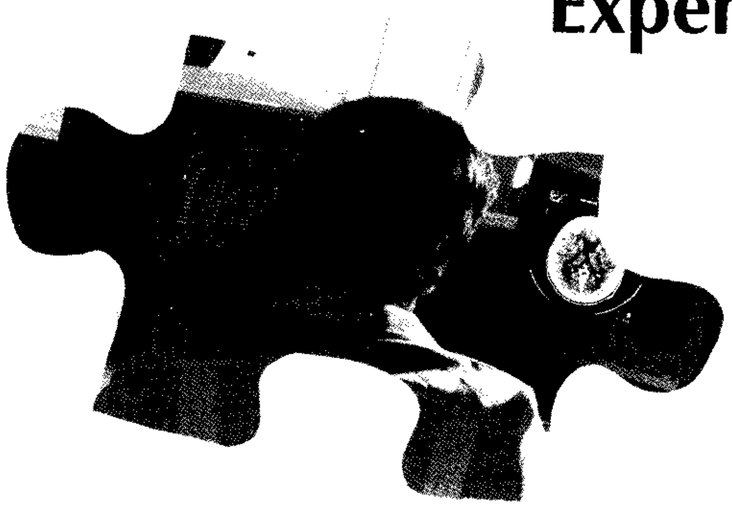
CHAPTER 6

Understanding Research Expenditures



Contents

Boxes

Figures

Tables

Understanding Research Expenditures

University research is a smokestack industry. That the research university's capital costs are small and easy to cope with is a myth.

William F. Massy[1]

Introduction

Many researchers state that the problem with research funding in the United States is that it has not kept pace with inflation. "Inflation" in this context refers not to inflation in the Gross National Product, but to the rise in apparent research costs. Several factors contribute to research expenditures, but the most notable is the sheer size of the enterprise.

Contributing to confusion over the issue of costs in research are the numerous and sometimes inconsistent meanings of "costs," and the lack of a suitable measure of "research." Specific research activities generally become cheaper to complete with time, due to increasing productivity, for example, of computers and other technologies. However, advances in technology and knowledge also allow deeper probing of more complex scientific problems and create demand for greater resources. Because success in the research environment depends heavily on ''getting there first,' there is clear advantage to having the financial support to acquire additional staff and cutting-edge technology. Thus, competition drives up demand for funding. In this sense, the demand for more resources (costs of research) will continue to outpace any increases in Federal funding. (For a more complete discussion, see chapter 1.)

Available data suggest that an increase in the number of scientists supported by Federal funds combined with real growth in their salaries and benefits have figured heavily into total Federal expenditures.[2] In recent years growth in research budgets (i.e., support) has also been accompanied by a growth in researcher's expectations (i.e., demand). In addition to increased competition through the 1980s for available agency research funding,[3] research expenditures on scientific projects (both direct and indirect) have grown, generally above the rate of inflation. Some claim that research requires more expenditures today because of complexity: what was done yesterday can often be done cheaper today, but 'tomorrow's science' may cost more. As understanding of natural and social phenomena increases, the questions to be answered become more intricate, resulting in increased expenditures or ''sophistication inflation."[4] Complying with increasing layers of regulation has also been cited as responsible for increased expenditures.[5]

Unfortunately, few systematic analyses have been performed to evaluate these claims. Complicating questions on the cost of research are incomplete and murky data on research expenditures. Definitions of what is being measured over time are straightforward, but the activity that they purport to capture is constantly changing. In addition, much of the current debate over expenditures takes place within

[1]William F. Massy, ''Capital Investment for the Future of Biomedical Research: A University Chief Financial Officer's View,' *Academic Medicine,* vol. *64,* August 1989, p. 433.

researchers are now submitting more proposals to improve their chances of maintaining or increasing previous support levels. National Science Foundation, "NSF Vital Signs: Trends in Research Support FY 80-89," draft report, November, 1990, p. 3. The National Science Foundation (NSF) found that the average number of proposals submitted by an investigator to win one NSF award had risen from about 1.5 to 1.7. NSF notes that these data do not address the extent to which the increase in proposal submissions to NSF is the result of perceived difficulty in winning awards or other factors such as growth in the population of research fields or greater pressure to win awards for professional advancement.

[3]U.S. Congress, Office of Technology Assessment, ''Proposal Pressure in the 1980s: An Indicator of Stress on the Federal Research System," staff paper of the Science, Education, and Transportation Program, April 1990.

[4]*Science: The End of the Frontier*? a report from Leon M. Lederman, president-elect, to the Board of Directors of the American Association fOr the Advancement of Science (Washington DC: American Association for the Advancement of Science, January 1991), p. 6; and D. Allan Bromley, "Keynote Address,' *Science and Technology and the Changing World Order,* colloquium proceedings, Apr. 12-13, 1990, S.D. Sauer (cd.) (Washington DC: American Association for the Advancement of Science, 1990), p. 11.

[5]National Science Foundation, *Scientific and Engineering Research Facilities at Universities and Colleges: 1990* (Washington, DC: September 1990), p. xvii.

the context of agency budget constraints and pressures felt by research performers. Determining g what is an adequate amount of Federal money for the conduct of research is not easy, and is only compounded by confusion over true costs.[6]

Analysis of expenditures for the conduct of research focuses on what Federal agencies are willing to spend for personnel, facilities, and instrumentation, but gives neither an accurate picture of what the needs are nor whether expenditures are being totally recovered by the research performers.[7] Individual components of the research budget have not risen significantly, with the exception of salaries and fringe benefits. However, more scientists and engineers are doing research; they are getting paid more for their work, and they are spending more. Annual expenditures, including operating, equipment, and capital (facilities) spending per full-time equivalent investigator, are estimated to have increased from $85,000 (1988 dollars) in 1958 to about $170,000 by the late 1960s, where they leveled off through the 1970s. In the 1980s, expenditures rose to $225,000 (see figure 6-l).

Thus, an academic scientist today spends almost three times as much (in real terms) for research as in 1958. Figure 6-2 shows that expenditures have risen in every component (personnel, facilities, equipment, students, other) for three decades. However, available data point to personnel and indirect cost expenditures as the most important components of increases. Personnel expenditures have less accounting flexibility: unlike facilities and instrumentation costs, they cannot be deferred or depreciated.[8] Federally supported academic research is salary intensive. This leads to salaries and fringe benefits affecting the direct cost equation more than nonpersonnel items.

Indirect costs have been rising faster than direct costs. Academic institutions claim that is because the more expensive items, such as facilities and administration, more often fall into the indirect cost category, while controllable expenditures, such as research personnel and graduate students, fall into the direct cost line. The confusion about indirect v. direct costs of research is, in part, complicated by philosophical differences about where expenditures should be assigned. For at least the past 20 years, a debate has been carried on between university administrators and Federal granting agencies over who should pay for what in academic-based research. Although the grant is for research, it is signed with an institution, which incurs expenditures beyond the scope of the research being performed. It has been the practice of the Federal Government to consider research as integral to the university mission and, therefore, its cost should be shared by both parties.[9]

This chapter looks at the issue of research expenditures from two perspectives—the Federal Government as funder, and the research university as performer.[10] Available data concerning specific budget items (e.g., salaries, instrumentation, indirect costs, and facilities) are presented. These data are collected by granting agencies and tend to reflect agency expenditures rather than actual costs to the researcher. Expenditures, as recognized from the perspective of the university research performer, are also discussed as a component of financial planning, proposal-writing strategies, and changing expectations.

[6]For an illustration, see Daniel E. Koshland, ''The Underside of Overhead, " *Science, vol.* 248, May 11, 1990, p. 645; and letters, published as ''The Overhead Question," in response to Koshland's editorial, *Science,* vol. 249, July 6, 1990, pp. 10-13.

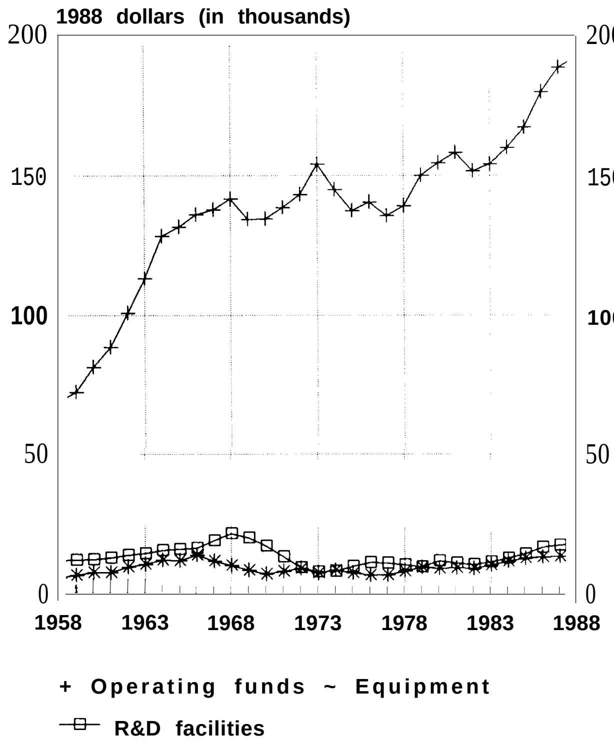
[7]Analysis is confounded by the expenditure accounting schemes that vary from research institution to institution, making comparisons both difficult and perilous, For au attempt to compare expenditures at two public and two private universities associated with the performance of National Science Foundation-funded research, see G.W. Baughman, "Impact of Inflation on Research Expenditures of Selected Academic Disciplines 1967- 1983,' report prepared for the National Science Foundation and the National Center for Educational Statistics, Nov. 8, 1985. Also see Research Associates of Washington *Higher Education Price Indexes: 1990 Update* (Washington, DC: 1990).

[8]For at least the fifth consecutive year, faculty salaries have increased more than the cost of living. From November 1989 to November 1990, *the* consumer price index increased 6.3 percent. During that same period, average faculty pay increased 7.1 percent. Reported in 'Faculty Pay and the Cost of Living," chart, *The Chronicle of Higher Education,* vol. 37, No. 17, Jan. 9, 1991, p. A15.

[9]This practice fuels what is known as the ' 'full cost recovery' debate. See Stephen P. Strickland, *Research and the Health of Americans* (Lexington, *MA:* Lexington Books, 1978).

[10]Expenditures in industrial research are not considered here, but have been addressed in two other OTA reports. See U.S. Congress, Office of Technology Assessment, *Making Things Better: Competing in Manufacturing,* OTA-ITE-443 (Washington, DC: U.S. Government Printing Office, February 1990); and *Government Policies and Pharmaceutical Research and Development* (Washington DC: U.S. Government Printing Office, forthcoming 1991).

Figure 6-l—Academic R&D Expenditures per FTE Investigator by Type of Expenditure: 1958-88
(in thousands of 1988 dollars)

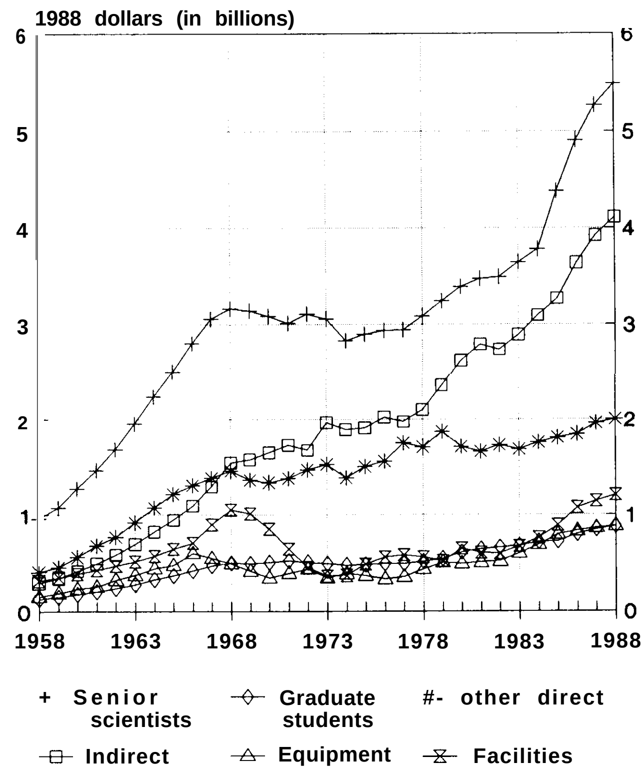


NOTE: Constant dollars were calculated using the GNP Implicit Price Deflator.

DEFINITION OF TERMS: Operating funds refer to current fund expenditures for academic research and development (R&D) activities that are separately budgeted and accounted for, including expenditures for senior scientist and graduate student compensation, other direct costs, and indirect costs associated with conduct of academic research. Equipment includes reported expenditures of separately budgeted current funds for the purchase of academic research equipment, and estimated capital expenditures for fixed or built-in research equipment. R&D facilities include estimated capital expenditures for academic research facilities. Full-time equivalent (FTE) investigators include those scientists and engineers conducting funded (separately budgeted) academic R&D; the FTE is an estimate, derived from the fraction of faculty time spent in those research activities, nonfaculty scientists and engineers employed to conduct research in campus facilities (except federally funded R&D centers), and postdoctoral researchers working in academic institutions.

SOURCE: Government-University-Industry Research Roundtable, *Science and Technology in the Academic Enterprise: Status, Trends and Issues* (Washington, DC: National Academy Press, 1989), figure 2-45.

Figure 6-2—Estimated Cost Components of U.S. Academic R&D Budgets: 1958-88
(in billions of 1988 dollars)



NOTE: Constant dollars were calculated using the GNP Implicit Price Deflator.

DEFINITION OF TERMS: Estimated personnel costs for senior scientists and graduate students include salaries and fringe benefits, such as insurance and retirement contributions. Other direct costs include such budget items as materials and supplies, travel, subcontractors, computer services, publications, consultants, and participant support costs. Indirect costs include general administration, departmentadministration, building operation and maintenance, depreciation and use, sponsored-research projects administration, libraries, and student services administration. Equipment costs include reported expenditures of separately budgeted current funds for the purchase of research equipment, and estimated capital expendituresforfixedor built-in research equipment. Facilities casts include estimated capital expenditures for research facilities, including facilities constructed to house scientific apparatus.

DATA: National Science Foundation, Division of Policy Research and Analysis. Database: CASPAR. Some of the data within this database are estimates, incorporated where there are discontinuities within data series or gaps in data collection. Primary data source: National Science Foundation, Division of Science Resources Studies, Surveyof Scientific and Engineering Expenditures at Universities andColleges; National Institutes of Health; American Association of University Professors; National Association of State Universities and Land-Grant Colleges.

SOURCE: Government-University-Industry Research Roundtable, *Science and Technology in the Academic Enterprise: Status, Trends and Issues* (Washington, DC: National Academy Press, 1989), figure 2-43.

Photo credit: Research Triangle Institute

The cost of complying with regulations of research procedures and equipment is one of a long list of changing expenditures for Federal research. However, indirect costs and salaries are the largest expenditures in federally funded research.

Expenditures From the Federal Perspective

This section explores what is known about research expenditures from the perspectives and databases of two granting agencies—the National Science Foundation (NSF) and the National Institutes of Health (NIH). It also includes a discussion of cost data collected by NSF pertaining to all Federal research and development (R&D) (as that is the level at which the available data are aggregated), as well as analyses conducted by the National Academy of Sciences and other cost analysts.

Direct v. Indirect Costs

The Office of Management and Budget (OMB) guidelines for indirect costs include those that are incurred for common or joint objectives and therefore cannot be identified readily and specifically with a particular sponsored project, an instructional program, or any other institutional activity.[11] Indirect costs reflect the contractual arrangements between the agency and a particular university, regardless of actual expenditures at that university. The rate is negotiated based on allowable charges, past experiences, and expectations for the period under negotiation. The indirect cost ratio is the proportion of total award budget applied to indirect costs. In general, all research agencies pay the same indirect cost rate at a given institution (the Department of Agriculture is the exception in that formulas are used). Direct costs are those that can be identified with a particular sponsored project, instructional program, or any other institutional activity; or that can be directly assigned to such activities with a high degree of accuracy.

The guidelines for calculating costs were developed in conjunction with OMB Circular A-21 and have been in force since 1979. OMB also specifies the method for calculating the indirect portion of salaries and wages paid to professional employees. A requirement exists for assigned workload to be incorporated into the official records and for that system to reflect 100 percent of the work for which the employee is being compensated.[12] Thus, the record should show the percentage of time spent on research, teaching, and administrative duties.

