Chapter 3

Demographic Trends and the Academic Market for Science and Engineering Ph. D.s

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THE NEAR-TERM DECLINE

Nowhere does a confluence of demographic trends produce more dramatic results than in the projected hiring pattern for new Ph. D.s in the Nation's universities and colleges. Two trends are at work here. First, the decline in higher education enrollments projected for the 1982-97 time period by the National Center for Education Statistics (NCES) and others (see chapter 2) should reduce the total demand for faculty proportionately. The subsequent increase in probable enrollments over the 1997-2010 period should lead to an increase in the size of the professorial.

A second trend has to do with faculty retirements, and reflects an earlier demographic event —the spectacular growth in college faculty that accompanied the arrival of the post-World VVar II baby boom generation on campus in the 1960s and early 1970s. The near tripling in full-time equivalent (FTE) higher education enrollments that took place between 1960 and 1975 (from 3 to 8.5 million) was accompanied by an equivalent near tripling in the size of the full-time instructional staff (from 154,000 to 440,000).1 This created an age distribution among college and university faculty in the late 1970s that was heavily skewed toward 35 to 40 year olds and away from 50 to 65 year olds. Figure 3-1 compares the actual age distribution of faculty in 1978 with a model age distribution that would be characteristic of a steady-state equilibrium with constant faculty size. ' The overrepresentation of 30 to 40 year olds, and underrepresentation of 55 to 65 year olds are quite obvious.

As a result of this skewed age distribution, the rate of retirement of college and university faculty is low and will continue to remain so until the early 1990s. Figure 3-2 shows the combined death and retirement rates projected for the major science and engineering fields through the course of the century by Charlotte Kuh.[3] A "steady state" rate, assuming all faculty work for 35 years, from receipt of Ph.D. at age 30 to retirement at age 65, and no faculty growth, would be 2.5 to 3.0 percent per year. [4] It is clear that none of the fields displayed in figure 3-2 reach that rate until the 90s, and only the social sciences surpass 2.5 percent per year before 1994. Thus the period of low faculty retirement and death rates coincides with the period of possibly declining student enrollments.

The confluence of these two trends leads to a period of extremely weak demand for new doctorates in academia from the early 1980s through the mid-1990s. Figure 3-3 illustrates the gap between the projected demand for new faculty, which averages 6,500 to 16,000 per year during this period, ' and annual awards of doctoral degrees, which average about 30,000 per year. This compares quite unfavorably with the 1960s when, as shown in chapter 2, the supply of new Ph. D.s averaged 17,000 per year and the demand for faculty (including both doctoral and nondoctoral faculty) averaged 26,000 per year. It is also considerably worse than the situation in the early 1970s, when the supply of new Ph. D.s averaged 31,000 per year and the demand for faculty (growth plus replacements) also averaged about 31,000 per year, according to OTA analysis. " It

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'N'~tl(~nal Research Council, *Research Excellence Through the Year 2000* (Washington, DC. National Academy 01 Sciences, 1979), p 1 9.

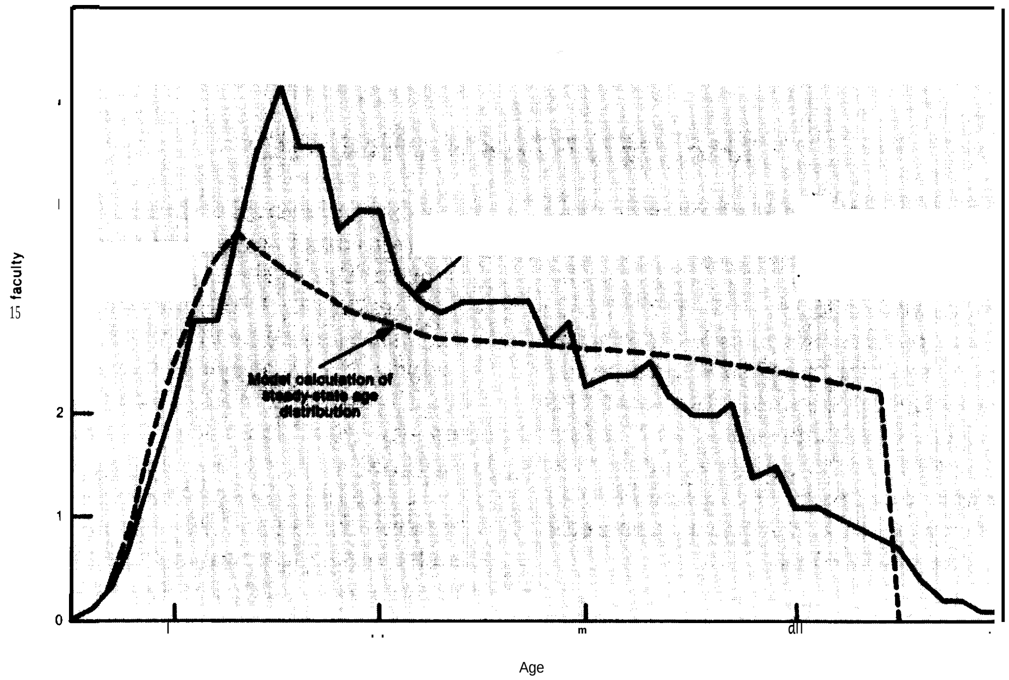
[3]Ibid., p. 23.

[4]Ibid., p. 24

William G. Bowen, *Report of the President* (Princeton, NJ Princeton University>', April 1 98 1), p. 20: Charlotte Kuh and Roy Radner *Preserving a Lost Generation*, report t o the Carnegie Co u ncil on Policy Studies in Higher Education, October 1978, p 9.

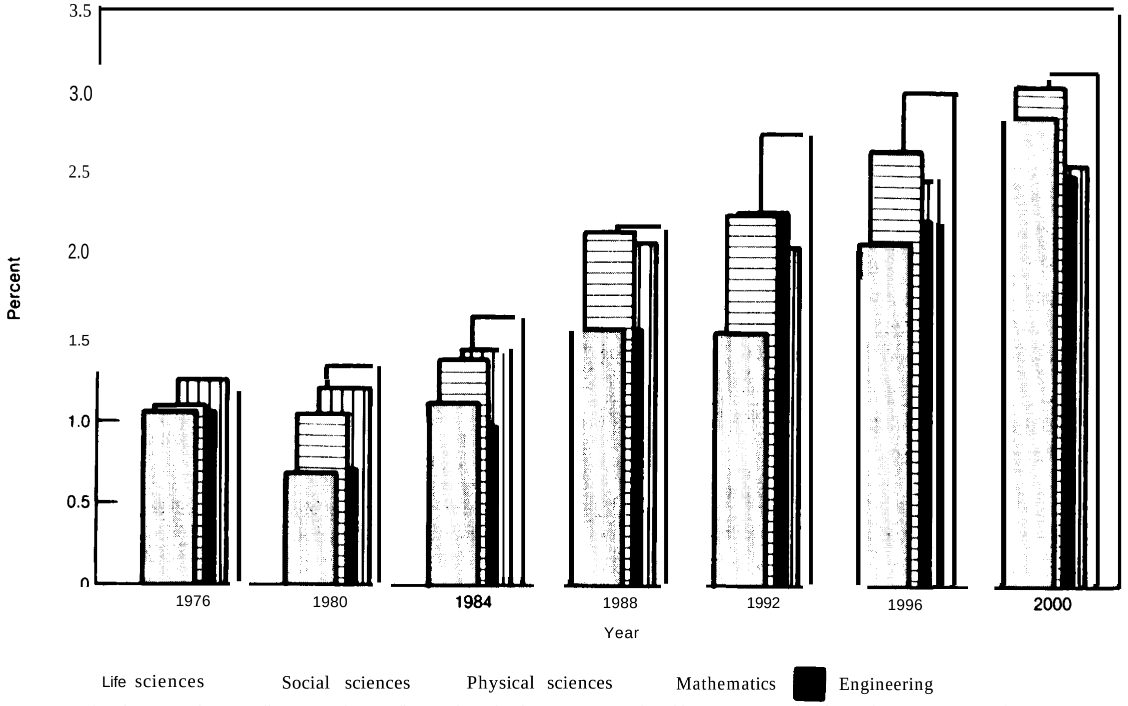
'According to the National Center for Education Statist ics there were 403,700 FTE faculty employed in 1 970; 502,700 in 1 975 and 528,700 in 1980 That translates to growth rates of 19,800 per year between 1970 and 1o75 and 5,200 per year between 1975 and 1980; U.S. Department of Education, *Condition of Education* (Washing-

