DOCUMENT RESUME

ED 383 261 HE 028 374

AUTHOR Geiger, Roger L.
TITLE Historical Patterns of Change: The Lessons of the 1980s.
PUB DATE Feb 94
NOTE 31p.; Paper presented at the Annual Meeting of the American Association for the Advancement of Science (San Francisco, CA, February 18-23, 1994).
PUB TYPE Viewpoints (Opinion/Position Papers, Essays, etc.) (120) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Educational Finance; Educational History; *Educational Trends; *Financial Support; Higher Education; *Institutional Role; Research and Development; Research Needs; *Research Universities; Science History; *Scientific Research; Trend Analysis
IDENTIFIERS *1980s; Scientific Revolution

ABSTRACT

This paper seeks to assess the current state of academic research in light of long-term trends in the development of science. It presents three perspectives on the growth of scientific research: (1) Derek de Solla Price's (1963) hypothesis that science has exhibited exponential growth, roughly doubling every 15 years since the 17th century; (2) National Science Foundation (NSF) data on research and development (R&D) expenditures in the United States, which demonstrate a constant relationship to gross domestic product (GDP) since the 1960s; and (3) a more nuanced approach that shows that since the mid-1980s, development has experienced relative decline, applied research has been stable, and basic research has expanded slightly, even while academic research has exhibited vigorous, exponential growth. The paper then discusses how universities in the 20th century have had to implement new organizational arrangements in order to claim an increasing share of GDP for research. It argues that in the current funding environment, universities seem unlikely to extend the previous growth, despite robust demand for basic research in American society. (Contains 16 references.) (MDM)

American Association for the Advancement of Science Annual Meeting
San Francisco 18-23 February 1994

SESSION:

Research Universities in a Changing Funding Environment

HISTORICAL PATTERNS OF CHANGE: THE LESSONS OF THE 1980S

Roger L. Geiger
Pennsylvania State University
403 S. Allen St. Suite 115
University Park, PA 16801-5202

ABSTRACT

This paper seeks to assess the current state of academic research in light of long-term trends in the development of science.

Part One: Scientific growth is viewed from three perspectives. Derek de Solla Price hypothesized that science has exhibited exponential growth, roughly doubling every fifteen years since the 17th century; and this has been true of basic research in the U.S. since 1960. NSF data on R&D, however, show a constant relationship with GDP since the 1960s. Since the mid-1980s, development has experienced relative decline, applied research has been stable, and basic research has expanded slightly. Academic research has nevertheless exhibited vigorous, exponential growth.

Part Two: During the 20th century, universities had to implement new organizational arrangements in order to claim an increasing share of GDP for research. During the 1980s this occurred through arrangements for pooling public, private, and university funds.

Part Three: In the current funding environment, universities seem unlikely to extend the previous growth, despite robust demand for basic research in American society. Finances are strained, and institutional priorities have turned away from research toward student-centered concerns. Public policies seem to be turning away from the fruitful partnerships of the 1980s. In all likelihood, we are entering another period of stagnation like the 1970s and can expect to experience many of the same deleterious effects of that dismal era.

HISTORICAL PATTERNS OF CHANGE IN ACADEMIC RESEARCH

Roger L. Geiger
Pennsylvania State University

1. Macro-Trends in Science and R&D in the United States

Discussions of funding for research are usually concerned with a very limited time horizon: the greatest concern is next year's appropriation; the far future is only invoked to urge the doubling of research support in the next three or five years. Little thought seems to be given to larger questions and macro-developments. How much of the economic activity of an advanced industrial society should be devoted to research and development? What is the the empirical relationship between basic research, applied research, and development? Where should these activities take place? The literature on science and technology policy is largely silent on these matters, as is the literature on futurology. Yet, if we had some answers about where we are and where we seem to be headed, or at least signposts, we might be better able to appraise suggestions about doubling science budgets, about enlarging the pipeline of scientific and engineering personnel, or about the strengths or perils of our current drift.

In this section I will offer three views of the expansion of R&D--1) a theoretical perspective developed by historian of science Derek de Solla Price; 2) what I will call the conventional view, taken from familiar charts regularly published by the NSF; and 3) a more nuanced view that disaggregates changes in R&D expenditures.

The theories of Derek de Solla Price on the growth of scientific activity have, it seems, been around long enough to have been forgotten. He noted in the early 1960s that scientific activity, by a number of estimated indices, had roughly doubled every fifteen years since the inception of modern science in the seventeenth century.[1] Price was most intrigued by the phenomenon of exponential growth, not least because such growth is ultimately unsustainable. Instead, he hypothesized that scientific growth should follow the contours of a logistic curve (Figure 1). Although Price was writing at the beginning of the 1960s, he believed that American science had already passed the midpoint of the logistic curve, and was thus on the verge of facing the consequences of saturation. Impending saturation, in most cases of logistic growth, produced crisis conditions. For that reason, saturated growth did not smoothly trace the right side of the logistic curve, but would more likely to follow one of a number of discontinuous or violent patterns. The most interesting of these for our purposes is "escalation": whereby exponential growth occurs in stages--reaching a ceiling under one set of conditions, but then resuming when new conditions permits a new phase of growth. (Figure 1A)[2]

Price did not regard research expenditures as an adequate measure of scientific activity (his own further work concentrated on bibliometrics); so his comments on this topic were rather sketchy. He did insist on separating Development from Science. And, despite the looming threat of saturation, he thought that expenditures for science should grow more rapidly than the economy (or GDP).[3] We do not have a time series on research expenditures long enough to test Price's hypothesis; however, what is available is most intriguing. Real expenditures for Basic Research* doubled from 1960 to 1975, and then doubled again from 1975 to 1990 (Figure 2).

Thus, Price seems to have been wrong about the onset of saturation: we apparently still live in an era of exponential growth. It would be a mistake, however, to assume that this course is inevitable or inherent to science. The irregular pattern of escalation shown in Figure 2 suggests that human choices are involved.