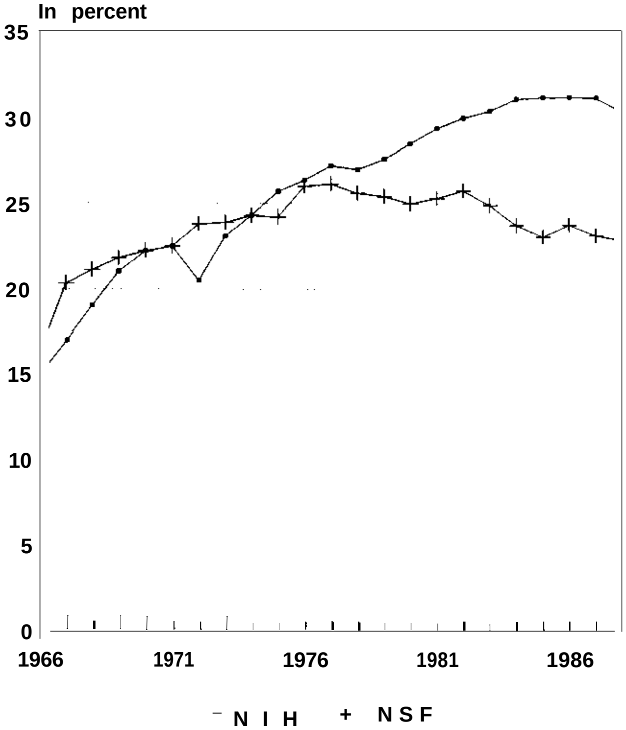
Every major research university has an indirect rate established for the current fiscal year for recovery of costs associated with sponsored research. These rates have evolved over many years as a result of direct interaction and negotiation with the cognizant Federal agency. There is a wide range of indirect cost rates among universities, with most noticeable differences between public and private institutions; rates tend to be higher at private institutions.[13] Rates vary because of: 1) real and significant differences in facilities-related expenditures, 2) tacit or overt underrecovery by some universities, 3) imposition of arbitrary limits by

[11] U.S. Department of Commerce, Bureau of Economic Analysis, *Biomedical Research and Development Price Index.- Report to the National Institutes of Health* (Washington, DC: Mar. 30, 1990).

[12] Ibid., p. 18. Also see U.S. Congress, Office of Technology Assessment, *The Regulatory Environment for Science*, OTA-TM-SET-34 (Springfield, VA: National Technical Information Service, February 1986), pp. 73-76.

[13] Rep. John Dingell's Energy and Commerce Subcommittee on Oversight and Investigations launched in late fall 1990 an investigation Of indirect cost practices at universities, beginning with Stanford. See Marcia Barinaga, "Stanford SailS Into a Storm,' *Science*, vol. 250, Dec. 21, 1990, p. 1651; "Government Inquiry,' *Stanford Observer*, November-Deeember 1990, pp. 1, 13; and Marcia Barinaga, ''Indirect Costs: How Does Stanford Compare With Its Peers," *Science, vol. 251*, Feb. 15, 1991, pp. 734-735.

Figure 6-3—indirect Cost Ratios for NSF and NIH: 1966-88 (indirect cost as a percent of total R&D cost)



KEY: NIH=National Institutes of Health; NSF=National Science Foundation.

SOURCE: National Science Foundation, Policy Research and Analysis Division, estimates based on unpublished NIH and NSF data, 1990.

some government agencies in the negotiation process, and 4) diversity in assigning component expenditures as direct or indirect.[14]

Figure 6-3 indicates the trends in indirect costs as a proportion of total research expenditures for NIH and NSF. In part, the ratios vary because NIH separates direct and indirect costs, and proposals are evaluated based mainly on direct costs. NSF, on the other hand, considers total costs in making an award (usually after merit review).

Confusion about the relationship between the indirect cost rate and what is allowable for adminis-

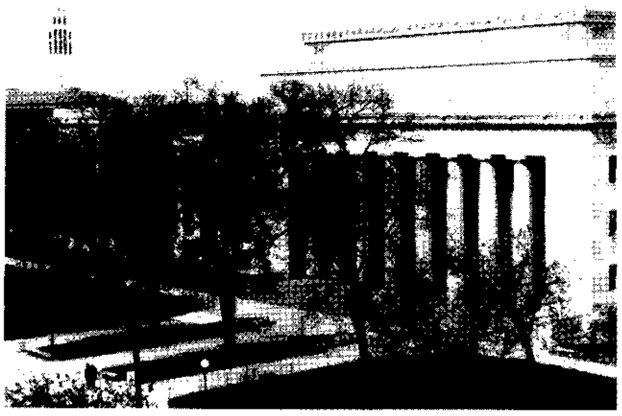


Photo credit: University of Michigan

Indirect cost rates vary in part because of differences in campus facilities. The University of Michigan, pictured here, devotes many of its facilities to research.

trative and student service components reflects the difficulty of separating expenditures along lines of research, instruction, and other functions.[15] Equipment and facilities-related components of the rate seem to be less controversial, perhaps because of better documentation of expenses in these areas. Some have advocated that two rates should be calculated for indirect costs-one for facilities and equipment, and one for all other components, such as administrative, library, and student services.[16] This view has considerable relevance as universities renovate or replace aging facilities and equipment.

Aggregate Expenditure Data for Personnel, Facilities, and Equipment

Expenditures for facilities and equipment are frequently cited as a drain on the academic financial resource base. These data, however, mix actual and planned expenditures. As universities compete against industry and each other for resources, funding needs grow, as does spending. Competition in the university environment has also driven up the "set up' price of the average scientist.[17] Data on salaries and personnel are more reliable because

14 Association of American Universities, *Indirect Costs Associated With Federal Support of Research on University Campuses: Some Suggestions for Change* (Washington, DC: December 1988).

15 Eleanor C. Thomas and Leonard L. Lederman, Directorate for Scientific, Technological, and International Affairs, National Science Foundation, "Indirect Costs of Federally Funded Academic Research, " unpublished report, Aug. 3, 1984, p. 1.

16 Association of American Universities, op. Cit., footnote 14.

17 The Government-University-Industry Research Roundtable, *Science and Technology in the Academic Enterprise: Status, Trends, and Issues* (Washington, DC: National Academy Press, 1989), p. 2-33.

these cost categories cannot be deferred and are documented annually.

Personnel

For the past three decades, personnel expenditures have accounted for about 45 percent of total costs of academic research charged to the Federal Government, consistently the largest share of the budget. Salaries have been on the rise and from 1981 to 1988 the number of scientists and engineers employed in academic settings increased steadily from about 275,000 to almost 340,000.[18] Increased numbers of investigators and rising salaries (and the benefits that go with them) have driven up the price of the personnel component of direct costs. In future years, it is anticipated that the personnel component of research budgets will rise further due to a faster rate of inflation in salaries than in other categories such as equipment and facilities.[19] And the fiscal year 1991 appropriation for NSF lifted the $95,000 annual salary cap on principal investigators that can be charged to a grant.[20]

The patterns for spending on graduate students mirror that for principal investigators. Increases in the number of graduate students supported, however, were larger than the growth in the number of scientists due to a greater reliance on the research grant as a support mechanism.[21]

Research Facilities Construction and Renovation

Research facilities may be defined as the environment within which research is conducted, as opposed to research instruments, or the tools that scientists and engineers use to collect data. Facilities currently receive about 10 percent of the Federal R&D budget compared to about 6 percent at the beginning of the 1980s.[22] Most of the data available on scientific and engineering research facilities are collected by NSF on a biennial basis in response to the 1986 National Science Foundation Authorization Act (Public Law 99-159). The act required NSF to design, establish, and maintain a data collection and analysis capability for the purpose of identifying and assessing the research facilities needs of universities arid colleges. Data are not available before 1986. The assessments are based in part on estimates, relying on reported capital projects-both actual and planned-and anticipated spending for construction and repairs of research facilities.[23] Actual expenditure data are derived from expenditures in previous years.

In constant 1988 dollars, annual capital expenditures for academic science and engineering facilities nearly tripled during the ''golden age" from $1.3 billion in 1958 to $3.5 billion a decade later. Expenditures dropped to $1 billion in 1979 (1988 dollars) and stand at $2 billion in 1988. Presently, the Federal share of facilities funding is 11 percent, down from a high of 32 percent in the 1960s.[24]

In 1986-87, academic institutions initiated major repair and renovation projects in academic research space totaling $840 million. In 1988-89, this figure rose to $1.04 billion.[25] Estimated deferral rates for repair and renovation are $4.25 for every dollar spent in 1990, up from $3.60 in 1988.[26]

Institutions' spending for *new* construction of research facilities was expected to grow from $2.0 billion in 1986-87 to $3.4 billion in 1988-89, an average increase of about 30 percent per year.[27] A 1990 update revealed that costs for 1988-89 new

---

18Ibid., p. 2.34, based on National Science Foundation data.

19National Science Foundation, *The State of Academic Science and Engineering* (Washington, DC: 1990), pp. 119-149. Of course, personnel expenditures would be much higher if full salary and fringe benefits were charged to the Federal Government. Most universities absorbsubstantial portion of such expenditures. Some agency programs will pay for only 2 to 3 summer months. Leonard Lederman, Directorate for Scientific, Technological, and International Affairs, National ScienceFoundation, personal communication, December 1990.

20‘ ‘NSF Back To Normal After Budget pause, ’ *Chemical & Engineering News, vol. 68, No. 48, Nov. 26, 1990,* p. 12.

21National Science Foundation, op. cit., footnote 19, pp. 124-125.

22Ibid., pp.134-139.

23According t. National Science Foundation commentators on this October 1990 OTA draft chapter, estimates of ‘need'' denote deferral Of facilities expenditures (both new construction and repair/renovation project..), not an institutional “wish list. ” National Science Foundation staff, personal communication, December 1990.

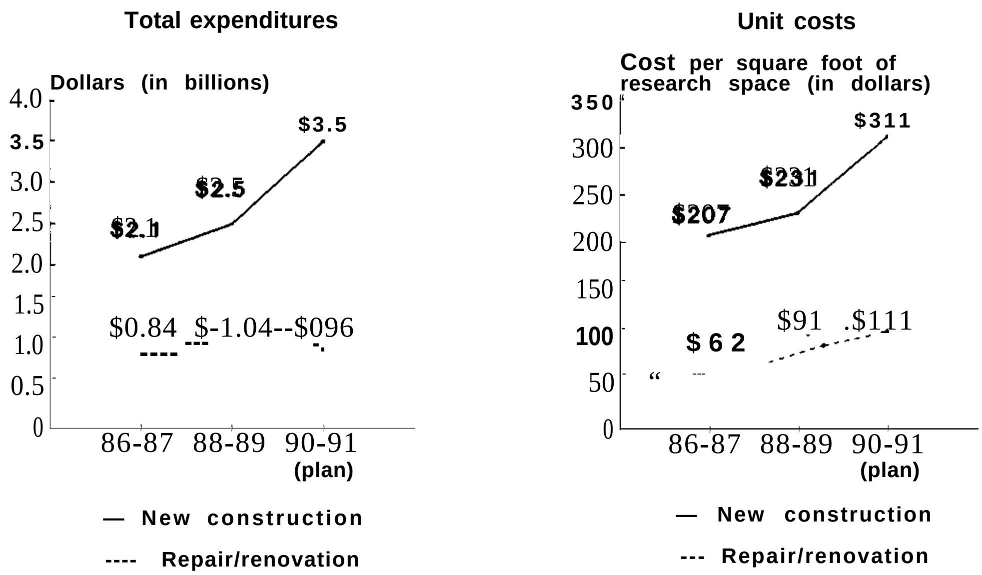
24&, ernment-University-Industry Research Roundtable, op. cit., footnote 17, pp. 2-28, 2-29.

25National Science Foundation, op. cit., footnote 5, p. Xvii.

26Ibid., p. xix.

27National Science Foundation, Scientific *and* Engineering *Research* Facilities at *Universities and* Colleges: *1988* (Washington, DC: September 1988).

Figure 6-4—Total Expenditures and Unit Costs for Recent and Planned Academic Capital Projects: 1986-91



NOTE: Estimates of research space are based on net assignable square feet assigned to organized research.

SOURCE: National Science Foundation, *Scientific and Engineering Research Facilities at Universities and Colleges: 1990*, final report, NSF 90-318 (Washington, DC: 1990), chart 4, and p. A-10.

construction projects totaled only $2.5 billion, considerably less than projected.[28] Private institutions among the top 50 recipients of Federal R&D funds report considerably higher spending levels than public institutions, both for construction and repair and renovation. The reverse is true among institutions not in the top 50, where spending levels are higher at public institutions.[29]

The unit cost of new construction (the cost per net square foot) grew in real terms from $207 in 1986-87 to $231 in 1988-89, an increase of about 12 percent per year (see figure 6-4). Construction expenditure increases of this magnitude, which are above the rate of inflation, are attributed in part to changing technical and regulatory requirements such as animal quarters,[30] biohazard containment safeguards, and toxic waste disposal facilities. These regulatory requirements are especially relevant to the medical and biological sciences, but vary with the institutional setting in which the research is conducted.[31]

The proportion of Federal support for construction is about 11 percent in private institutions and 8 percent in public institutions (see figure 6-5). The Federal Government also pays for renovation and repair costs in part through the indirect cost rate, and in 1988, the Federal Government supplied nearly $1 billion to support university infrastructure through indirect costs. Almost 20 percent was for facilities depreciation, while the rest was recovered for

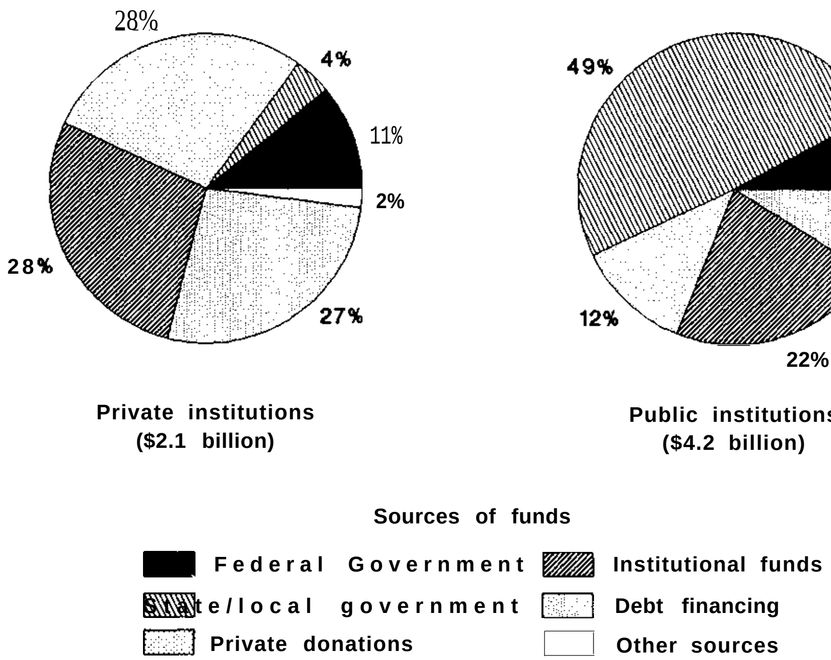
[28] National Science Foundation, op. cit., footnote 5. The report suggests that inability to obtain sufficient funding was the principal reason given by institutions for postponing or scaling back planned construction projects.

[29] Ibid., pp. 19-24.

[30] The Alcohol, Drug Abuse, and Mental Health Administration estimates that new regulations for animal care will cost $40,000 to $70,000 per grant for the care of primates and dogs. See Constance Holden, "A Preemptive Strike for Animal Research," Science, vol. 244, Apr. 28, 1989, pp. 415-416. An American Association of Medical Colleges survey of 126 medical schools estimated that animal rights activities cost U.S. medical schools approximately $17.6 million for increased security, insurance, recordkeeping, and compliance over the last 5 years; as reported in Washington *Fax*, July 23, 1990.

[31] Office of Technology Assessment op. cit., footnote 12, pp. 85-96. Also see Philip H. Abelson, "Federal Impediments to Scientific Research" *Science, vol.* 251, Feb. 8, 1991, p. 605. Abelson estimates that the Federal Government imposed more than 23 administrative reporting requirements on universities during the 1980s.