Figure 3.1 .—Actual and Steady-State Age Distributions, Full-Time Doctoral Faculty at Ph.D.-Granting Institutions, 1978



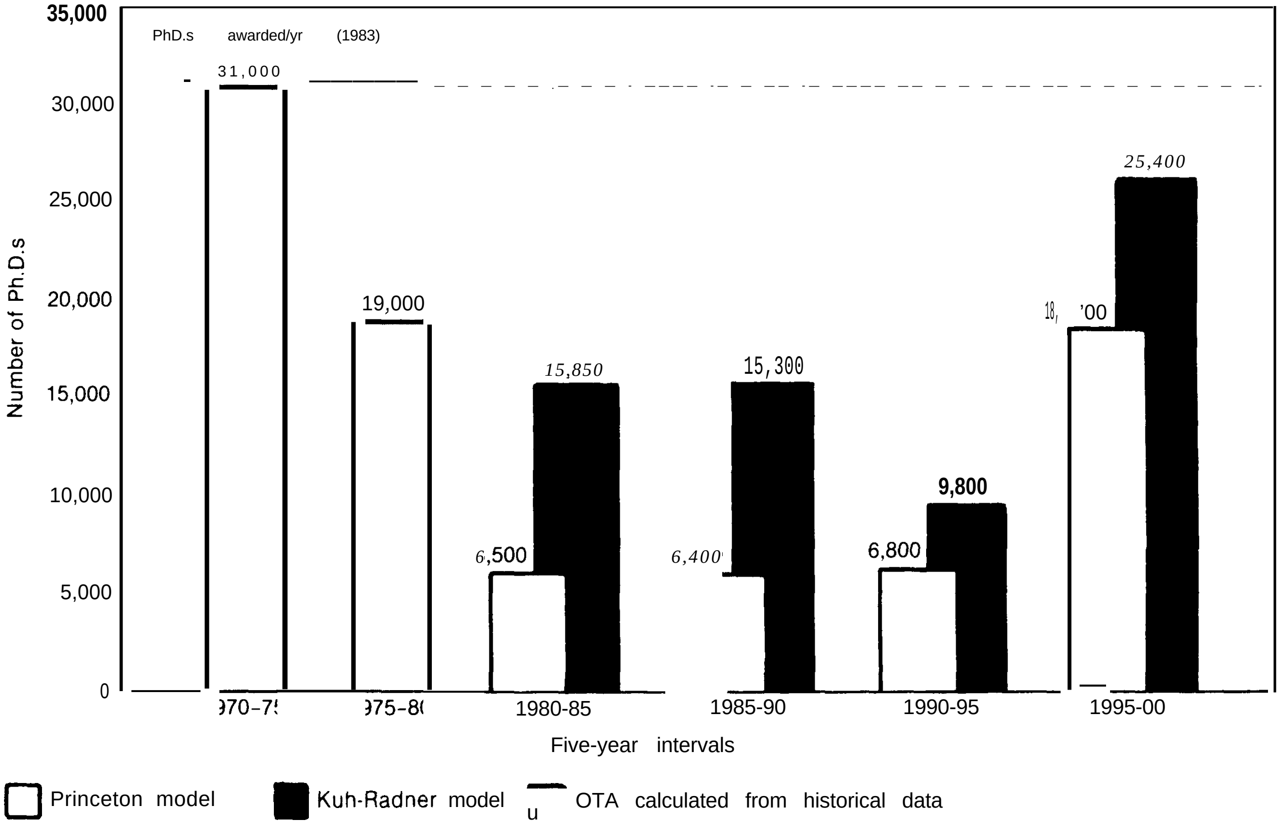
SOURCE National Research Council, Research Excellene Through the *Year* 2000 (Washington, DC National Academy Press, 1979), p 19

Figure 3-2—Combined Death-Retirement Rate, Percent of Faculty



SOURCE National Research Council, *Research Excellence through the* year 2000 (Washington, DC National Academy Press, 1979) p 23

Figure 3-3.—Annual Number of New Hires Based *on* Projections



SOURCES: William G. Bowen, *Report of the President* (Princeton, NJ: Princeton University, April 1981), p. 20; and C. Kuh and R. Radner, *Preserving a Lost Generation*, report to the Carnegie Council on Policy Studies in Higher Education, October 1978, p. 40.

is roughly comparable to the late 1970s, when 31,500 doctorates were awarded annually, but the number of new faculty slots averaged approximately 19,000 per year. Although over 40 percent of all science and engineering Ph. D.s enter industry *or* government, it is important to remember that most analysts assume that no more than 50 or 60 percent of all new faculty positions will be awarded to holders of the doctoral degree. The remainder will go to M.A. s, M.D. s, J.D. s, D. D.S. S, and other first professional degree holders.