The conventional view of scientific expansion in the United States lumps together Research and Development (Figure 3). It depicts, in constant dollars, an almost relentless upward march. True, we seem to have gotten ahead of ourselves in the 1960s, pushing R&D well above the trendline; but we compensated by underperforming in the 1970s. At the end of the 1980s we seem to be right about where we should be in terms of historical growth.

Figure 4 tells a somewhat different story, however. It shows R&D doubling as a percentage of GDP from 1953 to 1964, but then oscillating in a range slightly above or below 2.5% of GDP. Thus, R&D since the 1960s seems to have a fairly stable relationship to the total economy, so that the relentless upward march of Figure 3 is merely a function of real growth in GDP.[4]

* These terms are capitalized to indicate expenditure categories in NSF bookkeeping, not the activity itself.

How, then, can we reconcile Price's depiction of exponential growth with this apparently stable relationship to GDP? These massive figures should not be interpreted too precisely, but four factors are nevertheless germane here. 1) GDP too has been growing exponentially, although at a slower rate than the fifteen year doubling period hypothesized by Price for science. 2) Development overshadows Basic Research ("science" to Price) by a wide margin, and thus can obscure a more rapid rate of growth. 3) The federal government has substantially influenced these patterns, especially by creating "development events" like the Apollo Moon Project. And, 4) How one interprets these (and the following) Figures depends greatly on the most recent years: Some of the most dramatic developments have occurred at the end of the 1980s and the beginning of this decade, and are probably continuing today.

Figure 5 shows the proportion of GDP devoted to the three separate components of R&D. While each traces a somewhat similar pattern from 1965 to 1985, they take different directions after that date. Spending for Development peaked in 1985, and then diminished by 13 percent to 1992. Applied Research also rose to a peak in 1985, but then contracted only slightly. Basic Research, on the other hand, rose in the early 1980s, leveled off after 1987, and then grew again in the early 1990s.

Federal agencies supplied the majority of R&D funds in the U.S. until 1978, and still supply about 43 percent. The federal contribution to R&D has actually been remarkably stable as share of GDP (1.07 to 1.28%) since the early 1970s. Trends in nonfederal funds have been more dynamic.

Figure 6 shows the patterns of nonfederal funding for Development, Applied and Basic Research relative GDP. Development spending shows the same peak in the mid-1980s, followed by a decline of in this case about 10 percent. Applied Research shows an extraordinarily stable pattern from 1958 to 1980, and then a sharp rise in the first half of the 1980s. The following years in this case brought what appears to be another plateau just under 0.4 percent of GDP. Basic Research, on the other hand, experienced considerable relative contraction from the mid-1960s to the late 1970s. It then grew by two-thirds from 1980 to 1987, leveled off, and set a new peak in 1992.

The most significant featuyre of Figure 6 is that the long-term trend is clearly upward: the levels of the 1980s for all three activities is above those ofthe 1960s. I believe that these patterns can be viewed in a straightforward manner: Whereas the federal government has not felt the need to increase its investment in R&D (relative to GDP), the civilian economy has expressed a growing demand for these services. This undoubtedly reflects the increasing scientific and technological base of American industry. The trends of recent years are particularly intriguing, if also somewhat tentative: we seem to be calling for diminishing inputs of Development, but sustained higher levels of Applied Research and probably growing amounts of Basic Research.

The high demand for research may seem appropriate if, in fact, economic activity in the United States has become more science-intensive; but it is less clear why Development would not grow as well. One possible explanation is that computers (particularly engineering work stations) have improved efficiency to such an extent that more development is now accomplished at less cost. Another explanation would be the growing prominence of research-intensive industries (preeminently, biotechnology) in which there is less distance between the research frontier and final products.[6] In any case, these overall trends have been favorable for university research.

2. Academic Research

For the last quarter century, the primary role of universities in the national research economy has been to perform about one-half of the country's Basic Research. (Figure 7) Given the rapid growth of Basic Research since 1980, just maintaining this moiety has been a remarkable feat. In addition, universities have increased their share of Applied Research. This rise is part of a long-term trend dating from around 1960. Thus, in macroscopic terms, the impressive expansion of academic research since 1980 was a result of universities enlarging their share of Basic Research, the fastest growing part of R&D, and increasing their share of the slower-growing Applied Research component. As a result, academic R&D grew from 0.230 percent of GDP in 1980 to 0.324 percent in 1992, with the greatest gains in recent years (Figure 8). Clearly, the economy has had a growing appetite for academic research. But, how has that demand been accommodated?

The simplest form of growth to account for is when a single customer increases its volume of purchases. In fact, this is just what the best customer of academic research--the NIH--did during the 1980s. Still, transactions with NIH might account for, at best, 20 percent of the increased share of GDP. More generally, for an industry to dramatically increase its share of GDP, some kind of deeper structural adjustment is entailed--providing new services or products to new kinds of customers. The decade of the 1980s represents the fourth time in the twentieth century that university research has made such a structural adjustment.

The first structural change occurred between the First and Second World Wars, when universities began to perform research at the behest of external funders.[7] In those years, philanthropic foundations and, to a lesser extent, industrial corporations initiated significant funding of academic research. The second adjustment happened during and after World War II. The new sponsor on this occasion was the U.S. military. Although precise data is lacking, from the end of the war to the mid-1950s the armed services were the overwhelming source of increased funding for university research. The third stage of expansion, which began in the late 1950s, was fueled by the civilian agencies of the federal government--NIH, NSF, and NASA. This stage, as already noted, created the university research system that persisted into the 1980s. However, the funding trends already examined suggest that we have entered a new era.

Each of these stages was characterized by new social arrangements for mobilizing resources for academic research. Thus, the military phase was initiated by Vannevar Bush's Office of Scientific Research and Development, which was superseded in part by the Office of Naval Research. Another organizational invention, the Manhattan Project, was transmogrified into the Atomic Energy Commission, which perpetuated numerous ties with academic research. These arrangements persisted, and indeed persist today; but they were overlaid at the end of the 1950s by the civilian sponsors of academic R&D. NIH began its huge expansion of extramural research support in the mid-1950s; NSF received its first large appropriations after Sputnik, the same time that NASA was created. These civilian agencies not only greatly enlarged the demand for academic research, they also consciously sought to increase the supply through special programs supporting graduate students and facilities. These agencies mobilized resources for academic science (as did the military sponsors) by converting tax dollars into research grants and contracts. We all take this for granted, but in fact these arrangements represented **organizational innovations** which allowed academic research to tap additional social resources.