Figure 6-5-Relative Sources of Funds for Research Facilities: Academic Capital Projects Begun in 1986-89



NOTE: Percentages may not total 100 due to rounding.

SOURCE: National Science Foundation, *Scientific and Engineering Research* Facilities at Universities *and Colleges:* 1990, final report, NSF 90-318 (Washington, DC: 1990), chart 6.

operation and maintenance costs.[32] In absolute terms, Federal funds for new construction of research space more than doubled over the 1986 to 1989 period, and the increase was seen primarily at public institutions.

Equipment and Instrumentation

There is one comprehensive source of data on research equipment and instrumentation expenditures. The National Survey of Academic Research Instruments and Instrumentation Needs is a congressionally mandated, triennial survey program to monitor trends in academic research. It is sponsored jointly by NIH and NSF, and has been completed twice, first in 1983-84 and again in 1986-87.[33] A new survey is in progress. The survey collects data about expenditures, funding, and use of major research instruments (costing $10,000 to $1 million) in engineering, and in the agricultural, biological, computer, environmental, and physical sciences. Information is collected about both quantitative and qualitative changes in in-use instrumentation and equipment.

Results from these surveys show that there is substantial turnover in the national stock of in-use academic research equipment. About one out of every four systems in research use in 1982-83 was no longer being used for research by 1985-86, and about two out of five systems in research use in 1985-86 had been acquired in the 3-year period since the baseline data were obtained.[34] Computer science had the most rapid rate of expansion in stock (up 138 percent over the 1982 to 1986 period), with slow

32 Facilities have contributed greatly to the rising indirect cost reimbursements. Over the period 1982 to 1988, the Federal support of university infrastructure through indirect cost recovery grew by over 70 percent in real terms. See "Enhancing Research and Expanding the Human Frontier," *Budget of the United States Government, Fiscal Year 1992* (Washington, DC: *U.S. Government Printing Office,* 1991), pp. 61-62. This document further states that: "Each academic institution must provide a certification that its research facilities are adequate (to perform the research proposed) as a condition of accepting research grants. . . . [The] $12 billion of needed, but unfunded capital projects has not had an apparent effect on the ability of universities to accept Federal research funds. ' The $12 billion estimate comes from the 1990 National Science Foundation survey of universities.

33 National Science Foundation, *Academic* Research *Equipment in Selected* Science/Engineering *Fields: 1982-83* to *1985-86,* SRS 88-D1 (Washington, DC: June 1988).

34 Ibid.

Photo credit: Jay Mangum Photography

Researcher uses a CT scanner. State-of-the-art equipment often enables researchers to push the frontiers of scientific knowledge.

growth in mechanical engineering (up 23 percent) and materials science (22 percent). The data indicate that Federal and non-Federal expenditures for academic research equipment increased from $393 million (1982 dollars) in 1980 to $704 million in 1987.[35] Yet the mean purchase price per system for all in-use equipment in 1985-86 was $36,800, basically unchanged from 1982-83 (up only 1 percent after inflation). Computer science was the only field to show a substantial real change in the mean price per unit of in-use instrumentation, dropping 22 percent after adjusting for inflation,[36]

Federal involvement in funding academic research equipment declined somewhat from 1982-83 to 1985-86. Fifty-five percent of all systems in use in 1986 were acquired either partly or entirely with Federal funding support, down from 60 percent in 1982-83. Despite this relative decline, Federal support for in-use research equipment increased 30 percent in real dollar terms, from $663 million in 1982-83 to $906 million in 1985-86.[37] Data for select Federal funding sources are displayed in table 6-1. Not unexpectedly, funding for equipment under development, or considered state-of-the-art, grew at higher rates than existing systems. Qualitative upgrading (e.g., incremental improvement in the power and capability of existing equipment), however, varies across fields, e.g., chemistry experienced more upgrading than agricultural sciences.

Despite pronounced increases and improvements in equipment stocks in the 1980s, 36 percent of department heads still describe their equipment as inadequate (to conduct state-of-the-art research). In general, the survey data reveal that equipment stocks have been substantially replenished and refurbished during the period of 1982 to 1986 in all of the fields studied and in all types of institutions. There have been substantially increased levels of support for instrumentation from all sources, with most of this increased support coming from the colleges and universities themselves, as well as from businesses, private donors, and State governments. In relative terms, computer science was the greatest beneficiary of the overall increase in instrumentation support, particularly from Federal sources, with engineering suffering the most. Among all Federal sources of equipment support, NSF provided the largest share (33 percent of the total) .38

Within the biological sciences, biochemistry more than doubled its equipment stocks between 1984 and 1987, the fastest rate of growth of any major biological field. There appears to be an increasing need in the biological sciences for big-ticket items costing over $50,000 (1984 and 1987 prices for some items are shown in table 6-2). The percentage of department heads reporting equipment in this range as being their top priority for more Federal funding increased from 20 percent to 35 percent from 1984 to 1987.[39]

Expenditures for equipment were $200 million (1988 dollars) in 1958, rose to $600 million in the 1960s, fell to below $400 million in the 1970s, and

[35]Ibid., p. 17.

[36]Some universities, however, spend more on equipment than others. The top 20 research and development universities had in stock an average of $27.9 million worth of inuse equipment in the 1985-86 academic year. The average for the next 154 institutions was $6.9 million. National Science Foundation 1989, op. cit., footnote 19, pp. 130-133.

[37]National Science Foundation, op. cit., footnote 33, p. 17.

[38]Federal agencies provided 46 percent of the funding for biological science equipment use in 1987; the National Institutes of Health provided 76 percent of the Federal shine. Ibid., pp. 59-64.

[39]U.S. Department of Health and Human Services, National Institutes of Health, *Academic Research Equipment and Equipment Needs in the Biological Sciences: 1984-1987* (Washington, DC: June 1989), pp. 8-1 through 8-10.

Table 6-l—Selected Sources of Funding for 1985-86 National Stock of In-use Research Equipment and Percent Change From 1982-83,[a] by Field (in millions of 1985-86 dollars)

Field	Total research equipment	NSF	NIH	DOD	DOE	State/ university funds	Business donations
Computer science	$100 (85%)	$26 (123%)	$1 (UE)	$20 (99%)	<$1 (UE)	$25 (38%)	$20 (61%)
Engineering:	372 (34%)	38 (l%)	5 (UE)	59 (16%)	17 (15%)	135 (35940)	81 (47%)
Electrical	110 (59%)	11 (4%)	1 (UE)	23 (1 1%)	2 (UE)	30 (142%)	36 (187%)
Mechanical	71 (320/o)	7 (-12%)	<1 (UE)	16 (230/o)	1 (UE)	28 (66%)	13 (520/o)
Other	191 (23%)	20 (5%)	5 (UE)	20 (18%)	14 (45%)	78 (10%)	32 (43%)
Materials science	44 (26%)	19 (33%)	<1 (UE)	3 (UE)	4 (UE)	11 (23%)	2 (UE)
Physics/astronomy	221 (16%)	54 (l%)	1 (UE)	28 (13%)	29 (O%)	50 (88%)	14 (2%)
Chemistry	322 (44%)	85 (22%)	32 (64%)	.15 (54%)	17 (186%)	111 (38%)	28 (78%)
Environmental sciences	170 (47%)	30 (71%)	1 (UE)	10 (44%)	15 (70%)	56 (50%)	27 (39%)
Agricultural sciences	62 (61%)	4 (UE)	2 (UE)	<1 (UE)	1 (UE)	39 (55%)	6 (UE)
Biological sciences:	643 (48%)	51 (39%)	226 (44%)	7 (UE)	4 (UE)	247 (54%)	48 (53%)
in colleges/universities	283 (63%)	32 (26%)	79 (51%)	5 (UE)	2 (UE)	123 (89%)	19 (45%)
in medical schools	360 (389%)	19 (66%)	148 (41%)	2 (UE)	2 (UE)	124 (31%)	29 (59%)

[a]Percent change estimates are adjusted for inflation.

KEY: NSF = National Science Foundation; NIH = National Institutes of Health; DOD_ U.S. Department of Defense; DOE= U.S. Department of Energy; UE = unstable estimate: 1982-83 base is less than $4 million.

SOURCE: National Science Foundation, *Academic Research Equipment in Selected Science/Engineering Fields: 1982-83 to* 1985-86 (Washington, DC: June 1988), table A.

Table 6-2—Types and Expenditures for Most Needed Research Equipment: National Estimates for the Biological Sciences, 1984 and 1987[a]

Types of system	Percent of requests 1984	Percent of requests 1987	Median cost per system 1984	Median cost per system 1987
Preparative (e.g., centrifuges, scintillation counters, incubators)	33%	25%	$30,000	$35,000
Protein/DNA sequencers/ synthesizers	11	14	75,000	95,000
Electron microscopy	12	6	150,000	180,000
Light microscopy	4	3	30,000	35,000
High-pressure liquid chromatography	9	12	27,000	25,000
Cell sorters/counters	4	6	150,000	100,000
MNR spectroscopy	4	4	250,000	225,000
General spectroscopy	9	5	25,000	30,000
Mass spectroscopy	2	4	125,000	100,000
image analyzers	3	6	40,000	100,000
X-ray (other than imaging)	1	1	100,000	200,000
Computers	5	5	50,000	45,000
Other	6	9	30,000	45,000

aFindings are based on department chairs' listings of up to three "topmost priorities" in research instruments or systems.

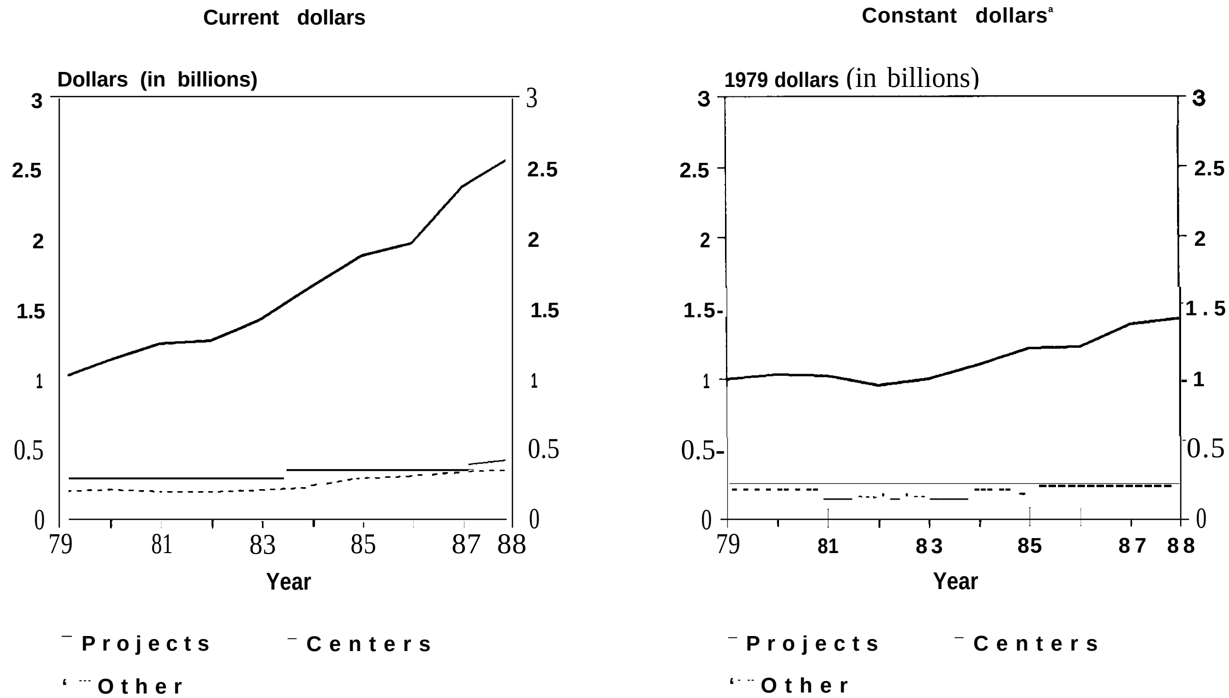
SOURCE: National Institutes of Health, *Academic Research Equipment and Equipment Needs in the Biological Sciences:* 1984-87 (Washington, DC: June 1989).

were over $800 million in 1988. The Federal share of funding was 75 percent in 1958 and now stands at about 60 Percent.[40] NSF found that instrumentation costs have increased (in real dollars) for state-of-the-art instruments, but costs for instruments of similar capability have been decreasing. In addition, obsolescence time was 7 to 10 years in 1975, while the 1986 estimate was 3 to 5 years. And these instruments require funds for maintenance and operation (about 4 percent of the purchase price) .41

[40]Government-University-Industry Research Roundtable, Op. cit., footnote 17, p. 17.

[41]National Science Foundation, op. cit., footnote 19, pp. 130-133. The enhanced power or sophistication of anew instrument, say, an automated DNA sequencer, is seen by researchers as justifying its cost, which is a relatively modest investment for sustaining, or *perhaps* enabling for the first time, the performance of frontier science. As Robert Borchers, associate director for computation at Lawrence Livermore National Laboratory, puts it: "We're scientists. When we hear about a faster machine, we're interested. " Quoted in Marcia Clemmit, "Livermore's Purchase of Japanese Supercomputer Is Blocked," *The Scientist,* vol. 4, No. 23, Nov. 26, 1990, p. 3.

Figure 6-6—Direct Costs Awarded for NIH Research Projects, Research Centers, and Other Research Grants: Fiscal Years 1979-88



[a]Based on the biomedical R&D price index, fiscal year 1979=100.

KEY: NIH=National Institutes of Health.

SOURCE: National Institutes of Health, *Extramural Trends: FY 1979-1988* (Washington, DC: June 1989), p. 18.

University researchers echo the same concerns about research expenditures for equipment: 1) instrumentation is becoming obsolete at a faster rate; 2) many are buying more computer equipment or using a universitywide computer system (for example, the University of Michigan spends over $160 million every year on information systems—10 percent of its operating expenses); 3) most research fields are becoming increasingly dependent on advances in research equipment; 4) support personnel are required in increasing numbers to operate equipment; and 5) maintaining research equipment for a laboratory takes a large amount of researcher time.[42]

Research Expenditures at the National Institutes of Health

The amount of dollars awarded for direct costs of individual investigator-initiated, or RO1, research at NIH has risen steadily since 1979. The direct costs in current dollars awarded that year increased by $1.5 billion, or 155 percent, to a fiscal year 1988 all-time high of $2.6 billion (see figure 6-6). In constant dollars, growth was $408 million, or a net increase of 41 percent. According to NIH's Division of Research Grants, the proportion of indirect costs to total expenditures has increased in 8 of the years from 1979 to 1989, ranging from just under 28 to over 31 percent. Nevertheless, when examining dollars awarded, and controlling for inflation, indirect costs are rising at a faster rate than direct costs (20 percent higher).

Personnel expenditures accounted for 65 percent of the $3.2 billion direct costs budgeted for fiscal year 1988 RO1 research. The next largest category of direct costs was supplies, at 12.4 percent. The equipment category has been stable at 5.2 to 5.6 percent since 1984 (see table 6-3). Noncompeting and competing continuation grants have higher expenditures for personnel than do new grants (68 and 64 percent, respectively, v. 51 percent for new

[42]From OTA interviews at University of Michigan and Stanford University, July-August 1990.

Table 6-3-Extramural Direct Costs by Budget Category at NIH: Fiscal Years 1979-88

Fiscal year	Total direct costs (in billions of dollars)	Personnel (in percent)	Equipment (in percent)	Supplies (in percent)	All other (including hospitalization, in percent)
1979	$1.4	66.80/0	6.2%	13.OYO	14.00/0
1980	1.5	67.8	5.2	13.2	13.8
1981	1.6	68.4	4.5	13.4	13.7
1982	1.7	69.5	4.4	12.7	13.4
1983	1.9	69.4	4.8	12.7	13.1
1984	2.1	68.5	5.2	13.1	13.2
1985	2.4	66.5	5.9	12.7	14.9
1986	2.6	67.8	5.3	11.6	15.3
1987	3.0	65.8	5.8	12.0	16.3
1988	3.2	64.9	5.6	12.4	17.1

SOURCE: National Institutes of Health, *Extramural Trends:* FY 1979-1988 (Washington, DC: June 1989), p. 61.

grants). Conversely, equipment expenditures are higher for new grants than for continuations.