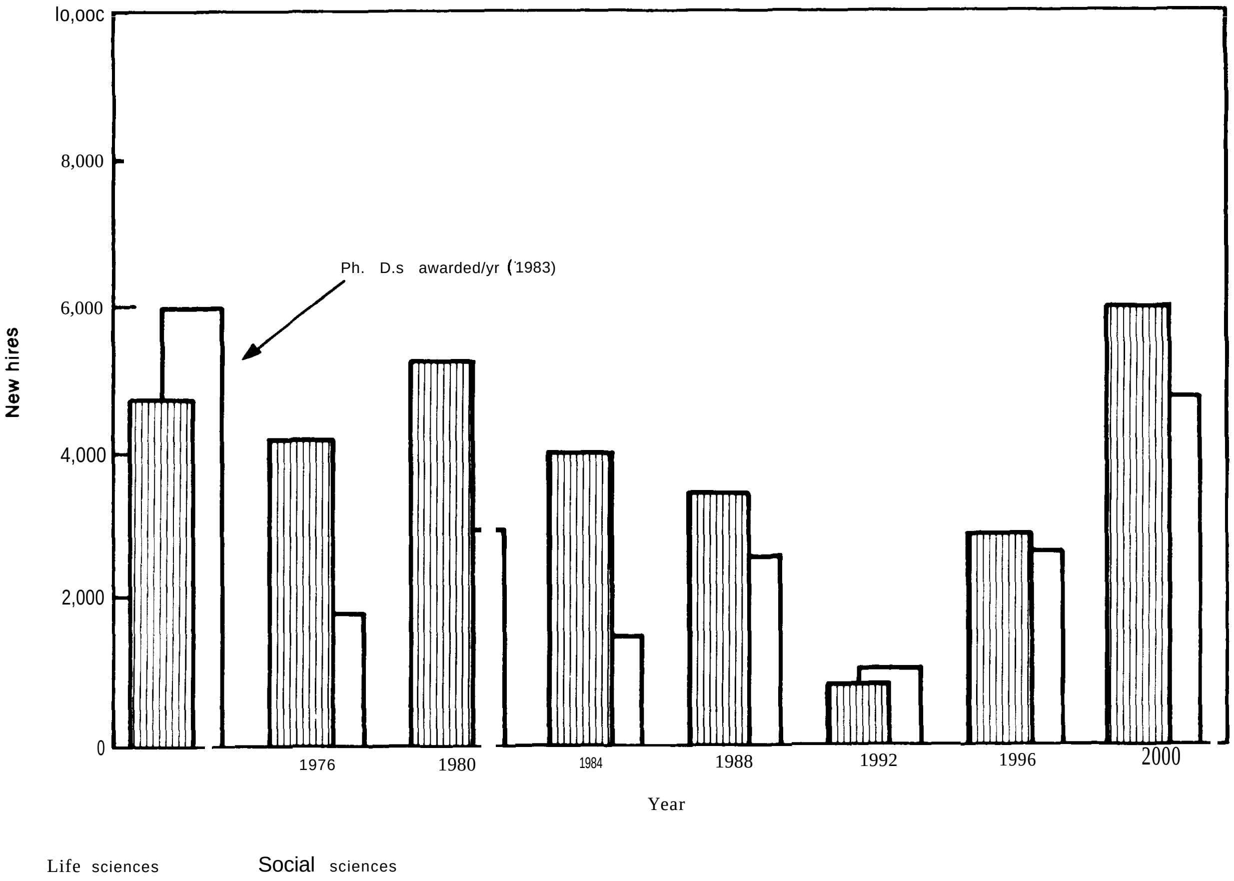
This decline in academic positions available to new Ph. D.s was first projected in the early 1970s by Alan Cartter. His projections were refined and modified by a number of analysts, including Roy Radner, Charlotte Kuh, and Louis Fernandez[7] between 1976 and 1980, but the basic findings remained the same. Kuh and Radner were so disturbed by the implications of this finding for the careers of young scholars that they entitled their

continued from p. 55

ton, DC: U.S Government Printing Office, 1985), table 2.12, p. 110 According to the National Research Council the combined death and retirement rule for faculty in the 1970s was about 1.2 percent per year; National Research Council, op. cit., p. 23, This translates into total deaths and retirements of 4,200 per year between 1970 and 1975 and 0,000 per year between 1975 and 1980, Charlotte Kuh and Roy Radner report tenured and nontenured quit rates of 0.5 and 4 percent per year in the mid- 1970s; Kuh and Radner, op. cit., table A-4, p. 41. Using those quit rates and the ratio of tenured to nontenured faculty reported by Kuh and Radner in the same source (70:30) resignations can be estimated to be 6,300 per year from 1970 to 1975 and 7,800 per year from 1975 to 1980 Adding growth plus retirement plus resignations for each 5-year period gives the total annual demand for new faculty of 31,000 for 1970-75 and 19,000 for 1975-80 reported in the text.

[7]Alan Cartter, *Ph. D.s and the Academic Labor Market* (New York: McGraw-Hill, 1976); Louis Fernandez, *U.S. Doctorate Faculty After the Boom: Demographic Projections to 1995*, Technical Report No. 4, Carnegie Council on Policy Studies in Higher Education, October 1978; Kuh and Radner, op. cit.; Roy Radner and L. S. Miller, *Demand and Supply in U. S. Higher Education* a report to the Carnegie Council on Policy Studies in Higher Education, 1976.

Figure 3.4.—Annual New Hires by Field



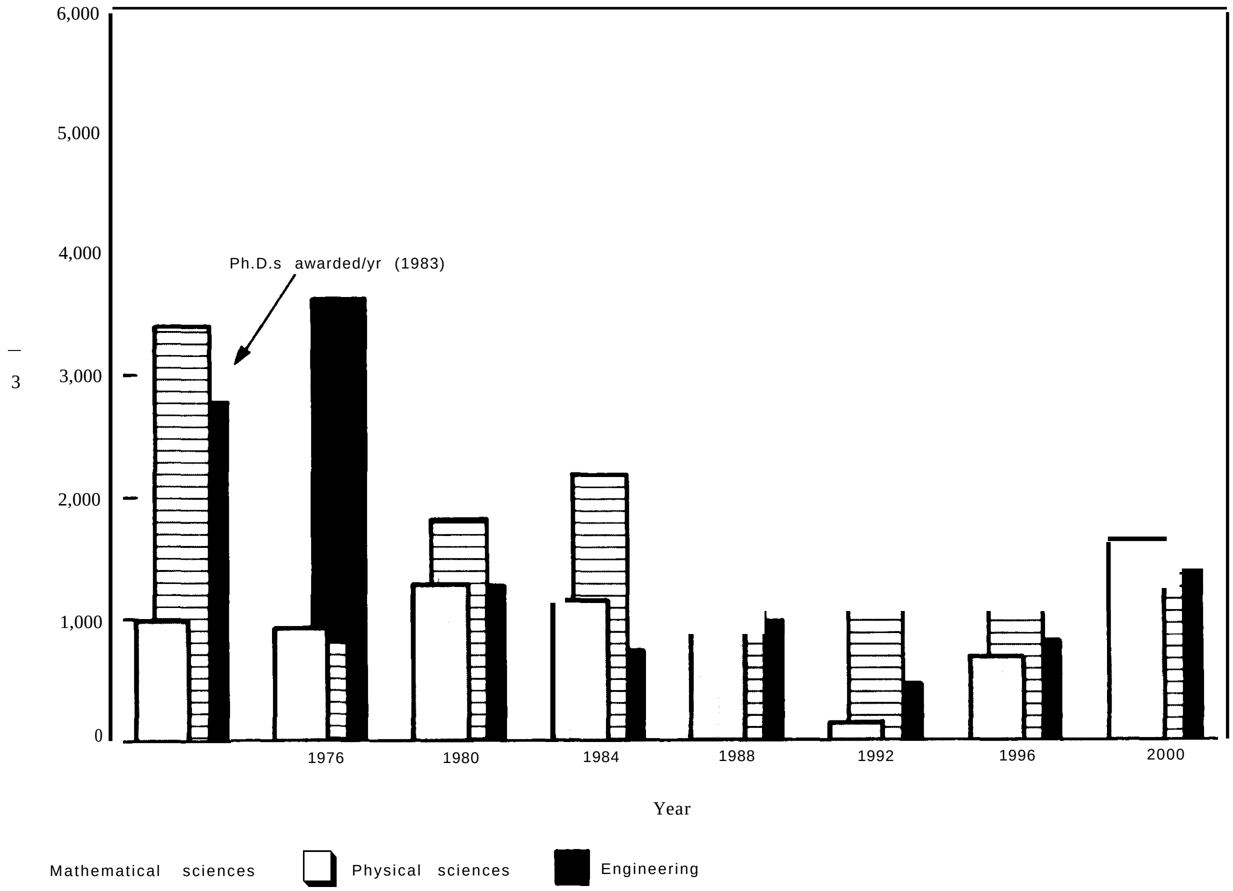
SOURCE National Research Council, *The Demand for New Faculty m Science and Engineering*, 7979 (Washington, DC National Academy Press, 1980), PP 176 and 177

study for the Carnegie Council on Policy Studies in Higher Education, *Preserving a Lost Generation: Policies to Assure a Steady Flow of Young Scholars Until the Year 2000.*