The obvious next question, then, is what were the organizational innovations of the 1980s that provided new services to new customers and mobilized additional social resources for academic research, or for research generally? Several candidates readily come to mind:

ORGANIZATIONAL INNOVATIONS OF THE 1980S

- Biotechnology firms
- Research consortia
- State technology programs
- NSF Engineering Research Centers
- Technology transfer progams, generally

While it is beyond the scope of this paper to examine these particular phenomena, their overall effect has been to tap additional funds for university research from industry, from governments, and in some cases from universities themselves. Biotechnology firms resulted from changes in the knowledge base that had direct and far-reaching commercial potential. The resulting demand for this knowledge had a huge impact on universities. The other examples all represent something new and distinctive about this era: they are devices for different actors to pool resources for research. This approach makes great sense. It is well accepted that social returns to Basic Research far exceed private returns. Cooperative research ventures reduce the private costs for each participant, bringing them more into line with private returns. The invention and implementation of new ways to pool research funds apparently brought additional funding for Basic Research and especially university research. With new ways to pay for research, the effective social demand for research rose.

To see how this actually happened, one should recall the atmosphere of the beginning of the 1980s. Widespread concern existed about the loss of American industrial competitiveness, and enhancing technology transfer from academic research to industry was touted as one possible remedy. On university campuses, however, there was considerable resistance to greater cooperation with industry. University attitudes were soon overtaken by events. The biotechnology revolution was a shock that eventually changed many minds and virtually forced changes in behavior. More generally, as the financial advantages of greater cooperation with industry became increasingly evident, universities became eager to embrace economic relevance as an explicit goal for their research. In practice, this usually meant implementing organizational innovations as well.

Industrially supported research was the fastest growing component of academic research in the 1980s. In an earlier study of this phenomenon, I found that increases in the first half of the decade seemed to be attributable to a rising volume of total industrial research. After mid-decade, however, universities significantly increased their share of industry-supported research--a sure sign that universities had found new means to deliver research services.[8]

The next largest source of growth in academic research came from universities themselves. The financial benefits of expanding research seem to have motivated universities to invest extensively in their own research efforts. In a recent study of changes in research shares of individual universities, Irwin Feller and I found a strong association between institutions that increased such investments and increases in institutional research share. The same study produced anecdotal evidence that state programs to encourage technology transfer also made important contributions to research growth.[9]

Generally, in order to give American society what it demanded--more economically relevant research--universities changed internally by fostering research that was less closely linked to academic (teaching) departments. This was largely done through the use of separate research centers (sometimes called Organized Research Units). The large numbers of research centers devoted to interacting with industry is a topic that has been studied by Richard Florida, and these findings will be presented later in this session.[10] They are quite cinsistent with the contention made here that such arrangements palpably affected the growth of academic research.

The cumulative effect of these and other changes was to dramatically increase the nonfederal resources directed to the support of academic research. Federal funds for academic research actually increased by 55 percent in real terms from 1980 to 1992, but nonfederal support rose by 140 percent. Federal funds at the beginning of the decade provided two-thirds of the support for academic research--a figure that had been stable since the early 1970s. In 1992, however, the federal contribution had fallen to 57 per cent--yet another indication that a new era is at hand. This brings us to the real focus of this session--how are the research universities likely to fare in this new era?

3. Academic Research in the New Era

Many of the signposts that are used to assess the current situation of academic research seem to point in contradictory directions. The relatively high expenditures for Basic Research seem to represent a robust demand in the economy. As a nation we are committed, at least rhetorically, to a policy of emphasizing and facilitating High-Tech industries, those in which the United States has an emphatic comparative advantage. There is nevertheless a great deal of pessimism about these prospects, stemming largely from the inevitable decline of defense-related R&D and the fact that industrial spending on Basic Research has leveled off.[11] Still, the most encouraging factors are to be found on the supply side of the ledger.

By all accounts American science is more productive than it has ever been, and the cascade of discoveries it has yielded is characterized by increasing potential for commercial application. According to Frank Press (past President of the National Academy of Sciences) the key elements in this process are "Research-based technologies." He has named a dozen of these which have huge, and certain, commercial potential in the foreseeable future:[12] Such emerging research-based technologies portend substantial continuing investments in research, much of it in academic research.

RESEARCH-BASED TECHNOLOGIES

Advanced Materials
Superconductors
Advanced Semiconductor Devices
Digital Imaging Technology
High Density Data Storage
High-Performance Computing
Optoelectronics
Artificial Intelligence
Flexible, Computer-Integrated Manufacturing
Sensor Technology
Biotechnology (Bioprocess, genetic engin; bioelectronics)
Medical Devices and Diagnostics

On the other hand, if we view the current scenario from the standpoint of research universities, future growth seems likely to be constrained by two conditions: inherent limitations on the number of positions for scientists, and the saturation of growth in current funding arrangements.

The predicament of universities arises from their nature as multi-function institutions. For much of their history the juxtaposition of undergraduate teachir ı, graduate training and research was exceedingly fruitful for advancing science. The arrival of the era of no-growth in the 1970s, however, introduced a major complication. Faculty structures are anchored in the teaching responsibilities of academic departments, and it thus became difficult to increase faculty/researchers under conditions of stable enrollments. During the 1980s expenditures for academic research grew by 77 per cent, but the number of regular faculty at research universities grew by about 10 percent. Moreover, Irwin Feller and I found that the most prestigious universities, which were characterized by stable faculty structures, tended to lose research share during those years.[13]

Universities were able to expand research to a significant degree during the 1980s by adding the kind of separate research centers mentioned above. The number of nonfaculty researchers increased considerably during the decade. Precise figures do not exist, but the 57% increase in postdocs from 1982 to 1990 is undoubtedly indicative.[14] Feller and I found significant gains in research share made by pure medical universities, which, as academic institutions, are relatively unconstrained by teaching imperatives and employ large numbers of nonfaculty scientists.