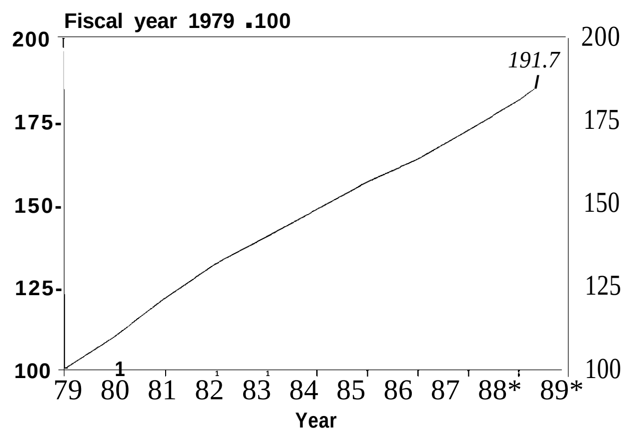
In recent years, NIH has conducted "downward negotiations' of noncompeting grant continuations, whereby the amount awarded in years after the initial award will be less than the original commitment.[43] This practice has resulted in uncertainty for the investigator as to what funding will be available from year to year.[44] It has also led to congressional criticism of financial planning at NIH (see box 6-A).

Calculating the Biomedical Research and Development Price Index

The Biomedical Research and Development Price Index (BRDPI) is a specialized price index calculated since 1979 by the Bureau of Economic Analysis of the Department of Commerce for NIH. The BRDPI is a freed-weight index designed to reflect price changes of the cost to NIH of supporting biomedical R&D. The index is calculated for fiscal years and is currently based on patterns of NIH obligations for fiscal year 1988[45] (see figure 6-7).

The BRDPI is comprised of three major subindices—intramural activities, extramural activities, and extramural nonacademic activities. Within each activity, price indices are available for major components such as personnel, supplies, and equipment. Intramural activities comprise all activities performed by NIH including R&D, as well as support functions for intramural and extramural research. Intramural activities are grouped into 27 categories that correspond to available price measures.

Figure 6-7—Biomedical Research and Development Price Index: Fiscal Years 1979-89



aProjected.

SOURCE: National Institutes of Health, *NIH Data Book:* 1989(Washington, DC: December 1989), inside back cover.

Figure 6-8 shows a comparison of the aggregate BRDPI with three other indices-the Consumer Price Index, the Producer Price Index, and the Gross National Product. The BRDPI has consistently increased at a faster rate than the other three indices, but has slowed in recent years. Table 6-4 displays the BRDPI for the years 1979 through 1989 (fiscal year 1988 is the base). In 1989, the index is highest for

43Marvin Cassman, "Issues Behind the Drop in the NIH Award Rate, " *ASM News, vol. 56,* September 1990, pp. 465-469. Late in 1990, the National Institutes of Health began consideration of a plan whereby funding adjustments would be made prior to award and not through across-the-board cuts.

44In contrast, the National Science Foundation awards a set amount for the grant over a multiyear period. Any cuts in the awards are across-tie-board, leading to less uncertainty for the grantees. Uncertainty has two distinct but related repercussions for principal investigators first, their anxiety level is raised regarding available monies for carrying out the next year's work under a multiyear grant, and second, their planning for needed personnel and infrastructure must include several contingencies.

45Bureau of Economic Analysis, op. cit., footnote 11, p. 1.

Box 6-A—Financial Planning at NIH: A Congressional Mandate

During its review of the fiscal year 1991 budget for the National Institutes of Health (NIH), the House Committee on Appropriations stated that:

> . . . despite large increases in funding for the NIH during the last decade, the system of Federal support for the health sciences is in crisis. While the Committee believes that this crisis has been overstated, it recognizes that problems with low numbers of new grants, high levels of downward negotiation of grant awards, and the general lack of stability in government support for the biomedical sciences are critical problems which must be addressed if the vitality and the morale of the research community are to be restored.[1]

Thus Congress, as it traditionally has done, gave NIH more than the Administration had requested for 1991, boosting its appropriation to $8.3 million. But the House and Senate appropriations bills, using similar language, "... excoriated NIH administrators for inadequate financial planning. "[2]

In response to this congressional criticism, NIH drafted a plan for managing biomedical research costs. It was circulated among scientific societies and university associations prior to a December 17, 1990, meeting of the NIH Director's Advisory Committee to register responses to the plan. Twenty witnesses testified. The NIH plan features six goals:

1. Set **4 years** as the average length of research project grant awards. Four years would allow NIH to provide funding continuity to investigators while ensuring that a greater number of competing awards are made each year.
2. Implement cost management measures so that the average cost of research project grants increases at the same rate as the Biomedical Research and Development Price Index (BRDPI).
3. Stop using the concept of "approving" grant applications and adopt the "success rate' method based on the ratio of applications funded to applications reviewed-a method used by other Federal agencies.
4. Fund the number of research training grants recommended by the National Academy of Sciences to the extent possible without jeopardizing NIH's ability to provide stipend increases for research trainees.
5. Manage the growth of NIH research centers by controlling NIH appropriations for centers rather than by establishing a ceiling on the number of centers,
6. Increase funding for other mechanisms to reflect inflation.[3]

As pointed out by John Briggs, deputy director of extramural research at NIH, who chaired the December 17 meeting:

> NIH must remain flexible enough to allow biomedical science to respond to public health emergencies and scientific opportunities, and this is reflected in the plan. In order for NIH to carry out its mission, each institute and center must maintain a balanced research portfolio with an appropriate combination of research project grants, center grants, training grants and other mechanisms. Cost management goals can and should be pursued through a combination of peer review actions and administrative controls.[4]

Responses to the NIH plan have been mixed.[5] While increases in research project (ROl) grants are attributable to increases in indirect costs, ". . . neither NIH officials nor researchers can pinpoint specific causes for the increase."[6] Linking indirect costs to the BRDPI is more popular than taking a ". . . total-cost restraint approach, "[7]

---

[1] U.S. Congress, House Committee on Appropriations, *Departments of Labor, Health and Human Services, and Education, and Related Agencies Appropriation Bill*, **report 101-591,** 101st Cong. (Washington, DC: U.S. Government Printing office, July *12, 1990),* p. *51.*

[2] David L. Wheeler, "IWH Plan Would Trim Length and Growth of Research Grants," *The Chronicle of Higher Education, vol. 37,* Dec. *12, 1990,* p. A21

[3] Based on "NIH Answers Congress With Six-Point Plan," ***Washington Fax,*** Dec. 18, 1990, *p.* 1.

[4] Ibid., pp. 1-2.

[5] Based on responses to a survey conducted by *Washington Fax and* reported Dec. 14 and 17, 1990, 80 percent of the respondents favor a single, agencywide policy for implementing Congress's 4-year plan for cost management at the National Institutes of Health.

[6] '~~ut Cost Prime Source of Increase in Dollars for RO1 Grants,'' *Washington Fax*, Dec. 7, 1990, p.1.

[7] *Washington Fax*, Dec. 17, 1990. Opposition to study section consideration of indirect costs is nearly unanimous. See "NIH To Focus on Quality Over Numbers," ***Washington Fax,*** Dec. ***19,*** 1990, p. 1.

Continued on next *page*

Box 6-A—Financial Planning at NIH: A Congressional Mandate--Continued

Developing a financial management plan is prudent for any agency; adopting and implementing one is more difficult.[8] At a December 18, 1990, meeting the NIH Director's Advisory Committee agreed that stabilizing NIH at 6,000 new and 24,000 total grants should be a ". . . target rather than a mandate. " Some have noted that inflation would reduce NIH's capacity to pay for 6,000 new grants each year, and that aiming for such a total would only perpetuate the current budget problems, a".. . dynamic of fat years and lean years."[9]

The committee's draft document will be reviewed by various NIH boards and councils during the first 2 months of 1991, prior to a presentation at congressional hearings in the spring. Many biomedical scientists fear that the grant pool would not be sustainable without sacrifices m facilities, equipment, and training, and that "... no sector of biomedical science should be cannibalized to serve another sector."[10]

Amidst the claims that Congress is micro managing by calling for expenditure containment at NIH, the language of appropriations is unequivocal. If financial planning does not improve, more radical options exist, including agency-specific limits on the indirect costs that the Federal Government will pay.[11] This story will most likely unfold well into the fiscal year 1992 appropriations process.

[8] In the absence of a permanent National Institutes of Health director, developing a financial management plan was seen by many as inappropriate. As Jerold Roschwalb, director of Federal relations for the National Association of State Universities and Land-Grant Colleges, puts it: "It may be good politics, it may be good appropriations, and it may be good mathematics, but it could lead to poor science. " Quoted in Wheeler, op. cit., footnote 2, p. A21.

[9] Quoted in David L, Wheeler, "Scientists' Complaints Prompt Revisions in NIH Cost-Cutting Plan," *The Chronicle of Higher Education*, vol. 37, No. 17, Jan. 9, 1991, p. A19. The director Of the National Institutes of Health's (NIH) division of financial management has form& through computer mode@ of the budget, that NIH could support 6,000 new grants per year if its congressional appropriations increased in the range of 7 to 9 percent annually. But ' . . . not everyone thinks that it's a good idea to set an annual goal and give it precedence over NIH-initiated projects, grants to large groups and institutional centers, and Other forms of research support." Jeffrey Mervis, ' 'NIH Debates Merit of Setting Grant Minimum,"2% *Scientist*, VOL 5, No. 2, Jan 21, 1991, p. 1. In this same article, acting NIH Director William Raub notes (p. 4) that: "In the course of making our annual budget request to Congress, the use of the number of new and competing grants that it would fund has been a powerful tool. Perhaps because they do not understand the details of our enterprise, the committees [that oversee NIH's budget] have found it very useful to think in terms of the number of pieces of research that they arc funding. And that information is reflected in the level of new grants.' Also see Elizabeth Pennisi,' 'Budget Increase for NIH won't Meet Expectations,' ' *The Scientist*, vol. 5, No. 5, Mar. 4, 1991, pp. 1,6.

[10] See *Washington Fax*, Dec. 14, 1990, p. 1. For fuller descriptions of this meeting and specific points of contention, see Barbara J. Culliton, "Biomedical Funding: The Eternal 'Crisis '," Science, vol. 250, Dec. 21, 1990, pp. 1652-1653; and Pamela Zurer, "Research Funding: NIH Airs Cost-Containme nt Plan," *Chemical & Engineering News, vol. 68, No. 52, Dec. 24, 1990,* pp. 4-5. Clearly, the issue of numbers of grants cannot be decoupled from the duration or avenge grant amount.

[11] For a discussion of various options, see Barbara J. Culliton, "NIH Readies Plan for Cost Containment, " *Science, vol.* 250, Nov. 30, 1990, pp. 1198-1199.

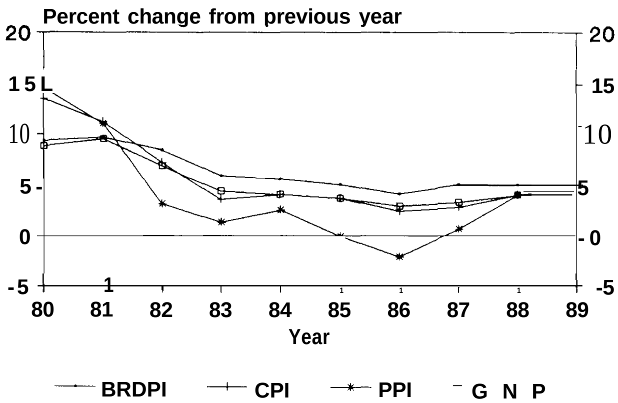
extramural activities, specifically nonpersonnel (supplies, travel, and consultants) and indirect costs. More telling is table 6-5, which compares percent changes from prior fiscal years for 1980 through 1989. This table shows general slowing of the increase in all areas, but most significantly in indirect costs for extramural activities.

Intramural expenditures have increased at a much slower rate than extramural expenditures, due to the modest increases in Federal employees' pay.[46] Increases in intramural expenditures appear to be leveling off from the sharp increases of the early 1980s (see figure 6-9). The aggregate extramural activities index has slowed to aboul a 5.5 percent annual increase heading into the 1990s. Extramural activities comprise R&D outside of NIH and financed by grants to universities and medical schools. A sample of universities provides the data for this index. Three subindices comprise this category-salary and wages, fringe benefits, and indirect costs.

Two sources are used to compute a wage and salary index for each institution: the *Report on Medical Faculty Salaries,* published by the American Association of Medical Colleges, and *Academe: The Annual Report on the Economic Status of the Profession,* published by the American Association of University Professors. Salaries for medical school

[46] Ibid., p. 13. The proposed fiscal year 1992 budget calls for a 13-percent increase in "research management and support,'" which covers the costs of administering the National Institutes of Health extramural research programs, especially the expenses of peer review panels (that have become 'more labor-intensive"). Reported in "Ways and Means," *The Chronicle of* Higher *Education,* vol. 37, No. 23, Feb. 20, 1991, p. A25.

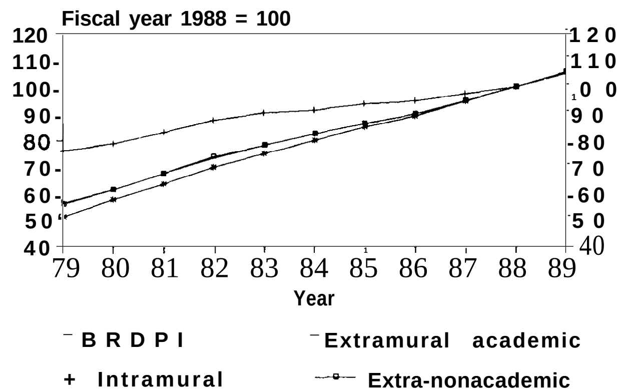
Figure 6-8—Comparison of BRDPI With Other Price Indices: Fiscal Years 1980-89



KEY: BRDPI=Biomedical Research and Development Price Index; CPI=Consumer Price Index; PPI=Producer Price Index; GNP=Gross National Product.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, *Biomedical Research and Development Price Index: Report to the National Institutes of Health* (Washington, DC: Mar. 30, 1990), chart 2.

Figure 6-9-NIH Biomedical Research and Development Price Index: Fiscal Years 1979-89



KEY: NIH=National Institutes of Health.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, *Biomedical Research* and *Development Price Index: Report to the National Institutes of Health* (Washington, DC: Mar. 30, 1990), chart 1.

faculty tend to be high and might have a disproportionate effect on salary calculations; biological scientists (not M.D.s) earn lower annual salaries (8 percent less) than scientists employed in most other fields.[47]

Indirect costs are calculated as a rate applied to direct costs. The ''quantity' of indirect costs, therefore, is virtually impossible to define. According to the Department of Commerce, if indirect costs increase as a result of additional R&D, the increase is not a price change. If no additional R&D is performed, an increase in indirect costs is a price change. The criterion used to evaluate a change in the composition of indirect costs is whether or not the change has an impact on the performance of R&D. For example, if a university purchases a more powerful central computer and the indirect costs rate rises because that purchase is allowable as an indirect cost, the performance of R&D is probably enhanced. OTA finds this exception to indirect cost increases problematic, since it is not well defined and enhancement of the performance of research is not considered in other categories of expenditure.

For calculation of the indirect cost index in the BRDPI, an indirect cost rate index and a direct cost index are computed. These two indices are then multiplied together. The calculation of the BRDPI is conducted every year with the base year scheduled to be reset in 1992.

Research Expenditures at the National Science Foundation

Data are available on research expenditures funded by NSF up to fiscal year 1989. Expenditures are reported for the conduct of research, which includes basic, applied, and development; for R&D facilities, which include land, buildings, and fixed equipment; and for major equipment. The portion of the R&D budget allocated to facilities has been at less than 1 percent for the past 10 years, until the addition of a facilities funding initiative in 1988. Direct costs are available for personnel, R&D facilities, equipment, and instrumentation. Other direct costs are reported in the aggregate, but include supplies, publications, consultants, computer services, subcontracts, travel, and fringe benefits. This category accounts for over 27 percent of the budget.

At NSF, equipment has risen from 9 percent of the R&D budget in 1981 to over 13 percent in 1989. Personnel has accounted for about 40 percent of the R&D budget over the last decade. Indirect costs have

[47]The number of institution used to create the academic salary and wage price index represents 96 percent of total obligations. Each institution's separate salary and wage index is multiplied by its weight of obligations derived from the National Institutes of Health (NIH) IMPAC file, which contains data on all NIH awards for direct and indirect costs. These weighted data are summed to create the Academic Salary and Wage Price Index. The source used to create the fringe benefit index is *Academe.* Again, a fringe benefit rate index is created for each research institution. See National Science Foundation, *Profiles—Biological Sciences: Human Resources and Funding* (Washington DC: 1989), p. 9.