In 1978 the National Research Council (NRC) asked Kuh and Radner to adapt their forecasts to science and engineering fields, as part of a study on *Research Excellence Through the Year 2000* (reference 2, above). Using National Science Foundation (NSF) and NRC data, Kuh and Radner prepared a set of projections for the number of new faculty hires that would be required each year from 1978 to 2000 for science and engineering as a whole, and for the major broad field categories. Those projections are summarized in figures 3-4 and 3-5 which also compare the number of new hires with the number of doctoral degrees awarded in 1983.[8] As can be seen, Kuh and Radner predict a weak academic market for science and engineering Ph. D.s from the early 1980s to the early 1990s followed by sustained growth through the year 2000. (The apparent growth in new hires in the physical sciences between 1980 and 1988 is the artifact of a spuriously high non-tenured quit rate built into the model for that group.)

[8]National Research Council, *The Demand for New Faculty in Science and Engineering*, 2979 (Washington, DC: National Academy of Sciences, 1980), pp. 62-63, 176-177.

Figure 3-5.–New Hires by Field



SOURCE National Research Council *The Demand for New Faculty In Science and Engineering 1979* (Washington DC National Academy Press, 1980) pp 176 and 177

PROBLEMS WITH PROJECTING THE DEMAND FOR NEW FACULTY

To determine whether or not Kuh and Radner's projections of a hiring decline from 1983 to 1995 are correct it would be useful to compare their near-term (1975-83) projections with recent historical experience. Unfortunately, that is a very difficult task, for two reasons, First, and most serious, is the extraordinary fact that no *organization—not NSF, nor NRC, nor NCES—actually measures the number of new faculty appointed in a given year*. Thus we cannot compare projections with any directly observed data.[9]

Peter Syverson and Lorna Foster of NRC have attempted to *infer* hiring rates indirectly from NRC's biannual Survey of Doctoral Recipients (SDRS), a longitudinal study of the career patterns of a lo-percent sample of science, engineering, and humanities Ph.D.s. Comparing responses to the 1981 and 1983 SDRS, Syverson and Foster estimate the growth in the number of faculty positions as "the change in the number of academically employed respondents between 1981 and 1983" and attrition as "the proportion of respond-

[9] In its most recent survey of Ph.D.-granting science and engineering departments the National Science Foundation asked chairmen to estimate the number of new full-time permanent appointments made in 1983, Unfortunately, this is a limited sample, and the results have not yet been published. Moreover, NSF has some reservations about the accuracy of reporting on this question. Personal communication from Christine Wise, Science Resource Studies Division, National Science Foundation, Sept. 23, 1985.

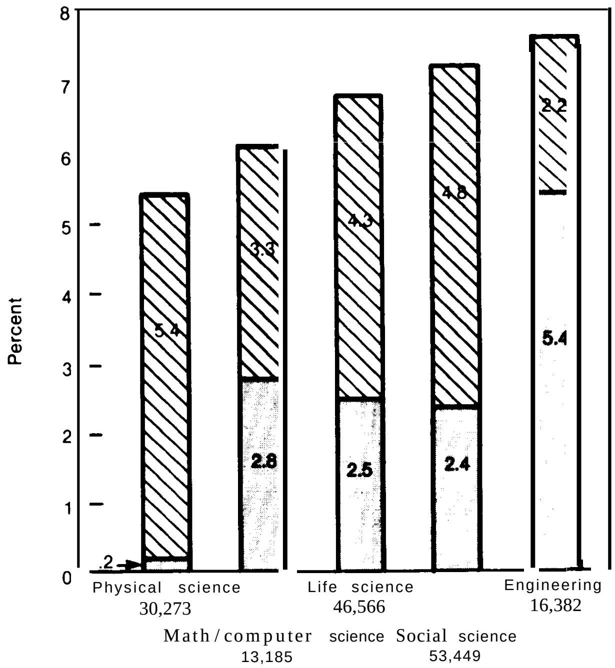
ents **who no longer reported academic employment" in** 1983.[10] Syverson and Foster find that "even when the academic labor market is in an overall steady state, as it now appears to be, there continues to be demand on the order of 5 to 7 percent" for both replacement and growth. See figure 3-6 for the percentages by field. Comparing annual doctoral degree production for 1983 with the calculated number of job openings they find ratios ranging from about 190 new Ph. D.s per 100 academic job openings in engineering and physical science to 109 per 100 in mathematics and computer science, with the life and social sciences directly in the middle.[11] (See figure 3-7.)

For individual fields we can compare Syverson and Foster's calculated new hires with Kuh and Radner's projected new hires for 1983. The results are displayed below.

Although the totals for science and engineering are reasonably close, there are clearly serious discrepancies between the projections and the calculated new hires in all fields, with the greatest differences appearing in the social sciences and engineering. The fact that some fields are substantially overprotected while others are underprojected indicates that the problem is probably not simply one of a lack of comparability in the populations being studied.

A second factor limiting the ability to treat projections from models such as that of Kuh and Radner as precise numerical predictions is the extreme sensitivity of those projections to assumptions made by the modellers about certain key parameters connecting enrollment to the demand for

Figure 3-6.—Replacement Demand As a Percentage of the Total Academically Employed—Science and Engineering, 1983



SOURCE Peter Syverson and Lorna Foster, New *Ph. D s and the Academic Labor Market* (Washington, DC: National Research Council, 1984), pp 4 and 7

faculty. These parameters include retirement rates, tenure and promotion rates, voluntary "quit rates, " and variations in the overall ratio of faculty to students from year to year. Robert Klitgaard reports that "reasonable variations" in one parameter alone, "quit rates, " lead to projections of new hires differing by a factor of 5 or 6 by 1985.[12]

[10] Peter Syverson and Lorna Foster, "New Ph. D.s and the Academic Labor Market, " Office of Science and Engineering Personnel Staff Paper No. 1, typescript, p. 2.