Utilizing research centers was an effective strategy for growth during the 1980s. Now, however, the conditions that prompted universities to make those extra-academic commitments are probably far less compelling. University finances have come under intense pressure; but more importantly, university priorities have shifted in the direction of undergraduate teaching and other student-centered concerns. Universities are in all likelihood becoming reluctant to invest discretionary funds in enterprises that are perceived to be distant from their instructional role. University priorities are important. Establishing separate research centers generally requires institutional initiative and commitment--qualities not likely to be forthcoming given the outlook now prevailing.

Yet, if Frank Press is correct, special units will undoubtedly be called for to accommodate the research-based technologies which are demanded by the economy and which will provide the foundations for future growth. In addition, if universities are inhibited from competing by their own internal priorities, they are unlikely to receive as much encouragement as they recently have from outside agencies.

The great success of the 1980s was in melding research support from public sources, from industry, and from universities in order to conduct research that no single party would be likely to support independently. Numerous opportunities for extending these kinds of arrangements probably exist. However, the public agencies that encouraged these alliances in the 1980s seem less inclined to perpetuate, let alone expand them in the years ahead. At the federal level, the will may exist for an active technology policy, but perhaps only in substitution for Basic Research support.[15] Perhaps more discouraging is the decline of state programs. During the course of the 1980s these programs seem to have become more applied in focus, and since 1990 they have declined in outlays. Given the difficulty of evaluating their impact, Irwin Feller has pointed out, they are increasingly difficult to justify politically.[16]

In conclusion, it appears likely that the conditions that produced the robust growth in academic research since 1980 have reached a point of saturation. In terms of historical patterns, this may be a repeat of, rather than an exception from, the last great period of expansion. When national expenditures for Basic Research peaked in 1968, entering a decade-long plateau, academic research continued to gain share for the next four years (Figure 7). Apparently, disaffaction with research struck nonacademic performers earlier and more severely--a most surprising development given the turmoil that engulfed universities in those years. Since the end of the 1980s, academic research again appears to be defying the national trend--a situation not likely to persist. If the pattern of the 1970s is repeated, then American universities are about to enter a new period of stagnation. Research universities are not likely to lose the great gains that they made during the 1980s, especially in adapting more effectively to changing social demands for research. But a period of stagnation or backsliding would nevertheless have unfortunate effects. The 1970s brought a deterioration in the international competitiveness of industry, in the relative capabilities of our research infrastructure, and in the output of scientists and engineers. Surely it would be more prudent to seek policies for encouraging consistent, moderate expansion instead of the discontinuities of that dismal era.

NOTES

1. Derek J. de Solla Price, Little Science, Big Science, and Beyond (New York: Columbia University Press, [1963] 1986), 1-29.

2. Price provides several examples of logistic escalation--the foundings of universities, the increase of energy levels in particle accelerators, and the discovery of chemical elements: Ibid., 25-27.

3. Price dismissed R&D expenditures as largely reflecting weapons development: Ibid., 136-39, 283n; Interestingly, a decade later Daniel Bell skirted the issue of the role of research in a postindustiral society for essentially the same reason: The Coming of Post-Industrial Society (New York: Basic Books, 1973).

4. The main features of the academic research system that

was erected after Sputnik persisted in its essential configurations into the 1980s: R. Geiger, "What Happened after Sputnik: Reassessing the Federal Impact on University Research, 1958-1968" in Nathan Reingold and David Van Keuren, eds. Science and the Federal Patron (forthcoming).

5. [open]

6. Frank Press, "Science and Technology Policy for the Post-Vannevar Bush Era," Address to the AAAS, 4/16/92.

7. R. Geiger, To Advance Knowledge: the Growth of American Research Universities, 1900-1940 (New York: Oxford University Press, 1986). Much of the following material is drawn from the author's sequel volume, Research and Relevant Knowledge: American Research Universities Since World War II (New York: Oxford University Press, 1993).

8. R. Geiger, "Industry and Research: The Revolution of the 1980s" in Susan L. Sauer, ed. Science and Technology and the Changing World Order (Washington, D.C.: AAAS, 1990), 137-48.

9. R. Geiger & I. Feller, The Dispersion of Academic Research During the 1980s: A Report to the Andrew W. Mellon Foundation Institute for Policy Research and Evaluation, Pennsylvania State University, May, 1993.

10. Richard Florida & Wesley M. Cohen, "The Financing of Research Centers." Draft, Feb. 1994.

11. Daniel S. Greenberg, "A New Deeper Pessimism Sweeps over Science," Science & Government Report 23, 13 (August 1, 1993):1-4.

12. Press, "Science and Tecnology Policy" [n. 6].

13. Geiger & Feller, Dispersion of Academic REsearch [n. 9].

14. NSF, Selected Data on Gradute Students and Postdoctorates in Science and Engineering: Fall 1990 (Washington, D.C.: NSF, 1991), 45.

15. Albert H. Teich, et al, Congressional Action on REsearch and Development in the FY 1994 Budget (Washington, D.C.: AAAS, 1993), 20-23; Science & Government Report 24,3 (Feb. 15, 1994).

16. Carnegie Commission on Science, Technology, and the Government, Science Technology and the States in America's Third Century (New York: author, Sept. 1992); I. Feller, "American State Governments as Models for National Science Policy," Journal of Policy Analysis and Management 11 (1992): 288-309.

