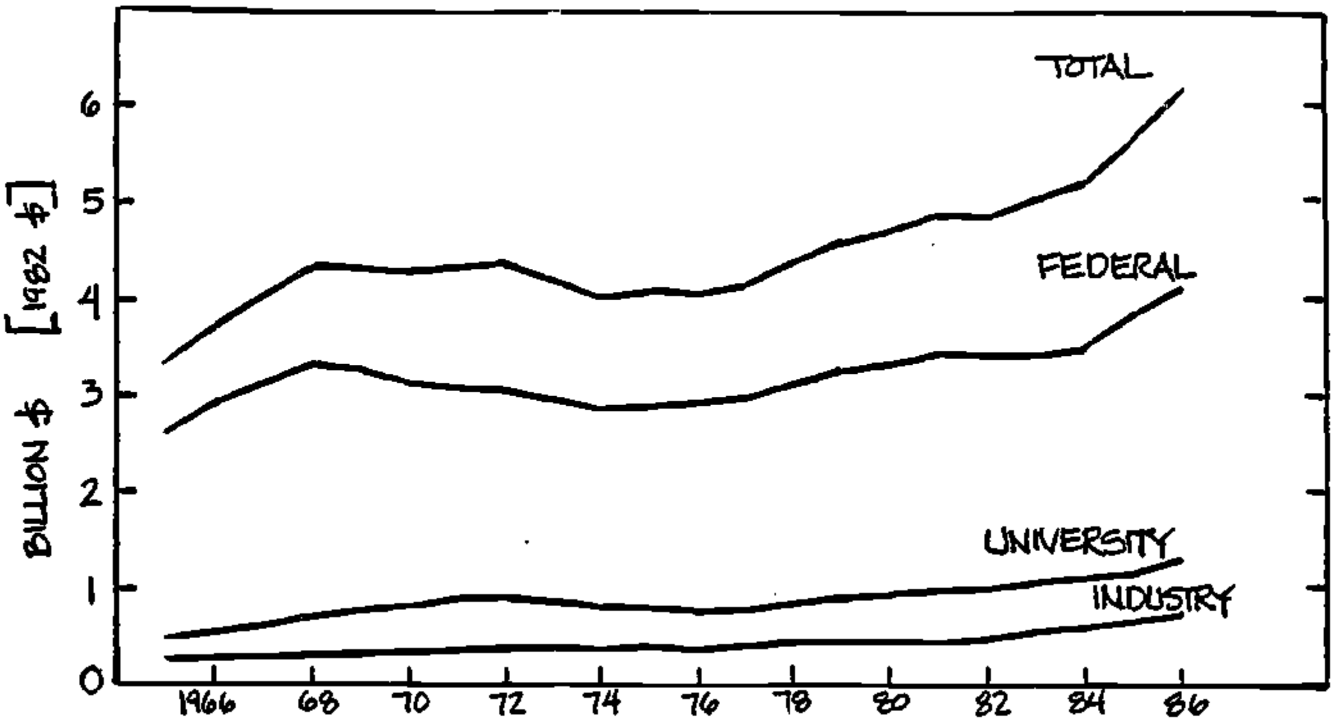
(a)

EXPENDITURES ON PERCENTAGE BASIS

(b)