Table 6-4--Biomedical Research and Development Price Index: Fiscal Years 1979-89 (1988 = 100)

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
All performers	56.5	61.8	67.8	73.6	78.0	82.5	86.7	90.3	95.2	100.0	105.2
Intramural activities	76.3	79.0	83.3	87.7	90.4	91.7	93.6	94.4	97.6	100.0	104.3
Personnel	66.4	71.0	76.9	82.1	86.4	89.3	92.6	93.5	97.7	100.0	104.6
Nonpersonnel	84.6	85.7	88,7	92.5	93.8	93.8	94.5	95.2	97.5	100.0	104.1
Research function	76.7	79.9	84.6	89.0	91.4	92.7	94.2	94.8	97.7	100.0	104.5
Support function	75.5	77.0	80.5	85.1	88,2	89.7	92.3	93.7	97.3	100.0	103.9
Extramural activities	52.4	58.2	64.6	70.7	75.4	80.6	85.3	89.5	94.7	100.0	105.4
Academic grants and contracts	51.5	57.4	63.7	69.8	74.7	80.1	85.0	89.3	94.7	100.0	105.5
Personnel	52.4	57.0	62.7	69.1	73.7	78.3	84.1	88.7	94.1	100.0	105.0
Nonpersonnel	62.3	71.2	79.3	83.6	86.2	89.0	90.2	92.2	96.1	100.0	106.2
Indirect costs	44.3	50.5	56.8	63.5	70.3	78.2	83.6	88.7	94.9	100.0	106.0
Nonacademic grants and contracts	55.7	61.5	68.2	74.3	78.2	82.5	86.6	90.5	64.9	100.0	105.2

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, *Biomedical Research and Development Price Index: Report to the National Institutes of Health* (Washington, DC: Mar. 30, 1990), table 1.

Table 6-5-Biomedical Research and Development Price Index: Percent Change From Prior Fiscal Year, Fiscal Years 1980-89

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Ail performers	9.4	9.7	8.6	6.0	5.8	5.1	4.2	5.4	5.0	5.2
Intramural activities	3.5	5.4	5.3	3.1	1.4	2.1	0.9	3.4	2.5	4.3
Personnel	6.9	8.3	6.8	5.2	3.4	3.7	1.0	4.5	2.4	4.6
Nonpersonnel	1.3	3.5	4.3	1.4	0.0	0.7	0.7	2.4	2.6	4.1
Research function	4.2	5.9	5.2	2.7	1.4	1.6	0.6	3.1	2.4	4.5
Support function	2.0	4.5	5.7	3.6	1.7	2.9	1.5	3.8	2.8	3.9
Extramural activities	11.1	11.0	9.4	6.6	6.9	5.8	4.9	5.8	5.6	5.4
Academic grants and contracts	11.5	11.0	9.6	7.0	7.2	6.1	5.1	6.0	5.6	5.5
Personnel	8.8	10.0	10.2	6.7	6.2	7.4	5.5	6.1	6.3	5.0
Nonpersonnel	14.3	11.4	5.4	3.1	3.2	1.3	2.2	4.2	4.1	6.2
Indirect costs	14.1	12.6	11.6	10.7	11.3	6.8	6.1	7.0	5.4	6.0
Nonacademic grants and contracts	10.4	10.9	8.9	5.2	5.5	5.0	4.5	4.9	5.4	5.2

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, *Biomedical Research and Development Price Index: Report to the National institutes of Health* (Washington, DC: Mar. 30, 1990), table 2.

fluctuated around 25 percent over the past 10 years.[48] The Academic Research Facilities Modernization program, authorized in 1988 as part of NSF's 5-year reauthorization, committed up to $80 million in fiscal year 1989, but no funds were appropriated for it in that year. Funds were finally obligated on September 1, 1990.[49]

Trend data on research expenditures administered by NSF are spotty. Expenditure data are readily available but do not provide a sense of actual costs incurred (or shared) by the researcher. While NSF routinely collects aggregate data on R&D spending and expenditures across the Federal agencies, its own databases are not nearly as comprehensive as those kept by NIH.

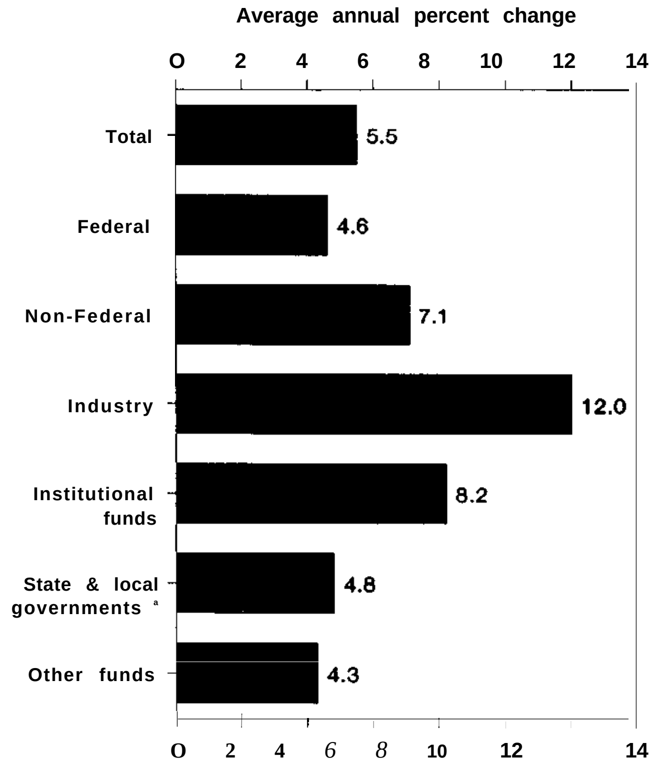
The Research Performer% Perspective on Expenditures

The definition of 'research performer' has many components. The most obvious is the researcher or team in a university, industrial facility, or Federal laboratory. Another level is the department or other organizational unit within a university or laboratory. At the most aggregated level are the laboratories and universities themselves. Given the concentration of research performance in universities, most expenditure data are based on this sector.

The Federal Government supplied $9.2 billion in research funds to universities in 1990. Industry supplied $1.1 billion and another $1.1 billion came from nonprofit institutions. Between 1978 and 1988, the average annual growth above inflation was 5.5 percent (see figure 6-10). Industry has provided most of the increase in funds, since growth of industrial finding for university R&D averaged 12 percent above inflation per year during that time period. Funding from nonprofit institutions increased annually by an average of 8.2 percent in real terms over that period, and the Federal Government increased its support of university R&D by an annual average of 4.6 percent above inflation. (Figure 6-11 presents Federal *basic* research by performer.)

Since the 1960s, the Federal research system has changed in many ways, not the least of which is in the nature of the research performer. For instance, during the 1960s, a professor with two to six students

Figure 6-10-Growth in University and College R&D Performance, by Source of Funds: Fiscal Years 1978-88 (based on constant dollars)



aExcludes general-purpose State or local government appropriations that universities use at their discretion for R&D.

NOTE: Figures were converted to constant 1982 dollars using the GNP Implicit Price Deflator.

SOURCE: National Science Foundation, *National Patterns of R&D Resources; 1990,* final report, NSF 90-316 (Washington DC: 1990), chart 13.

in one discipline at a major research university was the most prevalent production unit of research. In the 1990s, many other types of research units exist, in particular much larger research groups with many graduate students, nontenure track researchers, postdoctoral fellows, and technicians under one principal investigator. The rise of centers and university research institutes now augments the traditional array of disciplinary "departments" (see chapter 7).

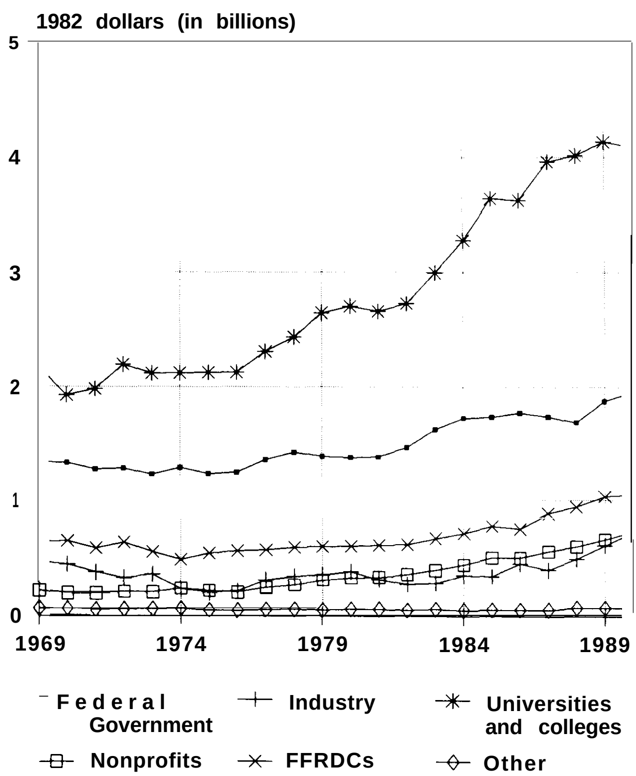
Similarly, the number of universities and Federal laboratories that conduct research has grown, expanding the group of researchers that pursue specialized forms of inquiry in the research system. These changes have occurred primarily to accommodate

[48] National Science Foundation budget office, personal communication, July-August 1990.

[49] In January 1991, the National Science Foundation announced the 78 research institutions awarded a total of $39 million under this Program. See Constance Holden, "Facilities Awards," Science, vol. 251, Feb. 8, 1991, p. 622.

292-863 0 - 91 - 7

Figure 6-n-Federally Funded Basic Research, by Performer: Fiscal Years 1969-90
(in billions of 1982 dollars)



KEY: FFRDCs include all Federally Funded Research and Development Centers that are *not* administered by the Federal Government. Other includes Federal funds distributed to State and local governments and foreign performers.

NOTE: Figures were converted to constant 1982 dollars using the GNP Implicit Price Deflator. 1990 figures are estimates.

SOURCES: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1955-1990* (Washington, DC: 1990), table 27; and National Science Foundation, *Selected* Data on Federal *Funds for Research and Development: Fiscal Years 1989, 1990 and 1991* (Washington, DC: December 1990), table 1.

growth in the system.[50] The annual rate of growth for doctoral scientists and engineers employed in institutions of higher education from 1977 to 1987 was just under 3 percent.[51] Some universities are feeling the strain felt by the scientific community, claiming that capital needed to fund renovations and new construction, equipment, administration, and personnel are rarely fully recovered through Federal funds.

Components of Research Expenditures at Universities

To document the effect of the research economy on changing university and laboratory structures, and to complement the Federal perspective presented above, OTA visited a public and a private research university---the University of Michigan (UofM) and Stanford University (SU) (see box 6-B). In addition, OTA visited at least one laboratory for each of the five major research agencies with intramural laboratories. However, expenditure data are scarce at the Federal laboratories and not uniformly collected. This section, therefore, discusses the performer's perspective on expenditures (with details derived from the two universities), and then outlines other issues that also influence spending in the conduct of research.

Both UofM and SU show evidence of robust research organizations, with excellent human resources, facilities, and financial support. This is as it should be in a top-ranked university with a long history of success (see box 6-C). Nevertheless, there was evidence of stress in the research environment at both institutions, although it was unclear whether this was a new phenomenon. Researchers said they were "running harder just to stay in place." University administrators wondered whether their institution could continue to expect resources to flow from the Federal Government, student tuition, and State and private sources.[52] Graduate students worried about whether their careers could ever be like those of their mentors.

Salaries

University personnel spoke of the rising competition for faculty with other sectors of the economy, and noted that faculty salaries have been rising significantly over inflation during the last decade. In 1988 dollars, the average salary and benefits for a full-time equivalent principal investigator in the natural sciences and engineering increased from $59,000 in 1981 to $70,000 in 1988. Before the 1980s, growth occurred much more slowly from $51,000 in 1958 (1988 dollars) to over $60,000 in

[50] See Roger L. Geiger, "The American University and Research," *The Academic Research Enterprise Within the Industrialized Nations: Comparative Perspectives,* Government-University-Industry Research Roundtable (cd.) (Washington DC: National Academy Press, 1990), pp. 15-35.

[51] National Science Foundation, Science and *Engineering Personnel: A National Overview,* special report (Washington, DC: 1990).

[52] Also see Susan Tifft, "Hind Times on the Old Quad," *Time,* Oct. 29, 1990, p. 92.

Box 6-B--OTA Interviews at Two Universities

To explore performer perspectives on research expenditures and on Federal research initiatives, OTA chose one public and one private research university for indepth study: the University of Michigan and Stanford University, OTA purposely selected two research institutions perennially in the top 10 of those receiving Federal research dollars, because of the breadth of research performed on campus, Also, the problems found at these universities in setting expenditures and expanding flexibility are thought to be indicative of problems on other research-intensive campuses.

In addition to receiving financial and personnel data from each university, OTA interviewed members of the administration, faculty, and graduate student population on campus. The interviews centered on two themes: 1) research expenditures, and 2) flexibility of the university and its departments to adapt to the changing Federal funding environment. Other issues discussed included the status of nontenure track faculty, hiring projections for individual departments, tenure promotion standards, and the graduate student perspective on careers in different fields.

The interviews sampled the range of personnel on campus. For example, at Stanford, OTA interviewed the president (Donald Kennedy), the dean and associate dean of research, two department chairs, three professors, three associate professors, one research associate (nontenure track), one postdoctoral fellow, two graduate students, the director and other members of the Sponsored Projects Office, the assistant controller, specialists in the Office of the Budget and the Office of Technology Licensing, and the director of the Stanford Synchrotrons Radiation Laboratory. The interviewees were selected from a number of disciplines, including the physical sciences, engineering, medicine, and the social sciences. At Michigan, a similar set of interviews was conducted.

OTA summarized the findings at each university and distributed the summaries to the campus hosts for comment. Select findings are used throughout this report, especially in this chapter,

SOURCE: OTA interviews, July-August 1990.

the early 1970s, but salaries receded slightly in the late 1970s to $59,000 in 1981[53] (see figure 6-12).

Universities are encouraged by faculty attempts to leverage their time with the help of postdoctoral fellows, nontenure track researchers, and graduate students who are paid modest salaries. Because of the shortage of faculty positions for the numbers of graduate students produced, young Ph.D.s have been willing to take these positions in order to remain active researchers. This availability of "cheap labor' is seen by many senior researchers as the only way they can make ends meet in competing for grants.[54]

Academic Facilities

Academic administrators claim that with growing frequency aging utility systems in laboratories and classroom buildings falter and break down.[55] A 1989 Coopers and Lybrand study found that:

- Since 1950, the facility space in colleges and universities has quintupled, representing some 3 billion square feet of classrooms, libraries, dormitories, offices, laboratories, and other space. Not all of this space was built to last. In particular, during the 1960s, many suboptimal buildings were erected, in the rush to meet the demand from the "baby boom" generation entering college.
- The capital renewal and replacement needs of U.S. colleges and universities are roughly $60 billion, of which slightly over $20 billion is ''urgent' —requiring attention within the next several years. Only $7.2 billion of the urgent category was targeted to repair facilities in the

[53] See Gov emment-University-Industry Research Roundtable, op. cit., footnote 17, p. 2-34.

[54] Labor economist Alan Fechter (*executive* director, Office of Scientific and Engineering Personnel, National Research Council, personal communication, Nov. 15, 1990) writes: ". . . personnel costs constitute roughly 45 percent of total costs and . . . this percentage has remained reasonably stable over time. Given that salaries of faculty (i.e., principal investigators) have been rising during the 1980s, this suggests that the staffing pattern of research projects has been changing, with the input of PIs decreasing relative to . . . other, less expensive resources. There is some evidence to support this hypothesis in the report of GUIRR . . . [that] finds in academia an increasing ratio of nonfaculty to faculty." See also ibid.

[55] Karen Grassmuck, "Colleges Scramble for Money to Reduce Huge Maintenance Backlog, Estimated to Exceed $70 Billion; New Federal Help Seen Unlikely," *The Chronicle of Higher Education, vol. 37,* Oct. 10, 1990, pp. Al, A34.