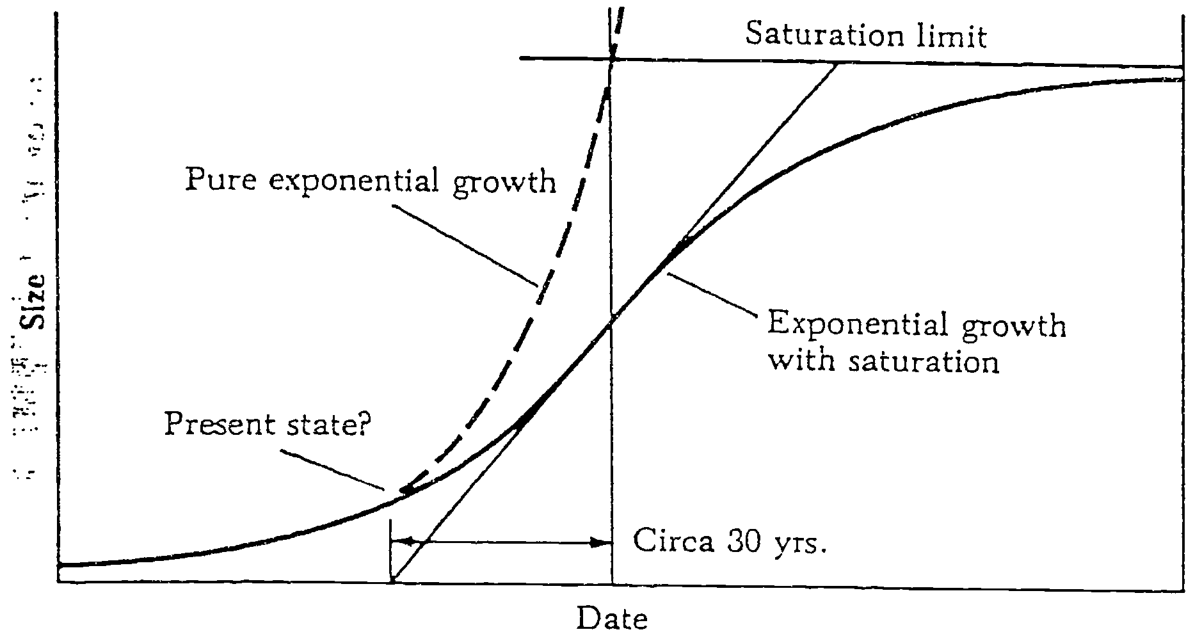


Figure 1 General Form of the Logistic Curve

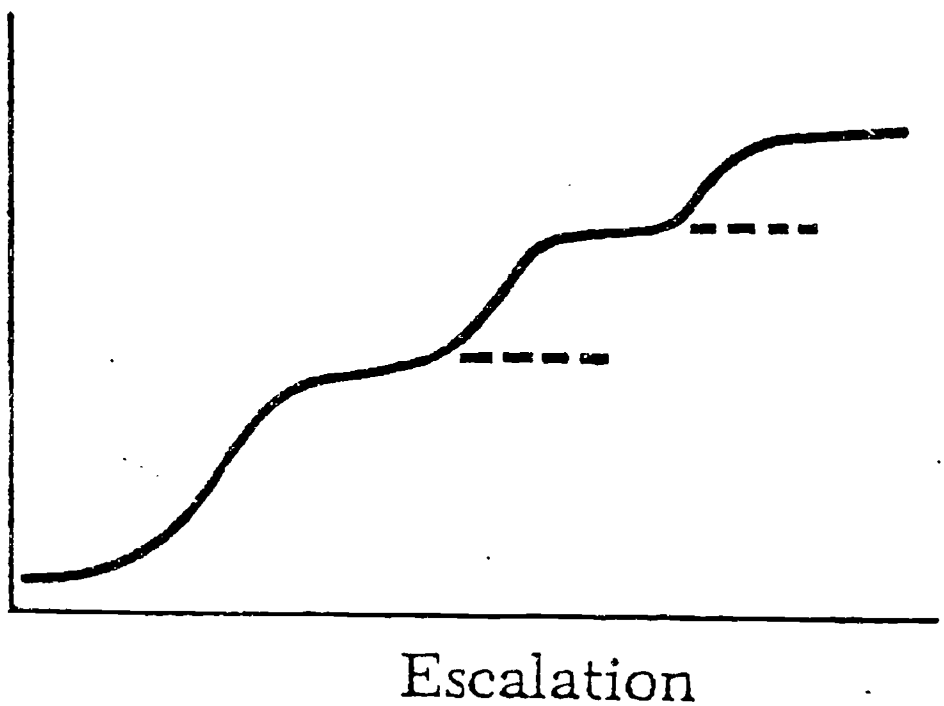
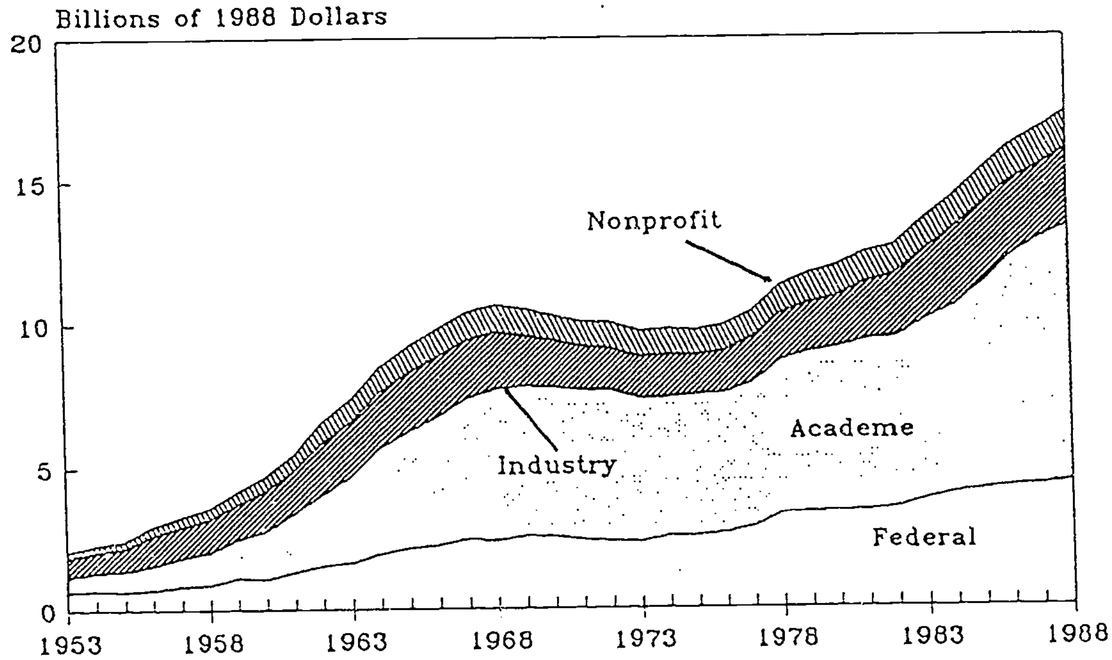