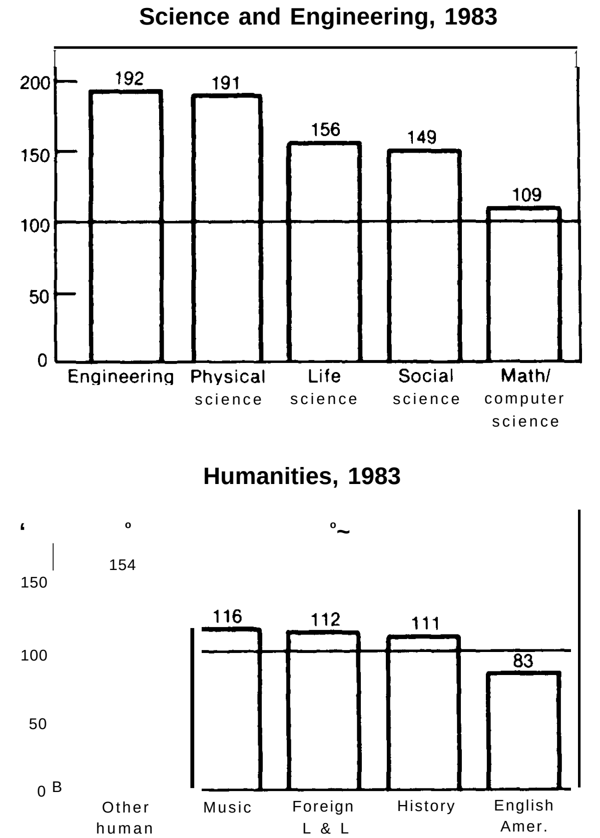
[11] Ibid., pp. 3 and 10.

[12] Robert E. Klitgaard, *The Decline of the Best?* Discussion Paper No. 65 D (Cambridge, MA: John F. Kennedy School of Government, Harvard University, May 1979), p. 16.

New Academic Hires, **by Science and Engineering Field, 1983**

	Kuh-Radner	Syverson	Syverson as % of K-R
Physical science	2,096	1,639	(78 percent)
Mathematical science	1,160	810	(70 percent)
Engineering	893	1,246	(150 percent)
Life sciences	4,348	3,179	(73 percent)
Social sciences	1,690	3,842	(227 percent)
Total	10,187	10,716	(105 percent)

Figure 3-7.— New Ph. D.s Per 100 Academic Job Openings



SOURCE Peter Syverson and Lorna Foster. New *Ph D s and the Academic Labor Market* (Washington, DC National Research Council 1984), pp *4* and 7

Lee Hansen and Karen Holden have calculated the effect of changing the mandatory retirement age from 65 to 70. They find that a 5-year shift in the retirement age assumed in their projection model causes a 63-percent drop in the projected number of new faculty hired in the 1987, and a 23-percent drop in projected new faculty hires in 1992.[13] For 1987, the number of projected new hires falls from 38.8 percent of its 1977 level to 14.5 percent, while for 1992 the projected percentage declines from 44.2 to 33.9 percent.

Klitgaard, in a provocative essay on the pitfalls of forecasting academic demand, shows the effects of changing assumptions about retirements, "quits," promotions, and faculty-student ratios. Taking a model developed by Louis Fernandez, Klitgaard simultaneously varies each of the above-mentioned parameters to the limit of its range of uncertainty and then adds or multiplies the variances produced. The result is depicted in figure 3-8 which shows a variation of a factor of 6 between the sum (or product) of the extreme highs and the sum (or product) of the extreme lows of all of the variables taken together.[14]

In April 1985, at the request of OTA, NRC convened a panel of academic labor market specialists to determine whether the projections made in the late 1970s are still valid, in the light of new data and subsequent analyses. The panel devoted a great deal of attention to the many uncertainties that surround projections of student enrollments, faculty retirements, "quit rates, " promotions, tenure decisions, and salaries. However, there was general agreement that the overall direction of change projected in the late 1970s was still valid. According to Michael McPherson, a participant at both the 1978 and 1985 NRC workshops:[15]

> One point that is very much worth underlining is that we all seem to be in rough agreement: the **1970s** projections of overall demand for teachers for the next decade aren't obviously wrong. People knew there were uncertainties when they were made; of course, uncertainties still exist, but if there is something really wrong with the projections, it is not anything that we have detected . . . .
>
> . . . . by and large, all people looking at this question generally have the same picture of what will occur. There is much agreement both about the major quantitative factors impinging on this set of labor markets and, at a broad level, about how the market will react to those forces.

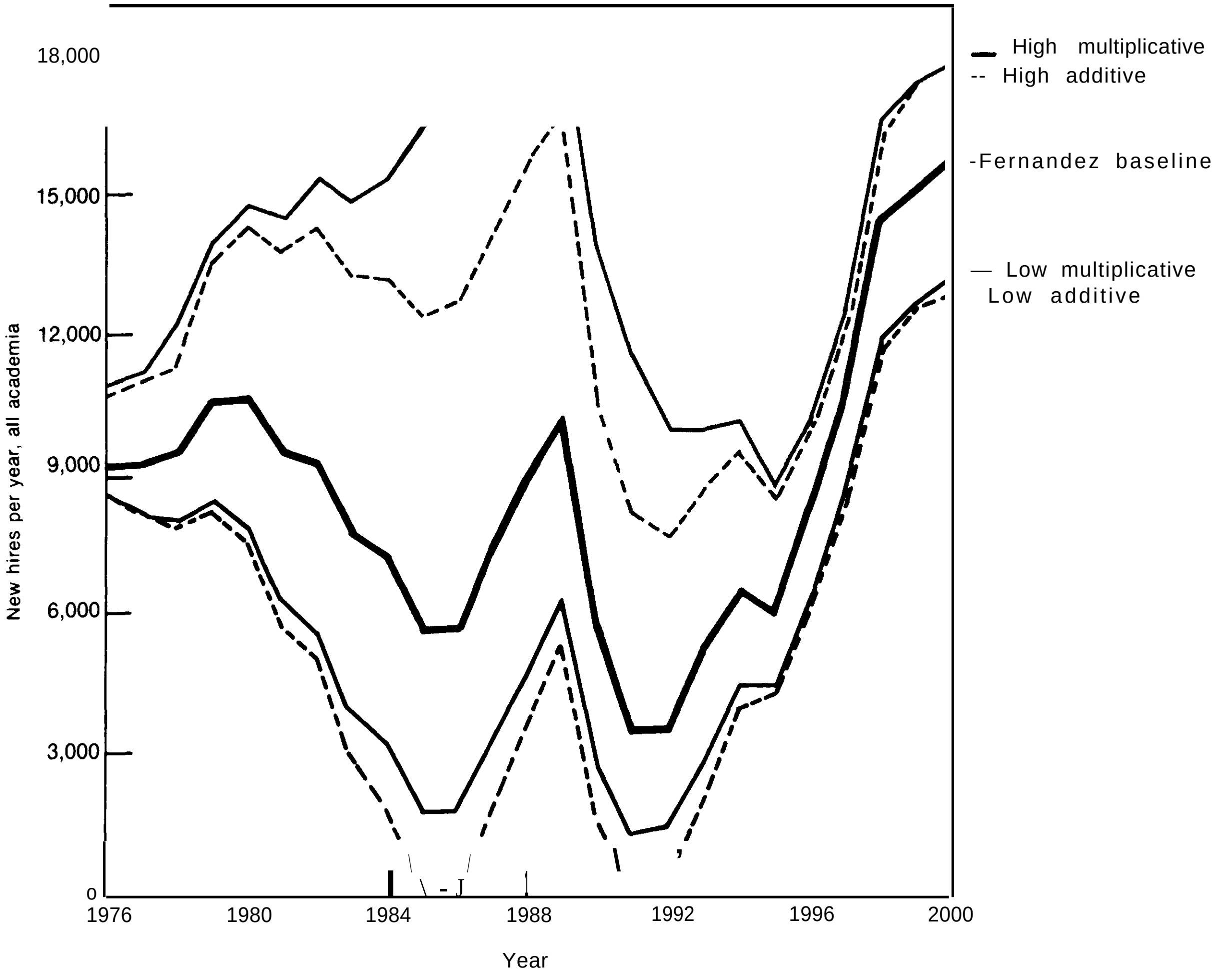
There was also substantial agreement that despite the consensus on overall trends, the range of uncertainty in the factors that influence demand make any numerical comparisons with predicted

[13] W. Lee Hansen and Karen C. Holden, "Critical Linkages in Higher Education: Age Composition and Labor Costs, *Insurance Mathematics & Economics,* vol. 4, No. 1, January 1985, pp. 60-61.