Box 6-C—Federal Funding at Two Universities

The University of Michigan (UofM) and Stanford University are in the top 10 universities receiving Federal funds. UofM was ranked fifth and Stanford was second in fiscal year 1988. Over the past decade, both universities have been the recipients of large (real) increases in total funds and Federal research dollars. For example, in constant (1980) dollars, UofM total revenues have risen from $600 million in 1979-80 to nearly $1 billion in 1988-89 ($1.5 billion in current dollars).

From 1979 to 1989, Federal research funds for UofM rose from $117 million (17 percent of total revenues) to $188 million (13 percent of total revenues) in constant 1986 dollars. In the period from 1976 to 1986 at Stanford, the total Federal R&D obligations to the university rose from $122 million to $194 million (1986 constant dollars). In addition, from 1973 to 1986, the funds available to principal investigators (PIs) to spend directly on research activities grew after inflation at an average annual rate of 2.6 percent.

The Department of Health and Human Services (HI-IS) is the largest Federal funder of research and development (R&D) at both universities ($124 million at UofM and $170 million at Stanford in fiscal year 1989). At UofM, HHS is followed by the National Science Foundation (NSF-$24 million), the National Aeronautics and Space Administration (NASA--$1 3 million), the Department of Defense (DOD--$1O million), and the Department of Energy (DOE-$9 million) in fiscal year 1989. At Stanford, after HHS comes NASA ($50 million), DOD ($45 million), DOE ($45 million), NSF ($30 million), and the Department of Education (ED--$1O million) in fiscal year 1989. From 1973 to 1985, Stanford's share of total Federal R&D funding (across all agencies) has remained around 2.7 percent.

Proposal Success Rates

Stanford and UofM, like most top 10 universities, have a higher proportion of awards per proposals submitted than the average for other research universities. For instance, although UofM does not track its proposals directly, it estimates that two out of three proposals were awarded funds. At roughly two-thirds, its ''proposal success rate' is at least twice the national average of 20 to 35 percent for all proposals (with the exact percentage dependent on the agency).

Roughly the same proposal success rate is found at Stanford, although they distinguish between "new proposals' and 'renewals.'' For new proposals in 1989-90 (453 proposals sampled), DOD funded 35 percent; NSF, 36 percent; ED, 37 percent; DOE, 41 percent; HHS, 52 percent; NASA, 52 percent; and 57 percent averaged for all other agencies. Renewals had much higher success rates (470 proposals sampled): HHS funded 67 percent; DOD, 75 percent; NASA, 80 percent; DOE, 81 percent; NSF, 81 percent; ED, 100 percent; and 66 percent averaged for all other agencies.

Indirect Costs

At UofM, growth in the indirect cost expenditures for the university as a whole grew at an annual compound rate of 10.3 percent from 1979-80 to 1988-89. However, indirect costs for organized research did not rise as quickly-at a compound rate of 9.1 percent from 1980-81 to 1988-89. Although the cost of maintaining buildings, equipment, and plant operation for organized research were higher than for other buildings at the university, student services, libraries, and sponsored project research expenditures were lower.

In the early 1980s, the UofM negotiated indirect cost rate (ICR) for research underestimated the "true" rate by as much as 20 points in 1 year (1984-85). (Note that the cognizant agency for UofM is HHS, which traditionally allows lower ICRs than DOD.) At present, the negotiated rate of 58 percent only slightly underestimates the ' 'true' rate of 60 percent, even though a 58 percent ICR is the highest of ***all*** public universities.

Stanford's ICR was raised from 69 percent to 74 percent in 1987. However, this rate is currently under investigation by the Office of Naval Research (ONR) and the House Committee on Energy and Commerce.[1] Although Stanford's ICR is high, it is comparable to rates from other private research institutions, including Cornell University which has an ICR of 74 percent and Yale with an ICR of 72 percent.

In response to complaints about the high ICR and the rising tuition, expenditures incurred by the 1989 I.oma Prieta earthquake, and the lower than anticipated federally sponsored research, Stanford has embarked on a cost-cutting campaign. It will cut $22 million over 18 months out of a $175 million administrative operating budget.

[1]See Marcia Barinaga, "Stanford Sails Into a Storm," Science, vol. 250, Dec. 21, 1990, p. 1651; "Government Inquiry," *Stanford Observer,* November-December 1990, pp. 1, 13; and Marcia Barinaga, "John Dingell Takes on Stanford" *Science, vol.* 251, Feb. 15, 1991, pp. 734-737.

Salaries

Salaries at both UofM and Stanford have risen above inflation over the past two decades (exact figures were not made available to OTA). Both institutions state that higher salaries are required to attract faculty. Experiments with congressionally imposed (now rescinded) salary caps at NSF and the National Institutes of Health, which provided upper limits on annual investigator salary rates charged to research grants (even though only a few months of support maybe sought in the grant), affected both universities. (Note that faculty were not required to reduce their salaries as the university made up the difference.) For example, if every faculty member at UofM had an NSF grant, then one-quarter of the faculty would have been affected by the $95,000 salary cap.

Facilities

Over the last 15 years, UofM has completed nearly $1 billion in new construction and major renovation. The amount of building space on campus totals over 22 million square feet. Many of the structures date to before 1950, and no building is ''temporary. Also, the university has demolished very few permanent, older buildings. Since the 1960s, Federal and State funds have been limited for facilities, and expansion has occurred slowly at UofM compared with other universities around the country.[2] Recently the university has been outfitting buildings with energy-efficient equipment, such as new thermal windows. Also, environmental regulations have required some improvements. For instance, a large effort to install or replace fume hoods is under way.

At Stanford, an ambitious new construction project—the Near West Campus---has begun. There are plans for at least five new buildings, providing primarily state-of-the-art laboratory and office space. Most of the funds for construction are from private sources, but if measures are not taken (such as a successful cost-cutting campaign, or an adjustment of the ICR by ONR), Stanford's indirect cost rate could rise to account for the depreciation of the new buildings.

Both Stanford and UofM question their abilities to meet their perceived need for new and renovated buildings. Each would like to see an expanded Federal facilities program for academic research.

Projections for Future Federal Support

UofM and Stanford project an overall slowing of growth in Federal R&D support. Whereas both universities had come to expect a 10 to 15 percent increase per year during most of the 1980s, the increase in Federal funds at Stanford in 1989, for example, was 9 percent. University personnel forecast that similar limited growth will continue into the 1990s. Adjustments will have to be made on both campuses to accommodate slowed growth in Federal funding.

[2] **Note** that the university system **in** Michigan expanded to other campuses in Michigan during the college boom in the 1960s and 1970s. Most of these satellite campuses have since closed.

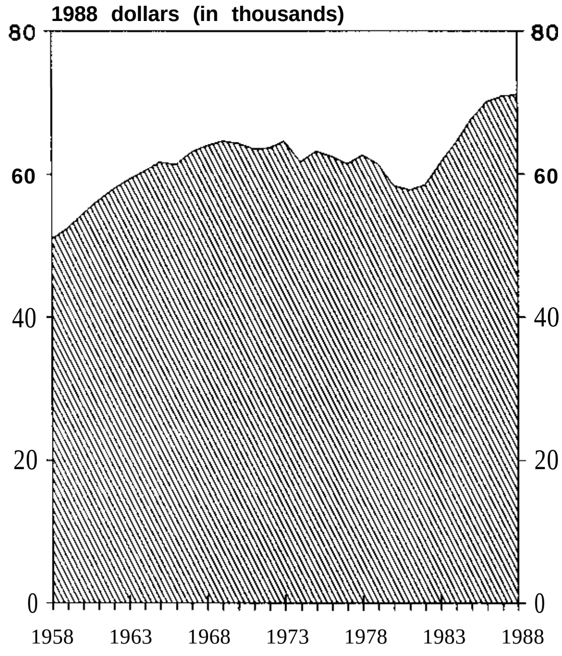
> Nation's major research universities. Most of these needs, therefore, exist within other academic sectors, including liberal arts and community colleges.[56]

Many claim that facility reinvestment has not kept pace with growing needs, and Coopers and Lybrand estimate that for every dollar spent on maintenance and replacement, $4 are deferred. They further estimate that current costs to replace a laboratory are roughly $200 per square foot, while classrooms require less than $100 per square foot.

However, the picture is not as clear as the above data would suggest. When asked by NSF if their facilities are poor, fair, good, or excellent, a majority of the research administrators and deans at the top 50 research universities replied that their facilities were "good to excellent," 'whereas a majority of the research administrators and deans in the schools below the top 50 estimated that their facilities were "fair to poor. " The average top 50 university will spend $1 to $2 million or more on facilities each year, while the schools below the top 50 will most often spend less than $1 million. For public universities, 50 to 60 percent of these funds come from the

[56] *The Decaying American Campus: A Ticking Time Bomb* is a joint report of the Association of Physical Plant Administrators (APPA) of Universities and Colleges and the National Association of College and University Business Officers in cooperation with Coopers and Lybrand, authored by Sean C. Rush and Sandra L. Johnson, APPA (Alexandria, VA, 1989). APPA's most recent ' 'deferred maintenance" cost estimate is $70 billion. Also in 1990, 42 percent of college and university presidents surveyed by the American Council on Education called deferred maintenance a key campus issue for the next 5 years, up from 14 percent in 1989. See ibid., p. A34.

Figure 6-12—Average Salary and Benefits Paid Academic Ph.D.s in Natural Sciences and Engineering: 1958-88 (in thousands of 1988 dollars)



NOTE: Constant dollars were calculated using the GNP Implicit Price Deflator.

DEFINITION OF TERMS: Academic Ph.D.s in the natural sciences and engineering include academic employees who have been awarded the Ph.D. degree in the following fields: life sciences, including agricultural, biological, medical, and otherhealth sciences; physical sciences, including astronomy, chemistry, and physics;engineering, including aeronautical and astronautical, chemical, civil, electrical, and mechanical engineering; environmental sciences, including oceanography, and atmospheric and earth sciences; and mathematics and computer science, including all fields of mathematics and computer-related sciences. Compensation includes salaries and fringe benefits, including insurance and retirement contributions.

DATA: National Science Foundation, Division of Policy Research and Analysis. Database: CASPAR. Some of the data in this database are estimates, incorporated where there are discontinuities within data series orgaps in data collection. Primary data source: National Science Foundation, Division of Science Resources Studies, Survey of Scientific and Engineering Expenditures at Universities and Colleges; National Institutes of Health; American Association of University Professors; National Association of State Universities and Land-Grant Colleges.

SOURCE: Government-University-Industry Research Roundtable, *Science and Technology in the Academic Enterprise: Status, Trends and Issues* (Washington, DC: National Academy Press, 1989), figure 2-47.

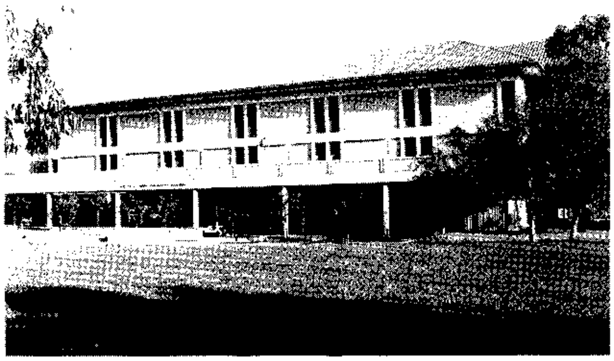


Photo credit: Stanford University

Research universities support many facilities devoted in part to research, such as the Seeley C. Mudd Chemistry Building at Stanford University pictured here.

States and 30 percent from bond issues. For private universities, roughly one-third comes from the Federal Government, while another one-third is from donations.[57]

The crux of the facilities problem is that academic centers can always use new or augmented buildings, but how much is enough? One method to judge would be based on the research fostered by each new facility. Unfortunately, there is no acceptable method to measure the quality or quantity of increased research capabilities or of "missed" research opportunities. Even though "need" may not be quantified in the different sectors of the research enterprise, a demand certainly exists. For example, when NSF solicited proposals for a $20 million program in 1989 to address facilities needs, it received over 400 proposals totaling $300 million in requests.[58]

Historically, the Federal Government has never been the primary source of funding for academic facilities, conceding support to private donors, States, and localities. Indeed, the proportion of Federal monies out of all the monies spent on academic facilities has never topped one-third. Now it is less than 10 percent.[59]

The issues surrounding the research infrastructure are complicated. There is a need for improvement—as evidenced in many research environments-but

[57] Michael Davey, *Bricks and Mortar: A Summary and Analysis of Proposals to Meet Research Facilities Needs on College Campuses* (Washington, DC: Congressional Research Service, 1987).

[58] The National Science Foundation program also requires a 50-50 match for requests ranging from $100,000 to $7 million. Some, including the President's Science Advisor, estimate the price of academic facilities modernization to be $7 billion. See Jeffrey Mervis, ' 'Institutions Respond in Large Numbers to Tiny Facilities Program at NIH, NSF," *The Scientist,* vol. 4, No. 8, Apr. 16, 1990, p. 2.

[59] Davey, op. cit., footnote 57.

the need is very hard to quantify or assess. In addition, the extent of the Federal role—should there be a Federal facilities program?-is in question. Do deteriorating facilities affect the quality of research underwritten by the Federal Government? Academic earmarks for facilities continue to play an ad hoc role that unfortunately fails to address the facilities renovation issue directly or systematically (as a formal Federal facilities program perhaps would, see box 6-D).

Indirect Costs

One of the most worrisome issues on many research campuses is the high cost of 'overhead' or indirect costs. As part of the ''fill cost recovery for research" doctrine in the Federal Government, universities charge the Federal Government for facilities maintenance, administrative expenses, and other expenditures that ensure their capacity as research performers but cannot be directly associated with specific projects. The standard procedure is for the university to negotiate a single rate that will be charged to all Federal grants with the cognizant Federal agency (either the contract audit agency of the Department of Defense or the Department of Health and Human Services, depending on the institution).[60] For example, in 1990, Stanford University charged 74 percent in indirect costs to every grant, so a grant of $100,000 in direct costs might be submitted at a total cost of up to $174,000.[61] (Overhead can be computed on only certain direct costs, resulting in a total charge to the government of less than $174,000.) Indirect cost rates have evolved over the last 30 to 40 years, and clearly reflect institutional idiosyncrasies and practices of the cognizant agency.

Over the past three decades, indirect costs have claimed a much larger proportion of academic R&D finding. In 1958, federally reimbursed indirect costs comprised 10 to 15 percent of academic R&D finding. By 1988, that share had risen to roughly 25 percent.[62] In addition, some agencies allow more in indirect costs. For example, in 1988, the indirect cost as a percent of the total R&D expenditures at NIH was 30 percent, whereas it was less than 24 percent for NSF (a proportion unchanged since the mid-1980s).[63] Medical schools typically have high indirect cost rates, both because of the extra facilities expenditures associated with their activities and because they tend to be associated with the research universities that have high indirect cost rates.[64]

The indirect cost rate at the University of Michigan is 58 percent, which is high for a public university. Because the State assumes part of the cost of maintaining its universities, the indirect cost rates are usually lower than at private universities. In addition, at State universities, indirect cost monies are often transferred directly to State coffers, so that the university has little incentive to pursue a higher indirect cost rate or to employ the administrative personnel needed to comply with Federal audit requests to justify new rates.

Many university administrators report that the monies received in indirect costs do not cover their expenditures. They worry about further erosion of the indirect cost base, due to the perception in many quarters of high rates of overhead and resistance to the indirect cost increases experienced by many universities over the last decade.[65] The chief recommendation offered by a 1988 Association of American Universities report was that the indirect cost rate

[60] Association of American Universities, Op. Cit., footnote 14, p. 7.

[61] As a result of the Defense Contractor's Audit Agency's (DCAA) ongoing investigation of Stanford's indirect cost rote, an interim rate of 70 percent has been negotiated as of Feb. 1, 1991. William Massy, Stanford University, personal communication, February 1991. DCAA'S preliminary analysis indicates that Stanford, which requested a new indirect cost rate of 78 percent, could justify only a 62 percent rate. Stanford has yet to rebut this claim. See Marcia Barinaga, "Was Paul Biddle Too Tough on Stanford?" Science, vol. 251, Jan. 11, 1991, p. 157; Kenneth J. Cooper, "Stanford Will Try to Explain Price of Knowledge,' *The Washington Post, Mar. 13,* 1991, p. A15; and Kenneth J. Cooper, "Panel Looks for Liability in Stanford Billings Case," *The Washington Post, Mar. 15,* 1991, p. A21.