FIGURE 1A

Figure 2

Basic Research By Performing Sector: 1953-1988

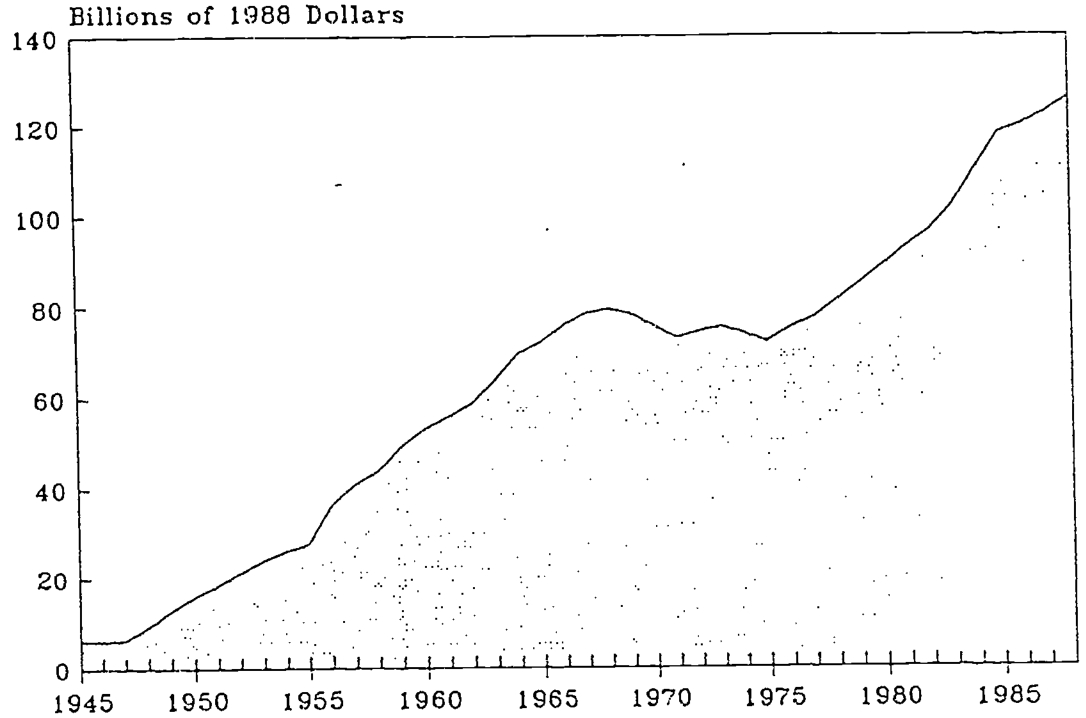


Source: PRA estimates based on NSF surveys

Chart IA-6

Figure 3

Total R&D: 1945–1988

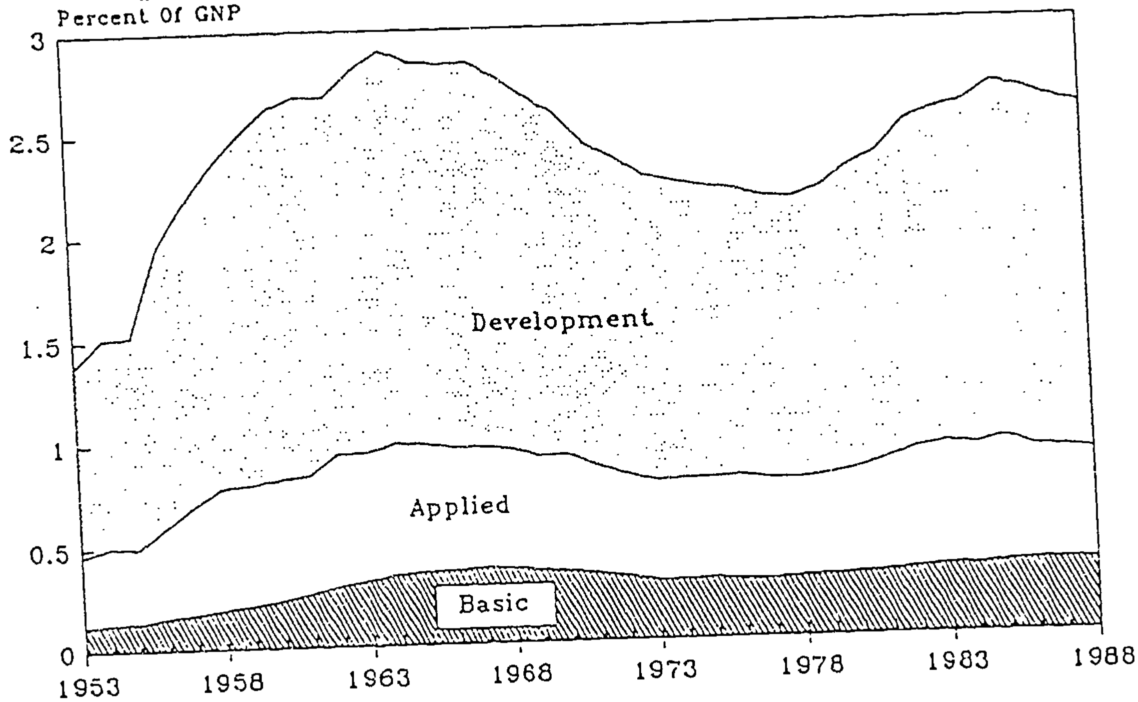


Sources: DOD, NSF surveys

Chart IA-1

Figure 4

Significance of R&D to the U.S. Economy (R&D Expenditures as Fraction of GNP): 1953-1988