[14] Klitgaard, op. cit., p. 19.

[15] National Research Council, "Draft Proceedings of the Workshop on the Forecasting of Demand for University Scientists and Engineers, " Apr. 8, 1985, pp. 32 and 49.

Figure 3-8.—Sensitivity of Hiring Projections to Variations in Input Parameters



NOTE: The variability represented here does *not* include uncertainty in enrollments. Calculations and graph by author.

SOURCE: Robert E. Klitgaard, The *Decline of the Best?* Discussion Paper No 65 D (Cambridge, MA John F Kennedy School of Government, Harvard University, May 1979), p. 19

supply very problematic. McPherson summarized these uncertainties as follows:1[6]

> The workshop discussions . . . . highlighted a number of complications and qualifications, some of which were acknowledged in the earlier work. Among the most important of these were the following:
>
> 1. The *Research Excellence* study focused on the demand for teaching faculty, but research support generates academic hiring too, especially in major universities. Some universities are evolving elaborate patterns of nonfaculty research staffing, partly in response to anticipated declines in teaching positions. To the extent that universities can successfully decouple teaching from research hiring in this way, the effects of fluctuations in enrollment on research effectiveness may be mitigated.
> 2. *Research Excellence* and related studies treated the pace of retirements as mechanically determined by faculty demographics, whereas in fact retirement should be seen as a decision influenced by, among other

16 Michael S. McPherson, "Numbers and Quality: Analyzing the Market for University Scientists and Engineers," National Research Council, *Forecasting of Demand for University Scientists and Engineers: Proceedings ofa Workshop* (Washington, DC: National Academy Press, 1985), p. 1.

things, the economic incentives facing retirees.

3. Research Excellence followed the modeling work of Radner and Kuh in supposing that universities would respond to declining demand for faculty by reducing the rates at which they promoted people to tenure .... So far that is apparently not happening: universities are hiring more faculty off the tenure track but continue to promote tenure-track faculty as before.
4. The models on which *Research Excellence* relied dealt with academia as a whole, but in fact different segments of the academic system may behave very differently in the years ahead.
5. It is similarly important to recognize that different fields within science and engineering are likely to fare very differently, owing both to variations in research funding and in student course preferences.

Because of these uncertainties, participants at the workshop generally felt that it is more important to analyze existing data and refine our understanding of how the academic labor market works than to make detailed projections of the numbers of Ph. D.s required or produced in specific fields. In the words of Stephen Dresch:[17]

> . . . [we need] to have some reasonably sustained work in this area . . . nobody systematically asks, "What data should be collected to answer interesting questions?" Therefore, a lot of money used to collect data is, in fact, wasted because the data collected has fatal flaws: it tracks some flows in the system but doesn't permit tracking other flows, a situation that could very easily have been rectified if one had been striving for a complete picture. A lot of data, in fact, is incomplete and can't be spliced together. The other side is that, for all practical purposes, we really don't want to pay anyone to learn anything with these data. What we essentially want is to "buy" the aura of rationality in action . . .

McPherson summarized the situation as follows: 18

> On the qualitative side, we really need to understand better how this system behaves, recognizing that institutions and individuals adjust when conditions change. The simplest kinds of manpower forecasting models assume a great deal of rigidity—that people in institutions just continue to do what they used to do in the face of radical changes in conditions—but we know that is false, because in one way or another gaps get filled .... It is in the adjustment process that better qualitative understanding is needed. For that purpose the quantitative models are not really so much intended to be accurate predictions of the future as guidelines that show us where the adjustments will have to occur and direct our understanding.
>
> Now, to achieve this qualitative understanding, we don't really want to develop a super-elaborate, sophisticated structural model .... Instead, we should study the many variables—wage behavior, tenure policies and how they respond, how universities handle nonfaculty research positions—and build up from that a better understanding, not so much to predict but to understand how this beast operates. What we need is more basic research into these labor markets.

Participants at the workshop listed the following items for research on the qualitative aspects of the academic labor market: 19

1. How is the quality of students attracted to advanced study influenced by changes in labor market conditions? Will declining demand cause the best students differentially to select themselves out of scientific careers?
2. How do academic departments cope with hiring shortages like those now being experienced in engineering, and with what implications for research and teaching effectiveness?
3. How, and how effectively, do universities respond to reductions in demand for teaching faculty?
4. What factors influence the mobility of experienced Ph. D.s, both among fields and between academic and nonacademic employment?

Peter Syverson of NRC summarizes the state of the art of forecasting supply and demand in the academic market as follows :20

> At present our ability to forecast changes in the academic market is decidedly limited. For anything more refined than seat-of-the-pants planning, a far more precise model must be developed to accurately reflect the academic market up to and beyond the turn of the century.

[17] National Research Council, "Draft Proceedings," op. cit., p. 29.
[18] Ibid., p. 51.
19 McPherson, Op. Cit., p. 4.
[20] Syverson, op. cit., p. 12.

IMPLICATIONS OF THE NEAR-TERM TRENDS

The implications of the overall trends projected by labor market specialists in the late 1970s, and confirmed by the NRC workshop in April 1985, were discussed at great length in conjunction with the early forecast of a declining academic labor market for Ph. D.s in the 1980s and early 1990s. Kuh and Radner, for example, in their work on *Preserving a Lost Generation* argued that:[21]

> It is in both the national interest and the interest of individual institutions to assure a moderate but steady flow of young doctorate scholars into academia . . . . An academic enterprise in which half as many young faculty did twice as much teaching could not help but result in a considerably smaller amount of research, with considerable consequence for U.S, science . . . . When fewer and fewer people can be hired, the predictors (of creative and lasting scholarship) are likely to become more and more conservative. The young Ph.D. who has two published articles in addition to his thesis is likely to be chosen over the young Ph.D. who has an interesting area of research with a longer gestation period. "Mistakes, " after all, are much more costly when they can be spread over fewer people. But, in fact, the research with the longer gestation period may be more productive in the long run . . . . Programs are needed which allow [the research universities] to take some "long shots" in the hiring of young scholars. The larger the pool, the more likely that the best scholars will be found in it.

The 1979 National Academy of Sciences report on *Research Excellence Through the Year 2000: The Importance of Maintaining a Flow of New Faculty Into Academic Research*, cited above, enumerated in some detail the possible consequences for science of the projected decline in academic hiring of Ph. D.s. According to the Committee, "damage to the nation's research effort is likely to result from the expected constriction in the flow of new faculty" for a number of reasons:

1. the rate of research innovation, the inflow of new ideas, and the vitality of the research environment will be impaired;
2. continuity in the education and socialization of succeeding generations of researchers will be threatened; and
3. the perceived lack of opportunities for an academic career may discourage able and creative young people from pursuing careers in basic scientific research.