[62] National Science Foundation, op. cit., fOOtnote 19, p. 121.

[63] Ibid., p. 142; and Association of American Universities, op. cit., footnote 14. For example, restricting payment for overhead expenses to 14 percent on research projects funded by the Department of Agriculture has aroused concern that universities would have to decline such awards since they could not afford to do the projects. Fears that such an across-the-bored ceiling could be instituted at other agencies continue to mount. See Colleen Cordes, "Universities Fear That U.S. Will Limit Payments for Overhead Costs Incurred by Researchers,' *The Chronicle of Higher Education, vol. 37, No. 12,* Nov. 21, 1990, pp. A19, A21.

[64] William Massy, vice president for finance, Stanford University, personal communication, March 1991.

[65] ''Dingell Asks Defense Contract Audit Agency to Brief Staff on Stanford Overhead Expenses,' *Washington Fax,* Dec. 10, 1990. Also, see Susan Tifft, "Scandal in the Laboratories," *Time, Mar. 18,* 1991, pp. 74-75; and Kenneth J. Cooper, ''Five Major Universities Face GAO Audit of Research Bills," *The Washington Post, Mar. 16, 1991,* p. A2.

Box 6-D—A Federal Research Facilities Program? Perspectives From Academia

In August 1990, University of Wisconsin at Madison Chancellor Donna E. Shalala wrote to President Bush urging development of a comprehensive plan to finance university research facilities. She stated:

> 1 recognize that there are a number of important competing claims on the Federal budget, even from the academic community. However, a planned Federal strategy at this stage can well save us money in the long run, and make more effective our other investments in science and engineering research and training.[1]

Even if money were appropriated to a Federal facilities program, there would be tough choices, such as an equal distribution of funds by category of institution or some weighted scheme that favors research-intensive universities.[2] Stanford's former Vice President for Finance, William E. Massy, outlines the following possible pitfalls:[3]

> What would happen if research sponsors were to shoulder the load of paying for needed university science facilities? . . . Research sponsors might adopt the ''pay-now' strategy and provide the needed $5.85 billion up front, Congress is considering a facilities grant program, but it is hard to believe that anything like this amount could be provided over a few years without huge inroads on operating funds for research.
>
> On the other hand, if the 'pay-later' strategy were adopted by sponsors, institutions would have to come up with up-front money on their own and then try to recover it through the overhead rate. This could be done in one of two ways: 1. Use gifts, institutional funds, or State appropriations. . . .[4] 2. Use debt. . . .
>
> Providing direct grants for facilities is an attractive option on its face, but . . . amounts would probably be modest in relation to need because of the [Federal] deficit. There is a real danger that appropriations would be at the expense of operating funds for science. . . . One reason for favoring a grant program is that it makes facilities available to institutions that are unable to provide up-front finding. . . . But it is precisely the institutions that have not yet been successful in merit-reviewed scientific competition that have the most need for a facilities grant program and would benefit most from it. . . .
>
> Facilities funding on a "pay-as-you-go" basis through the indirect cost rates puts the burden . . . on the institutions, and then reimburses them for some or all of the present value of these outlays. . . . Indirect cost rates would rise, . . . [and] institutions would have to bear the risks that a facility, once constructed, could not be filled with sponsored research at full overhead recovery. (The Federal Government takes that risk in an u-p-front grant program.) . . .
>
> While the Federal Gove rnment would be unlikely to announce a ' 'won't pay" policy, that could happen by default if deficit reduction, "no new taxes,' social programs, and defense come to dominate the need for university science facilities. A "won't pay' policy would preclude facilities grants, and it might also open the way for caps on indirect cost rates and elimination of universities' tax benefits . . .

When the scope of a problem is unknown, as with the need for academic research facilities, questions of which is the most appropriate policy is even harder to answer. To this end, a six-university consortium, called the Center for Policy Research and Education, has been established to study university finance and cost containment, investigating ''. . . growth by substitution rather than by adding on cost. In the meantime, neither universities nor the Federal Government face the prospect of easy solutions.

---

[1] Quoted in Karen Grassmuck, ''Colleges Scramble for Money to Reduce Huge Maintenance Backlog, Estimated to Exceed $70 Billion; New Federal Help Seen Unlikely," *The Chronicle of Higher Education, vol. 37, No. 6,* Oct. 10, 1990, p. A34.

[2] Other administrative questions include: a single program or a line item in the budget of each research agency, a separate amount for repair and renovation v. new construction, and an institutional matching requirement. For further discussion, see Government-University-Industry Research Roundtable, "Research Facility Financing: Near-Term Options,'' working draft, February 1991.

[3] Drawn from William E. Massy, "Capital Investment for the Future of Biomedical Research: A University Chief Financial Officer's View, " *Academic Medicine,* vol. 64, 1989, pp. 435437, The dollar estimates for construction he cites are drawn from National Science Foundation, Scientific *and Engineering Research Facilities at Universities and Colleges: 1988* (Washington, *DC: 1989).*

[4] On the cost-efficiency of academic fundraising, see Liz McMillen, "A Study to Determine the Cost of Raising a Dollar Finds That Average College Spends Just 16 Cents, " *The Chronicle of Higher Education,* vol. 37, No. 1, Sept. 5, 1990, pp. A31-32.

[5] See ' 'Education Fiie,' *Stanford Observer,* November-December 1990, p. 14. The Department of Education's Office of Educational Research and Improvement is funding the consortium consisting of the University of Southern California, Rutgers-The State University of New Jersey, Harvard University, Michigan State University, the University of Wisconsin at Madison, and Stanford University. The Stanford component, at the Institute for Higher Education Research. will be headed by William Massy.

should be split into two rates -one for facilities and equipment (including operation, maintenance, and depreciation) and a second for all other components (including administration, library, and student services).[66] The academic research community is also hoping that OMB will reconsider Circular A-21, which deals with indirect cost practices.[67]

High indirect cost rates are often seen as detrimental to the researcher, because they increase the total expenditures for research grants while adding no additional money for research. For example, many Stanford University faculty are so concerned about a proposed increase in the indirect cost rate that they have pressured the university to cut administrative and facilities expenditures.[68]

Does the overhead rate reflect true differences related to the instructional capacity at universities or is it due to some accounting mechanism? Before new policies are crafted, data on actual expenditures should be collected and presented so they are amenable to comparisons across institutions. In the process, both universities and the Federal Government have much to gain in making the system more simple, transparent, and credible.

Changing Expectations and Competition

Research expenditures increase for reasons besides the line item components of a budget. Researchers also point to higher expectations for their research, which require more spending and competition in the university environment.

Academic researchers, both young and old, are asked today to publish more papers, shepherd more graduate students, and bring in more Federal funding than their predecessors.[69] To boost research productivity, faculty members hire postdoctorates and nontenure track (nonfaculty) researchers. Graduate students can-and do-take over portions of faculty teaching responsibility; tacticians and graduate students can maintain equipment and run experiments; and postdoctorates and nonfaculty researchers can advise students and assist in the operation of the laboratory.[70] All can **perform** research.

Photo credit: University of Michigan

The calculation of indirect costs is often difficult because of inherent problems with separating instruction from research activities on a university campus.

For example, in the chemistry departments of both UofM and SU, the average number of graduate students per faculty averages about six to nine. Some professors have as many as 25 to 30. Much chemistry research involves long hours in laboratories, so the pace of research is brisk as well as necessitating the participation of a greater number of graduate students. Once a faculty member in a department or related field succeeds in expanding his or her research group, others also expand their groups to keep pace.[71]

In this very competitive research system there is increasing pressure to perform more research and to publish more papers. Consequently, expectations and expenditures have risen. Perhaps one young faculty member at Stanford put it best:

---

[66] Association of American Universities, Op. cit., footnote 14.

[67] See "OMB Unlikely To Open Circular A-21 for Amendment According to IndirectCost Observers," *Washington Fax,* Dec. 12, 1990; "AAU Says Talks Continue at High Level in OMB To Reopen OMB Circular A-21," *Washington Fax,* Dec. 13, 1990; and Robert M. Rosenzweig, "The Debate Over Indirect Costs Raises Fundamental Policy Issues,' *The Chronicle of Higher Education,* vol. *37, Mar. 6, 1991,* p. A40.

[68] Faculty argue that Stanford's indirect cost rate detracts from the attractiveness of funding research at Stanford, i.e., they are at a competitive disadvantage. Eileen Walsh and Karen Bartholomew, "Indirect Costs Subject of Three Separate Reviews,"*Campus Report,* Sept. 12, 1990, pp. 1,6.

[69] This is especially true in entrepreneurial research areas such as biotechnology. See Henry Etzkowitz, "Entrepreneurial Scientists and Entrepreneurial Universities in American Academic Science," *Minerva, vol. 21, Nos. 2-3,* summer-autumn 1983, pp. 198-233.

[70] See Sidney Perkowitz, "Larger Machines Are Breeding Larger Research Teams,' *The Scientist,* Oct. 16, 1989, pp. 13, 15.

[71] This trend emerged from OTA interviews at Stanford University and the University of Michigan, July-August 1990.

> Each year, we have to write more papers and bring in more money than many of the senior professors ever produced in ***any year*** of their careers. When we were hired as assistant professors, we already had to have published five or ten papers, again more than any of them had to do. And, it keeps getting worse.[72]

Whether the premium on productivity defined by number of papers published is attenuating their quality is unclear. Bibliometric data, which provide a measure of use through citations, indicate that about 15 percent of all U.S. scientific papers are never cited.[73] Publishing requires research; doing more research requires spending more money. Thus, research expenditures are not just a ***cost*** issue, but a *spending* issue as well.

Relative Deprivation

When there is such pressure to compete, standards become ''whatever it takes to make it. ' Most professors understand how much money and how many graduate students they will need to help them produce enough papers to get tenure, promotions beyond tenure, and recognition in their field. Many hope to do more.

However, if they do not meet these expectations, some report a sense of failure.[74] Failing to meet self-imposed expectations only intensifies these feelings. This is true even if the economy of work has changed such that standards of productivity need to be revised, or if they have succeeded but not by as much or as quickly as they had hoped. Social scientists call this situation ''relative deprivation. ' Researchers, especially on campuses such as the University of Michigan or Stanford University, cannot be said to be "absolutely" deprived. They are able to acquire laboratory space, graduate students, and research monies; they produce very significant amounts of research; and the success rates for proposals at UofM and SU run at least twice if not three times the national average (roughly two out of three proposals are awarded funds, averaged over these two universities).

Nevertheless, the professors at UofM and SU have grown accustomed over the last 20 years to producing more graduate students, more publications, and funding for perhaps four of every five proposals they submit.[75] The adjustment to comparatively less has been difficult. Relative deprivation is real, but so is the greater sophistication of instruments, complexity of experiments, and amount of research that can be completed in a short time. There is also a trend toward an ''industrial model," where project teams are larger and responsibilities are more distinct within the group.[76] Research institutions are keyed to hastening and demonstrating research productivity.

Some experiments have been attempted on U.S. campuses to temper the drive for more research *output.* For example, at Harvard Medical School, faculty are allowed to list only five publications for consideration at tenure, with similar numbers set for other promotions. Thus, the quality and importance of the candidate's selected set of papers is stressed,

---

72 OTA interviews at Stanford University, August 1990.

73 This was originally reported as nearly one-half going uncited. See David P. Hamilton, ''Publishing By—rind For?—the Numbers, " *Science*, vol. 250, Dec. 7, 1990, pp. 1331-1332; and David P. Hamilton, "Research Papers: Who's Uncited Now?" *Science*, vol. 251, Jan. 4, 1991, p. 25. The data source, the Institute for Scientific Information, reports that the original estimate included notes, editorials, and meeting abstracts. When scientific articles alone are considered, uncitedness by 1988 of articles published in 1984 drops to 22 percent. For U.S. authors, the proportion is even lower (14.7 percent), one-half that for non-U.S. authors. See David A. Pendlebury, ''Science, Citation, and Funding," letter, *Science*, vol. 251, Mar. 22, 1991, pp. 1410-1411. Journals, however, appear to have increasingly assumed a more archival function of bestowing credit than of information exchange. Citation rates, however, are known to vary widely by field. This may reflect more on the ways researchers credit one another through bibliographic references than on how they actually use that work. See Derek de Solla Price, "Citation Measures of Hard Science, Soft Science, Technology and Conscience," *Communication Among Scientists and Engineers, C.* Nelson and D. Pollock (eds.) (Lexington, MA: D.C. Heath, 1970), pp. 3-22.

74 *Science: The End of the Frontier?* op. cit., footnote 4.

75 OTA interviews, op. cit., foomote 71.

76 Elsewhere this has been called the ''industrialization'' of science, or ''. . . a new *collectivized* form in which characteristics of both the academic and industrialized modes are intermingled. " See John Ziman, *An Introduction to Science Studies* (Cambridge, England: Cambridge University Press, 1984), p. 132, The dimensions of collectivized science, according to Ziman, include costly research apparatus, increasing aggregation of research facilities, and collaboration in research performance that redefines "teamwork." In the words of the National Science Board, ". . . modem science and engineering research is more organized, capital intensive, multidisciplinary, and cooperative than in the past. Our universities must adapt to this need.' National Science Foundation, ' 'The State of U.S. Science and Engineering, ''A View From the National Science Board, statemenaccompanying *Science & Engineering Indicators—1989*, February 1990. These dimensions are discussed further in ch. 7.

though measuring these characteristics, bibliometrics notwithstanding, remains contentious.[77]

Strong incentives militate against reducing research output. For instance, since most overhead is brought into the university by a small number of research professors (at Stanford, 5 percent of the faculty bring in over one-half of the indirect cost dollars[78]), proposals to reduce research output are not looked on with favor by many university administrations. Any measure that would curb the productivity of these professors would deprive the university of revenues. Thus, many universities try to *maximize the* level of research volume and output.[79]

OTA finds that research personnel at the two universities examined are experiencing relative deprivation. This would appear to be symptomatic of pressures felt on similar high-caliber research campuses. If so, then the Federal Government, by sending clear signals about the importance of scientific merit, education, and equity in allocation decisions, could aid universities in planning for a changing research economy (see box 6-E).

Responsiveness

Another factor leading to perceived instability in the research environment is the difference in time scales between changing national needs, on the one hand, and universities' capacity to respond to them, on the other. To build a research infrastructure, like any government contractor, universities must commit funds to construct facilities and to purchase equipment. If the Federal Government then decides to switch emphases, universities must continue to maintain this infrastructure. Also, no matter how resourceful one may be, there are few incentives for a professor to change research areas after having accumulated knowledge in one or two specialties.[80] It is perceived as being more cost-effective for the university to hire new younger faculty and buildup their research capacity than to try to convert an older researcher to a new field. Consequently, researchers in universities have little recourse if research emphases shift dramatically in Federal support for their particular field.[81]

An example of a *growing* department at the University of Michigan may help illustrate some of these points. In 1980-81, the Electrical Engineering and Computer Science (EECS) Department was perceived as weak. The central administration at UofM decided to invest resources in the department and pursue expansion. Most importantly, it decided on a few key research priorities: optics, solid state electronics, robotics, and microelectronics. The administration encouraged retirement of many of the older faculty and "weeded out" a few others. It hired faculty in the designated areas to fill the vacant slots and added a few faculty positions as well. EECS expanded its research capacity in areas that the Federal Government presently supports. It has subsequently received more Federal tiding. Unfortunately, EECS does not project, for the foreseeable future, the flexibility it experienced in the 1980s. The department attributes its flexibility to the hiring of new faculty, and doubts that this flexibility will continue as the faculty ages.

The development of EECS may be unique among university departments. As a survival tactic, universities have traditionally attempted to maintain broad departments, covering many subdiscipline, so that if funding in one area diminishes it has a minimal

---

77See N.L. Geller et al., "Lifetime Citation Rates to Compare Scientists' Work," *Social Science Research*, vol. 7, 1978, pp. 345-365; and A.L. Porter et al., "Citations and Scientific Progress: Comparing Bibliometric Measures With Scientist Judgments," *Scientometrics*, vol. 13, 1988, pp. 103-124. The National Science Foundation now limits the number of publications it will consider, as evidence of an applicant's track record, in reviewing grant proposals. See Hamilton, op. cit., footnote 73.