Source: PRA estimates based on NSF surveys

Chart IA-2

Figure 5
Development, Applied Research, and Basic Research
As a Percent of Gross Domestic Product
1953-1992

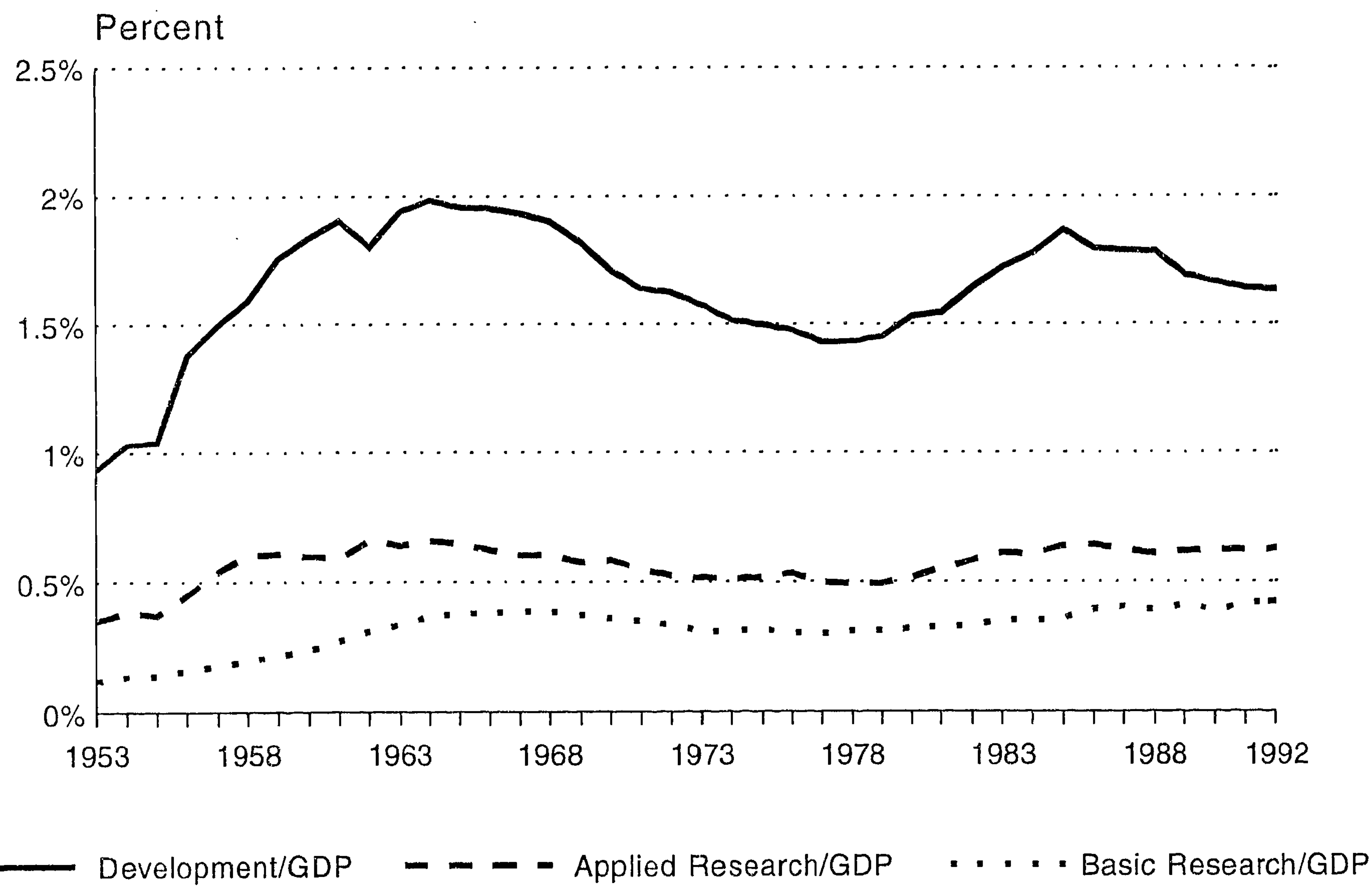


Figure 6
Nonfederal Sources of Funds for Development, Applied, and Basic Research As a Percent of Gross Domestic Product
1953-1992