The Carnegie Council on Policy Studies in Higher Education discussed the "implication of the demographic depression for faculty" in its 1980 report on the future of higher education :23

> The tenured professoriate in 4-year colleges will keep on aging with the ages of the modal group rising from **36** to *45* in **1980** to *56* to **65 in 2000.** This will increase the age gap between students and faculty, raise the average cost of faculty salaries, and make it hard to introduce new fields, new courses, new subject matter. Tenure ratios, which were **50** percent as recently as 1969, have now risen to 75 percent; and colleges encounter new rigidities in redeploying their resources.
>
> Some faculty members are potentially much more affected than are others: In the East and North more than in the South and West; in comprehensive colleges more than in community colleges; in less selective more than in more selective 4-year liberal arts colleges; in doctorate granting universities more than in research universities.

The response to these cries of alarm from distinguished educators and analysts is summarized in a review of the current state of the academic labor market in late 1984 by Michael McPherson. He finds that, to a remarkable degree, "the policy issues identified in the late 1970s and early 1980s" relative to the declining academic market for Ph.D.s "remain central and largely unresolved today. "[24]

[21] Kuh and Radner, op. cit., pp. 2-3.

[22] National Research Council, *Research Excellence*, op. cit., p. vi.

[23] *Three Thousand Futures: The Next Twenty Years for Higher Education* (San Francisco, CA: Jossey Bass, 1980), pp. 80-82.

[24] Michael S. McPherson, "The State of Academic Labor Markets, " November 1984 draft, p. 5, to be published in B.L.R. Smith (cd.), *The State of Graduate Education* (Washington, DC: The Brookings Institution, 1985).

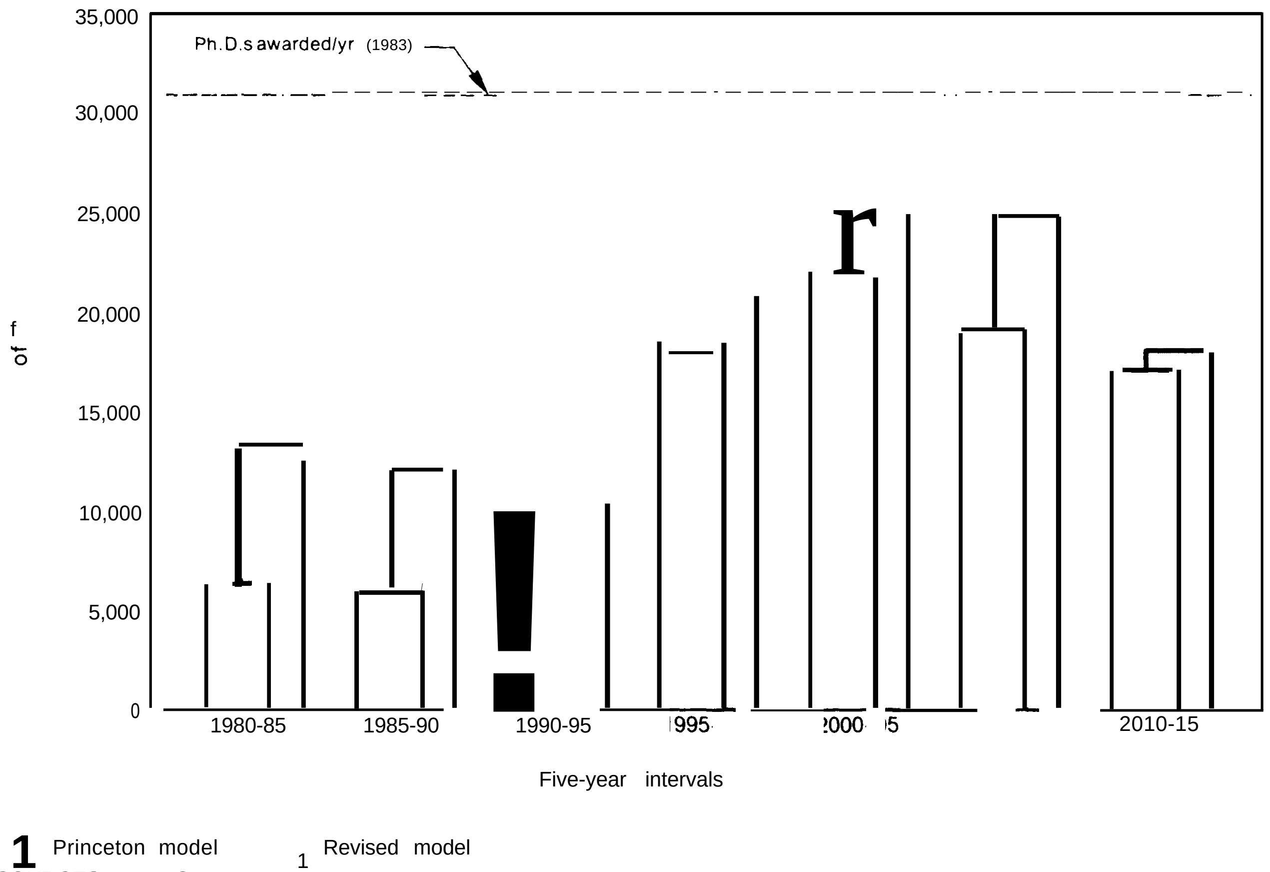
THE FURTHER FUTURE

All of the studies of the late 1970s ended their projections at the year 2000. Unfortunately that is just the beginning of a pronounced “rebound” period, when enrollments are expected to increase and large numbers of faculty hired in the 1960s and early 1970s are expected to retire. McPherson expresses the conventional wisdom when he states that “to the degree that student and faculty demographics are determining factors, data available now suggest that recovery will come quite late in this century and will not be strong.”[25] However, projections for the first decade of the 2lst century make the transition to growth appear considerably less smooth than McPherson argues. To examine the “rebound” in greater depth, OTA performed its own analysis of the period 2000-10, using the model developed by Herring and Sanderson for the 1981 Report of the *President of Princeton University* cited above. OTA first extended the Princeton model to the year 2015, using the same values for the input parameters as Herring and Sanderson, and population trends for 2000 to 2015 from the Census Bureau Projections of the Population, middle series, cited in chapter 2. The results, displayed as the white bars on figure 3-9, show a tripling in demand for new faculty, from 6,500 per year between 1980 and 1995 to 20,000 per year between 1995 and 201O.

OTA then revised the Princeton model to incorporate a different set of assumptions about resignations and retirements, which OTA believes track recent data on these two phenomena more closely than those of Herring and Sanderson. The

[25] Ibid., p. 29.

Figure 3-9.— Annual Number of New Hires Based on Projections



SOURCES William G Bowen, *Report of the President* (Princeton. NJ Princeton University, April 1981), and Off Ice of Technology Assessment analysis results are displayed as the striped bars on figure 3-9. As can be seen, the OTA assumptions lead to a level of new faculty hiring in the 1980-95 time frame that is nearly double that of Herring and Sanderson—12,000 per year. In the first decade of the 21st century, if the assumptions in the OTA simulation hold, the number of new academic hires per year could reach 25,000 per year, or double that of the early 1990s.