78Rick Biedenweg and Dana Shelley, *1986-87 Decanal Indirect Cost Study* (Stanford, CA: Stanford University, February 1988), p. xii.

79For example, Donald Kennedy, president of Stanford University (SU), said in an OTA interview (Aug. 2, 1990) that if the 1990s do not promise great increases in the Federal science budgets, SU will have to institute four means to balance its budget, and the first three have already been introduced: 1) restructure the budget for SU and instigate cuts; 2) boost the research volume to bring in more research dollars; 3) lobby for increased facilities programs from the Federal Government; and 4) move some indirect costs to thdirect cost lines to ensure full recovery.

80See John Ziman, *Knowing Everything About Nothing: Specialization* and change unscientific Careers (Cambridge, England: Cambridge University Press, 1987); and John Ziman, "Researches a Career, " *The Research System in Transition*, S.E. Cozzens et al. (eds.) (Dordrecht, Holland: Kluwer, 1990), pp. 345-359. "Thebuildup of accumulated skills and knowledge puts a lot of inertia into the academic research system, and. . . a premium on expansion as the easiest route toward reorientation of priorities. " Harvey Brooks, Harvard University, personal communication% February 1991.

81In the case of a national research mission, such as the War on Cancer, relabeling one's researchto qualify for mission money was a workable strategy. See K.E. Studer and D.E. Chubin, *The Cancer Mission: Social Contexts of Biomedical Research* (Beverly Hills, CA: Sage, 1980), especially ch. 3.

Box 6-E—Emulating the Research University: Beware

In the last few decades, many universities have aspired to emulate the top research universities, in the hopes of gaining a larger share of the Federal research pie. However, in the 1990s, the model of a research university may become less attractive, functional, and reproducible.

Research universities are characterized by strength across departments and other units where research is performed. For instance, Stanford University is not known particularly for strength in one field, or even several, but for across-the-board excellence in every discipline-within science and engineering and without. Similarly, these universities are the major recipients of Federal research and development funds and train the largest cadre of new Ph.D. s in those disciplines.[1]

Outside the top 50 to 100 institutions are hundreds of universities that also compete for Federal research funding.[2] They reason that an influx of Federal monies could ease some of the financial burdens they face, but moreover, could boost their capacity to do research and attract still more funding from other sources, Arguably, the research university has been a model for emulation even for institutions whose missions and resource base made them unlikely candidates to join the top 100. Institutional mobility is rare, but does occur.

Unfortunately, beneath the surface of many successful research universities lie many fiscal problems connected with their research enterprise:

1. The demand for research funding is rising in some fields faster than funding available from Federal and other sources, and some universities claim they cannot keep up.
2. Demands for state+ f-the-art facilities are increasing with little financial help from the Federal Government, so universities must tap State or private coffers to allow for renovation and new construction.
3. Charges abound that re search faculty are shirking their teaching commitments, and students complain that their education has suffered.

These problems notwithstanding, there is still an allure--and a necessity-to pursue Federal research dollars. In addition to competing quite successfully for disciplinary agency support, universities are attracted by Federal initiatives that enjoy ‘ ‘new’ priority funding. At the University of Michigan, for example, initiatives such as global

[1]In fiscal year 1988, 10 universities received almost one-quarter of the Federal research and development funds awarded to all academic institutions. They were Johns Hopkins, Stanford, Massachusetts Institute of Technology, Wisconsin-Madison, Michigan, Washington, California-San Diego, Cornell, California-Ims Angeles, and Columbia. See National Science Foundation *Academic Science and Engineering: R&D Funds—Fiscal Year 1988*, NSF 89-326 (Washington, DC: 1990), table B-37. These same 10 universities produced 15 percent of all science and engineering Ph.D.s. (3,303 of 20,738) that year. National Science Foundation *Science and Engineering Doctorates: 1960-89,* NSF 90-320 (Washington, DC: 1990), table 9. The distribution of honors, e.g., Nobel prizes and election to the National Academy of Sciences, reinforces the stratification among research universities and the role of a select few in the education and employment of U.S. scientists.

[2]For example, 1,719 institutions were supported by the National Institutes of Health (NIH) in 1990, but only 25 accounted for 38 percent of NIH's extramural funds. See ‘ 'NIH Policy Change Could Shake Up Distribution of NIH Extramural Funding, Official Says, ” *Washington Fax,* Nov. 23, 1990.

effect on the department as a whole. On the other hand, if one area receives increased support, the university will be prepared to take advantage, Due to increased competition for funds, the model of a multifaceted yet targeted department, such as EECS, may become more prevalent. Universities may find that concentrating their research capabilities in specific areas may enhance their competitiveness for Federal funding by augmenting their research track record and the availability of research facilities and equipment in those areas. Another tactic is the welcoming of non-Federal sources of research funding to campus, often to “leverage” Federal funding (see box 6-F).

In the current research economy, a broad base is increasingly difficult to maintain. Universities trying to achieve the status of the top 50 research institutions are bound to face numerous obstacles if they try to obtain-and sustain-success through a broad-based approach.

Summary

In this chapter, OTA has reviewed data on research expenditures from the perspectives of both the Federal Government and academic research performers. Fueled by increases in Federal, industrial, and academic spending on research, the national research effort and the levels of basic and climate change and the Human Genome Project are seen as ''bandwagons: once the university commits resources to participate, it runs the risk of absorbing the costs of the research infrastructure and personnel atler Federal support wanes.[3]

If the top research universities are struggling to maintain excellence, even with their inherent advantages, it may be unwise for other universities to try to become like them. It takes years to develop the breadth and depth of resources that makes a research university; it does not happen quickly.[4] Moreover, the classic research university model may simply be maladaptive for these times.[5] Maintaining the human and physical infrastructure that has accumulated over decades is a huge financial burden that affects all campus functions.[6]

Building targeted strength would appear to be a more sensible institutional strategy than striving for across-the-board excellence. Thus, one magnet laboratory funded by the National Science Foundation (and the State of Florida) will not transform Florida State University into a Massachusetts Institute of Technology. But Florida State might become world-class in research on high-energy magnetism. Such targeting demands concentrated fiscal and human resources, selective recruitment of faculty researchers, and construction of facilities. The Federal Government has a role to play in this effort. As recently stated: "It's the classic American challenge: What's the best tradeoff between the conflicting desires of preserving excellence and promoting diversity?'

Preserving excellence in research and teaching at U.S. researching universities is not a Federal obligation; it is a good investment. Research universities have strategic plans, critical masses of researchers, and the reputation for selectivity. However, those institutions that aspire to join the select group of top research universities in the 1990s might best reconsider the research university model-and proceed at their own risk.

---

[3]In the short run, resources that would have been devoted to instruction tend to get diverted to this high-profile esearch. Investing in fashionable research is an important part of the university portfolio, but the cost of some activities may have an adverse effect on others. This example is based on OTA interviews with University of Michigan adminitrators, July 1990.

[4]This was a recurrent theme at hearings held by the House Committee on Science and Technology, Task Force on Science Policy in 1985-86. For an analysis of members' and witnesses' concerns, see Patrick Hamlett, ''Task Force on Science Policy: A Window on the Federal Funding and Management of Research,'' OTA contractor report, October 1990. Available through the National Technical Information Service, see app. F.

[5]See Linda E. Parker and David J,. Clark, ''Departrnenud Responses to Fluctuation in Researc h Resources," *Research Management Review,* vol. 4, spring 1990, pp. 19-34.

[6]Perhaps the most striking evidence of a university's research intensiveness is the number of postdoctorates it employs. BY this measure, Stanford and Michigan are spectacular examples. At both institutions, postdoctorates in life sciences represent two to three times the number of postdoctoral appointees in all other fields combined. (Physical sciences is the runner-up on both campuses.) At Stanford, the number of life sciences postdoctorates doubled to 600 in 1988. This also represents almost twice the number of graduate (i.e., predoctoral) students in life sciences at Stanford. At Michigan the emphasis is reversed: although postdoctorates in life sciences grew from 160 to 280 between 1980 and 1988, the number of predoctoral students in these fields totaled three times the postdoctoral count. These differences in graduate students and postdoctoral numbers are probably reflected in the composition of research teams.

[7]Michael Schrage, ''Blurring the Line Between Funding Science and Funding Economic Growth,'' *The Washington Post,* Oct. 5, 199(J, p. F3.

applied research individually are at levels surpassing the "golden age" of the 1960s. However, the rise in demand for funds from the research community continues to outpace Federal funding increases.

This rise in demand is due primarily to increased *spending* on research, and only secondarily to increases in the ''costs' of individual components of research budgets. Increased spending appears to stem from the growth of the size of research groups under the direction of one principal investigator, a tendency toward growing pressure to produce more research, and an increasing complexity of equipment and facilities (although advances in technology can also decrease overall spending).

Reliable analyses of research expenditures by Federal agencies are not available. Information provided to the agencies by the performers is likely to combine actual need with the desire to pursue boundless opportunities in research. Some trends, however, are well documented. The number of scientists conducting research and supporting graduate and postdoctoral students has grown. Every agency has seen a growth in the number of grant applications submitted. In addition, average expenditures per investigator have nearly tripled, in real terms, since 1958. The obsolescence time for equipment and instrumentation has shrunk more than twofold, and facilities built in the 1950s and 1960s are in need of repair and renovation. The

Box 6-F—industry on Campus

Universities have been aggressive in seeking industry support for research in the 1980s, though the relationship between the two sectors has been a ' 'two-way street" for more than a half-century.[1] Industry funding of university research, though brisk in the 1980s, still represented just over 5 percent of all university research. (The highest proportions are found at engineering institutions--Georgia Institute of Technology, Carnegie-Mellon, Massachusetts Institute of Technology.) Most of that funding was geared to generic, nonproprietary knowledge aided by support for faculty, graduate students, and infrastructure. In other words, technology transfer, patenting, and commercial gain were not the primary motivations for academic-industry relations.[2]

Until recently, only certain fields have had relevance to industry investment for a profit motive: computer science, metallurgy, materials science, and chemistry.[3] More recently, biology has offered industry new techniques for the development of products and processes. As historian Roger Geiger points out:

> The case for the importance of the university role in economic development rests on two pillars: that industry has been underinvesting in generic research, and thus could profitably utilize additional research from universities; and second, that discoveries of potential commercial value were being made in universities, but were not reaching the market because of linking rnechanisms.[4]

In many fields, the demand for research funds are exceeding available funds from traditional sources--especially in fields that require large-scale, technologically advanced equipment and instruments, as well as more technicians with more skills. Concerns about sponsorship--military as well as industrial-skewing the research

[1] Large chemical and drug companies funded university laboratories for routine services, like testing, beginning in the 1930s. See Roger L. Geiger, ''Industry and University Research: The Revolution of the 1980s," Science *and Technology and the Changing World Order,* colloquium proceedings, Apr. 12-13, 1990, S .D. Sauer (cd.) (Washington DC: American Association for the Advancement of Science, 1990), pp. 138-148; and Paul E. Gray, "Advantageous Liaisons, " *Issues in* Science & *Technology, vol. 6, No. 3, spring* 1990, *pp. 40-46.*

[2] See Roger L. Geiger, ''Milking the Sacred Cow: Research and the Quest for Useful Knowledge in the American University Since 1920,' Science, *Technology, & Human Values, vol. 13, Nos. 3-4, summer &* autumn 1988, pp. 332-348.

[3] According to Richard R. Nelson, ''Institutions Supporting Technical Advance in Industry, " *American Economic Review*, vol. 76, May *1986,* pp. *186-189.*

[4] Geiger, op. cit., footnote 1, p. 147. For a case in point, see David Blumenthal et al., "University-Industry Research Relationships in Biotechnology: Implications for the University, " *Science, vol.* **232,** June **13, 1986, pp. 1361-1366;** U.S. Congress, Office of Technology Assessment, *U.S. Investment in Biotechnology,* OTA-BA-360 (Washington, DC: U.S. Government Printing Office, July 1988); and Phyllis B. Moses and Charles E. Hess, "Getting Biotech Into the Field, " Issues *in Science& Technology,* vol. 4, No. 1, fait 1987, pp. 35-41.

entire enterprise has grown at a rate above inflation and beyond what the current Federal budget can perhaps afford.

Competition for funds, coupled with a failure to meet research expectations on the part of many researchers, contributes to relative deprivation at many research universities. University researchers feel deprived because their resources (and subsequent outputs) have not met their expectations. Although many universities urge a quick infusion of money to ensure their responsiveness to national research missions as well as the scientific research base, from an "expenditures/costs" perspective, it may not be the appropriate role of the Federal Government simply to supply extra funds. Rather, the Federal Government could encourage both established and aspiring research universities to consider the funding environment and to adjust their research agendas, timetables, and needs accordingly.[82] Devising mechanisms for understanding and coping with research expenditures is one of the central challenges to the Federal system for finding research in the 1990s.

[82] It should be noted that, under the Florida and Federal Demonstration Projects, no-cost extensions on research grants and other means of expanding the authority of universities to control research budgets locally have been successfully tested. By providing flexibility, these expanded authorities create opportunities for cost savings and improved accountability. See Anne Scanley and William Sellers, Government-University-Industry Research Roundtable,''Summary of Interim Reports Submitted by Grantee Organizations Participating in the Federal Demonstration Project,'' unpublished document, Oct. 1, 1990.

agenda and undermining the spirit of open inquiry on campus are still voiced.[5] But the trend has not so threatened academic norms as to provoke a backlash.[6] Perhaps out of economic necessity, universities have accommodated.[7]

The "competitiveness" debate has legitimized academic involvement with industry, if not outright promoted it. There is an assumption that strengthening the links between industry and university research will improve America's economic malaise. A series of legislative and executive initiatives in the 1980s encouraged collaboration, such as the Patent and Trademark Amendments of 1980 (Public Law 96-517), the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96480), the 1981 Economic Recovery Tax Act (Public Law 97-34), and the National Cooperative Research Act of 1984 (Public Law 98462). In addition, the 1980s witnessed a growth of State economic development programs that aimed to stimulate university-industry cooperation in public universities, More and more, linkage between universities and industry has been viewed as essential and mutually beneficial.*

The resiliency of the university will continue to be tested by rising demands for research funds and the proliferation of missions served by experts on campus. In the 1990s, opportunistic funding of university research may give way to a moderation of corporate-sponsored research. Or such undertakings may continue to be physically segmented in a research institute or center as a way of detaching the industrial values it symbolizes from the core campus organization.[9] The existence of university-industry collaborations is not in doubt; the forms of these collaborations, however, will remain in flux.

---

[5] For example, see "saw-in University-Based Research: Who Controls? Who Tells?" *Science, Technology, & Human Values*, special issue, vol. 10, No. 2, spring 1985, pp. 3-1 14; and Henry Etzkowitz, "The Second Academic Revolution: The Role of the Research University in Economic Development," *The Research System in Transition*, S.E. Cozzens et al. (eds.) (Dordrecht, Holland: Kluwer, 1990), pp. 109-124.

[6] It has made "intellectual property' an academic as well as a Federal policy issue. For discussions, see Marcel C. LaFollette, "U.S. Policy on Intellectual Property in R&D: Emerging Political and Moral Issues, in S .E. Cozzens et al., op. cit., footnote 5, pp. 125-139; and U.S. Congress, Office of Technology Assessment Intellectual *Property Rights in an Age of Electronics and Information,* OTA-CIT-302 (Springfield, VA: National Technical Information Service, 1986). Also see Charles Weiner, "Universities, Professors, and Patents: A Continuing Controversy," *Technology Review,* vol. *89, No. 2,* February/March 1986, pp. *33-43.*

[7] For example, see George R. McDowell, *"m-t* Colleges of Agriculture: Renegotiating or Abandoning a Social Contract," Choices, second quarter **1988,** pp. 18-21.

[8] Office of Technology Assessment, op. cit., footnote 4. Also see Barry Bozeman and Michael Crow, "The Environments of U.S. R&D Laboratories: Political and Market Influences," *Policy Sciences, vol. 23, No.* 1, 1990, pp. 25-56.

[9] See Dorothy Nelkin and Richard Nelson, "Commentary: University-Industry Alliances," Science, *Technology, & Human Values, vol. 12,* winter *1987, pp. 65-74.* In other words, the value of academic research is likely to persist, if not grow. See Edward M. Scolnick, "Basic Research and Its Impact on Industrial R&D," *Research-Technology Management,* November-December 1990, pp. 21-26.