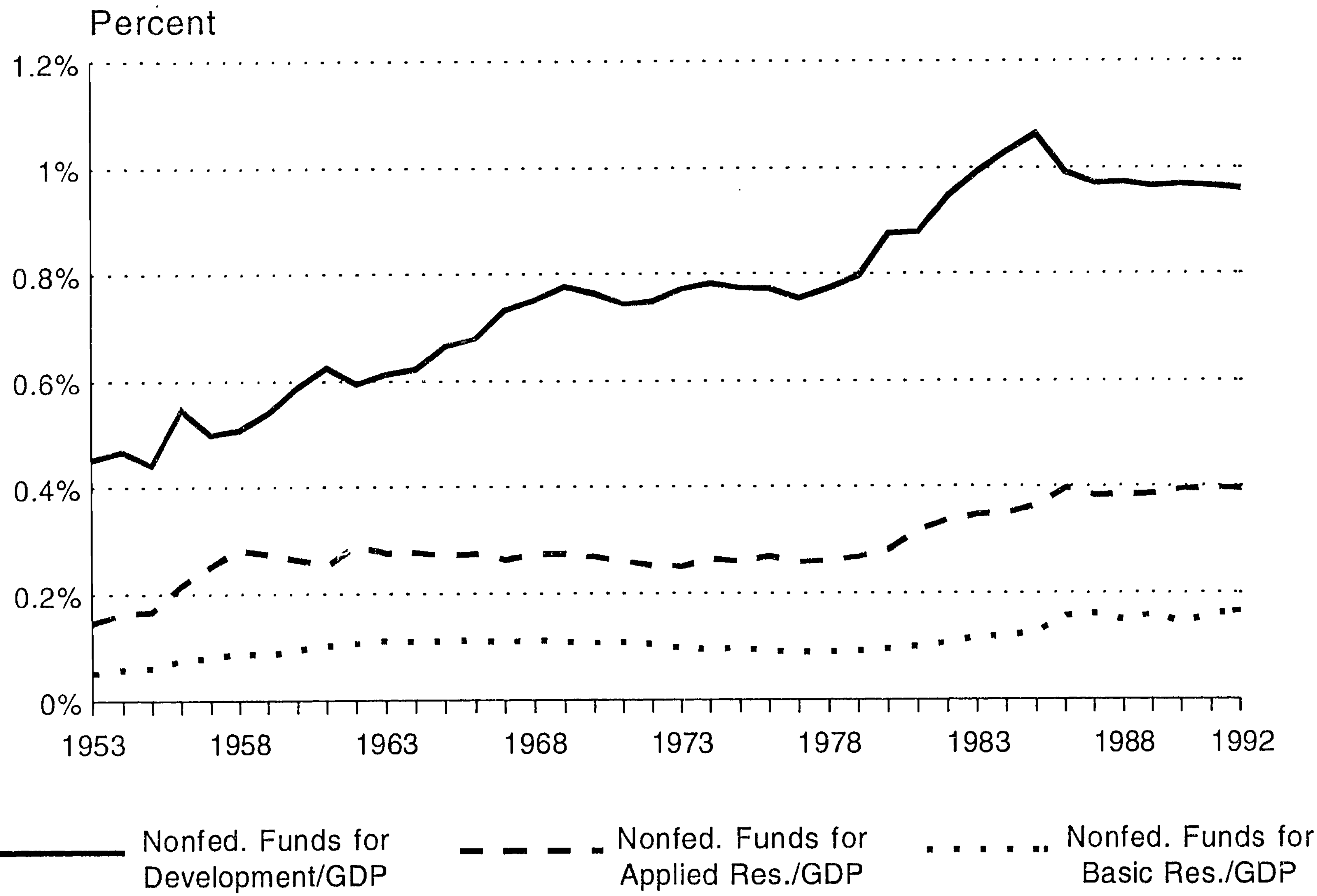


Figure 7
University and College Applied Research and Basic Research As a Percent of Total Applied and Basic Research
1953-1992

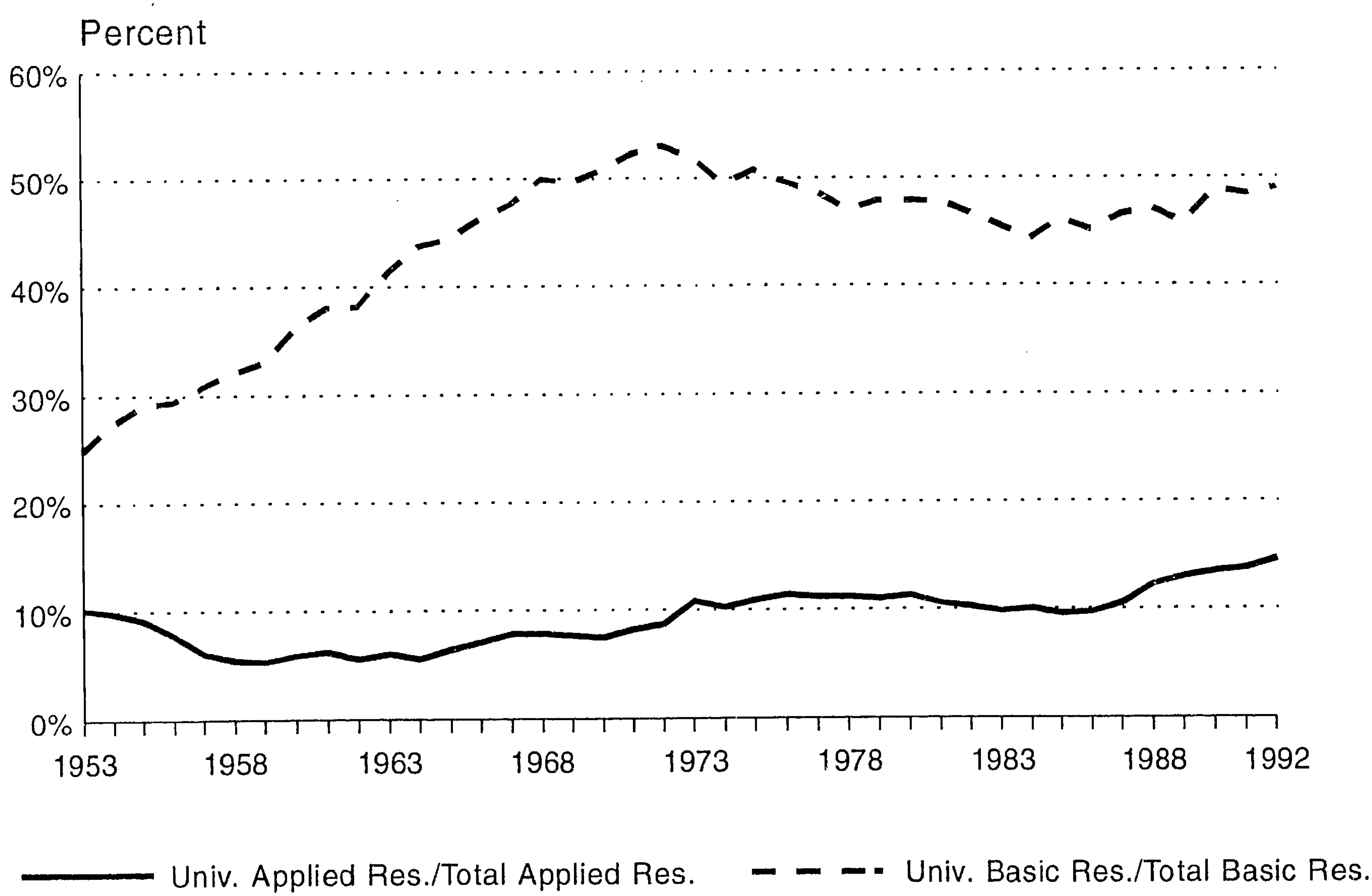


Figure 8
Academic Research & Development Expenditures As a Percent of Gross Domestic Product
1953-1992