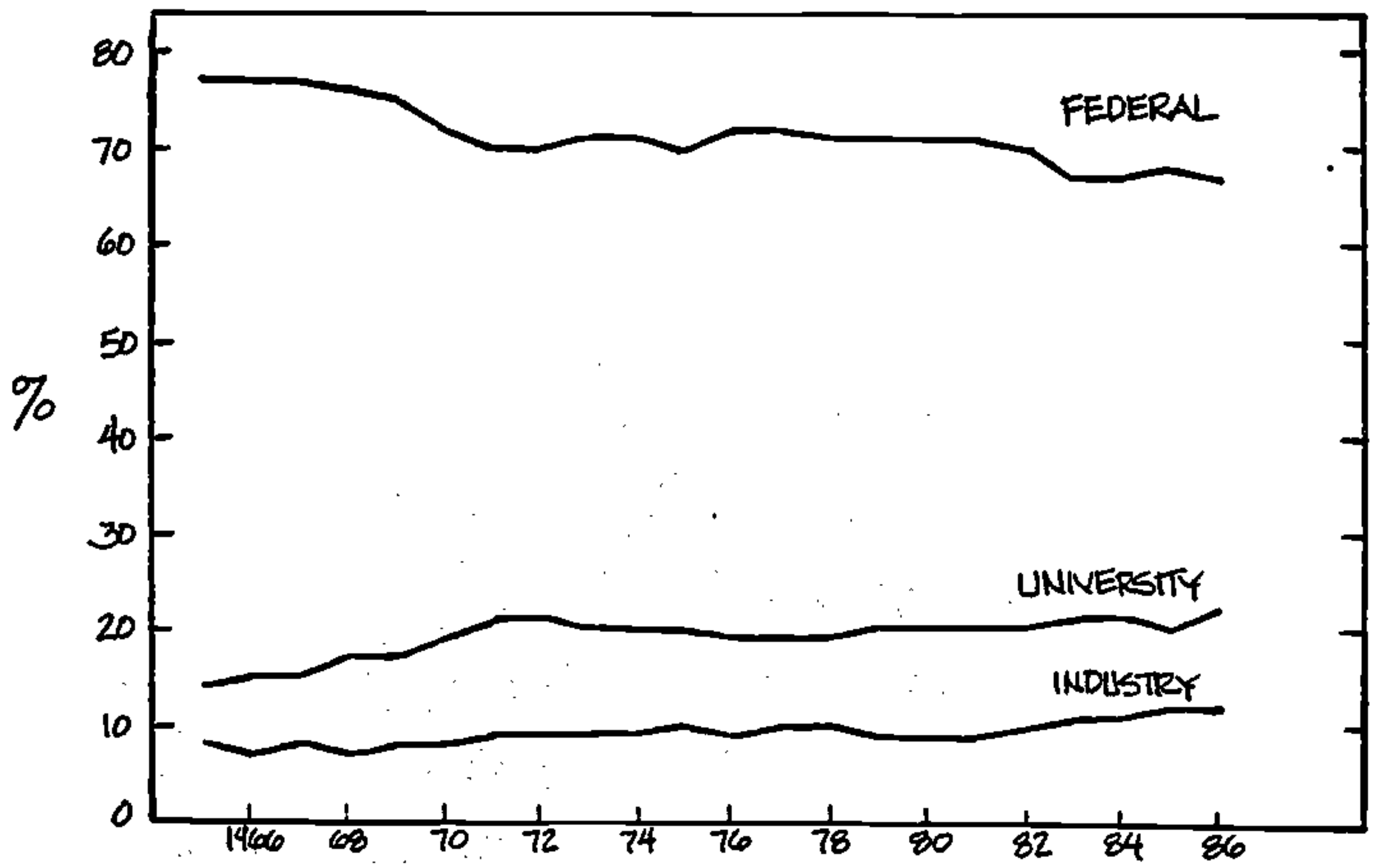
Fig. 3

EXPENDITURES FOR UNIVERSITY BASIC RESEARCH



(a)

EXPENDITURES ON PERCENTAGE BASIS



(b)

Fig. 4

FEDERAL OBLIGATIONS FOR UNIVERSITY RESEARCH AND DEVELOPMENT

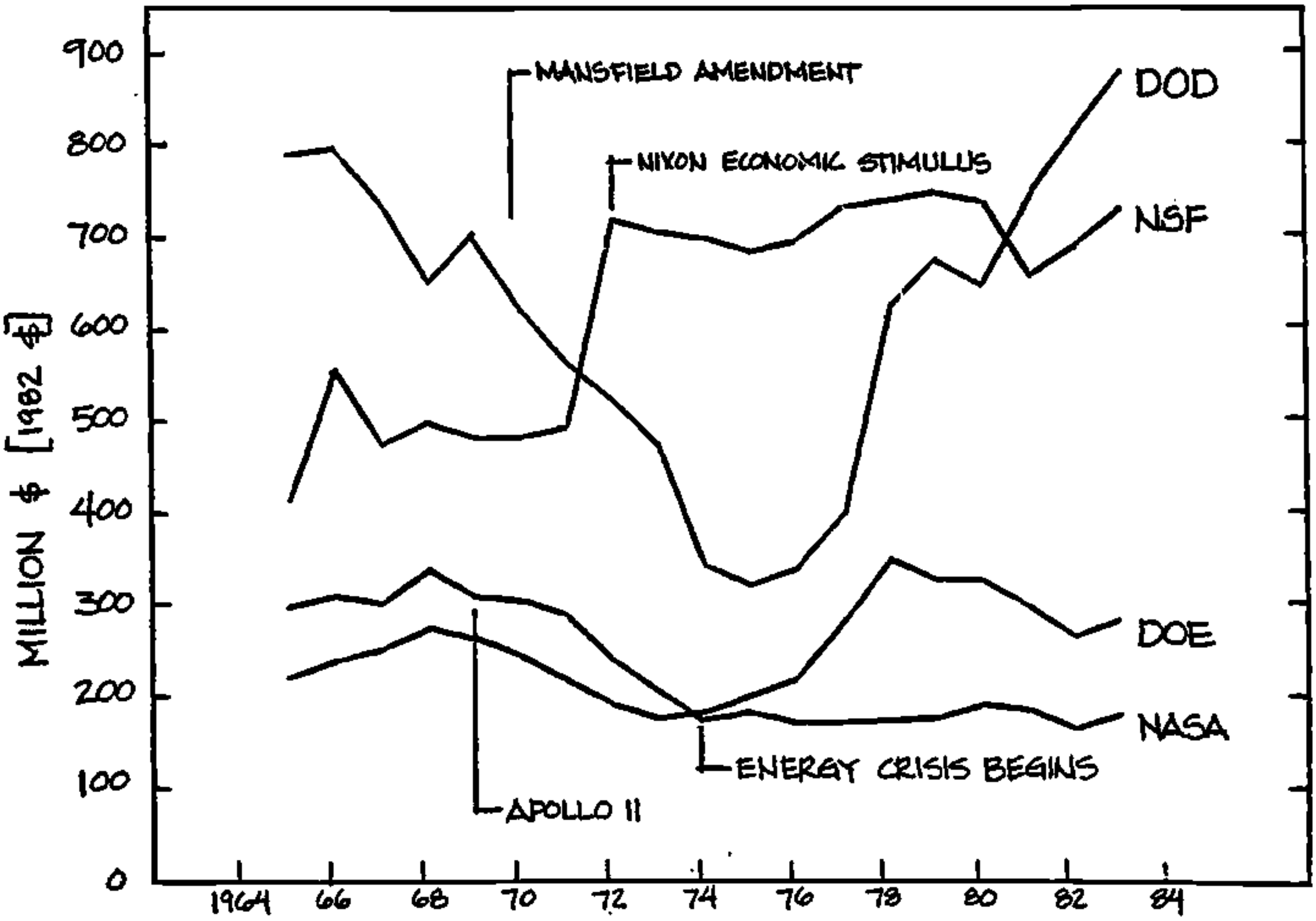


Fig. 5