Hansen and Holden project that new faculty hires could increase by a factor of 4 between 1987 levels and 2002. In their worst case scenario, in which most faculty choose to retire at age 70, the increase between 1987 and 2002 would be a factor of 10.[26]

The implications of this dramatic reversal of fortunes for universities and new science and engineering Ph .D. s have not been examined to date, Although it appears that the academic demand for new faculty will remain below the annual supply of new Ph. D.s, even in the boom years 2000 to 2010, that situation could, in fact, change dramatically if graduate school enrollments drop sharply in the 1990s due to the weak market for new-faculty in that time period. In other words, if graduate students respond to the market signals of the early 1990s by decreasing their enrollments in doctoral programs, there could be too few of them to meet the surging demand that will occur at the turn of the century. To avoid this potential market failure, it would be prudent to monitor new academic hires and, if the trends discussed above materialize, possibly institute countercyclical support programs in the early 1990s.

Even if the supply of new Ph.D.s increases to meet demand in the early 21st century, a countercyclical policy for the early 1990s maybe worth considering for a second reason. The large number of new faculty hired in the 1995-2010 time period will produce an age distribution among faculty in the second decade of the 21st century that is heavily skewed toward the young, as was the age distribution in the late 1970s. (See figure 3-1, above.) This could lead to a repeat of the low retirement, low replacement situation of the 1980-95 time period. To avoid a repetition of the "boom and bust" cycle of the 1960s and late 1970s it may be worthwhile to attempt to formulate a countercyclical policy to stimulate demand in the early 1990s.

The science and engineering fields appear to follow the general academic market fairly closely. OTA applied a revised version of the Princeton model to the most recent data from NSF on the age distribution of doctoral scientists and engineers employed at 4-year colleges and universities.[27] Using 1983 as a base year, OTA was able to project the number of new junior faculty appointments that would be made at 5-year intervals from 1983 to 2013, under different assumptions about retirements, resignations, and enrollments in science and engineering courses. Figure 3-10 shows the variation in the demand for new science and engineering faculty over the 30-year period under two extreme assumptions: one of high demand for science and engineering faculty, high rates of retirement among senior faculty, and high rates of resignation among junior faculty; and one of low demand, low retirements, and low resignations. These appear to represent reasonable estimates of the extreme levels of possible academic hiring of new science and "engineering Ph. D.s over the next three decades.

To refine its analysis, OTA applied its model to historical data on Ph.D. scientists and engineers in educational institutions for the years 1973 to 1983 published by NSF.[28] OTA found that a high demand, low retirement, low resignation scenario best fit historic data. Two versions of such a scenario are displayed in figure 3-11 which represents an educated guess based on historical experience as to the likely range of academic hiring of science and engineering Ph. D.s over the next 30 years. The number of science and engineering doctorates appointed by colleges and universities in the 1977-82 time frame, as calculated by OTA from NSF data, is also displayed in figure 3-11 as an average number of new hires per year over the 5-year period. As can be seen, the number of new scientists and engineers appointed by colleges and universities declines significantly in the 1983-98 time frame. It then increases to more than 9,000 per year in the 1998-2013 time frame. Similar pro-

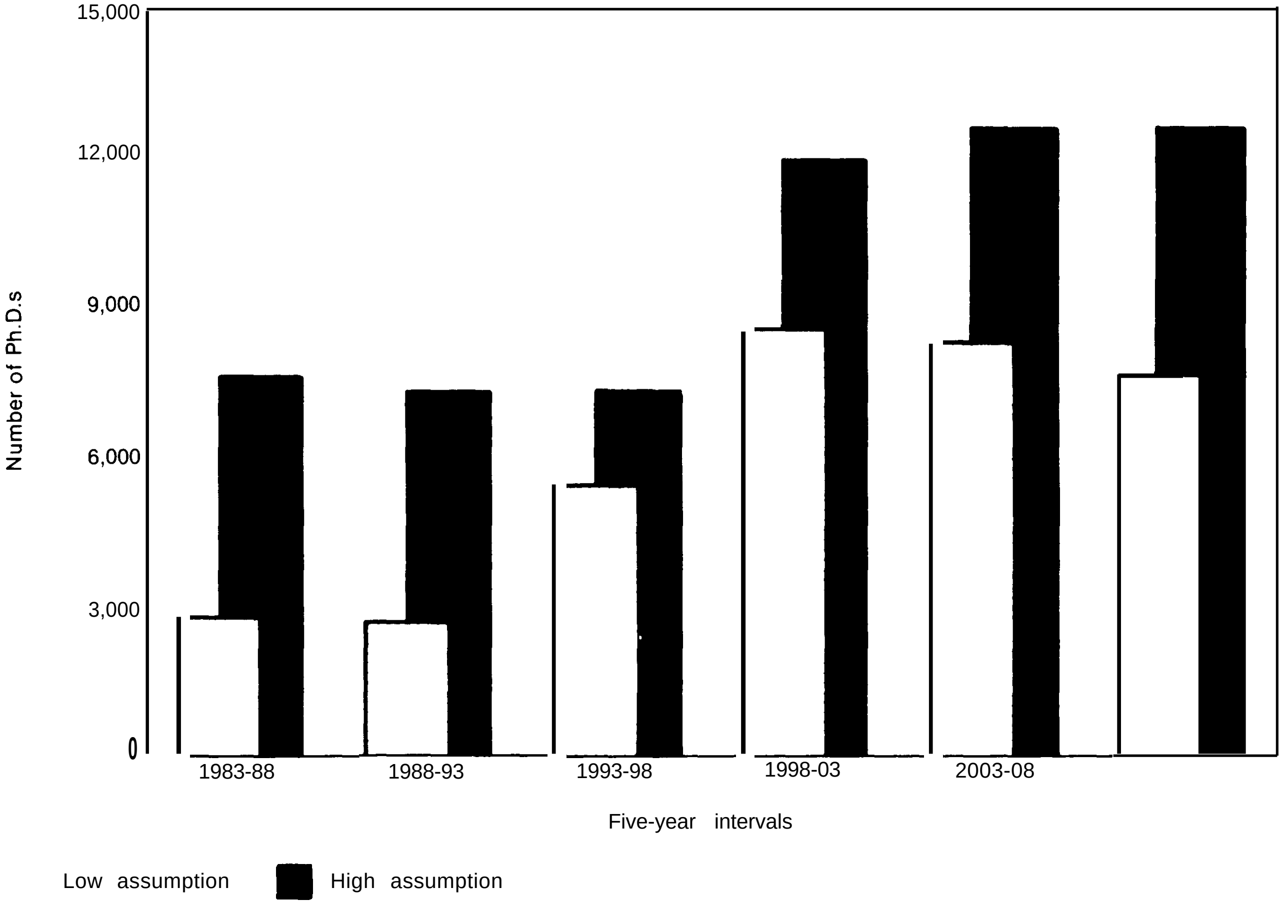
[26] Hansen and Holden, op. cit., p. 60,

[27] *Characteristics of Doctoral Scientists and Engineers in the United States: 2983*, NSF 85-303 (Washington, DC: National Science Foundation, 1985), table B-5, pp. 19-23.

[28] Ibid., table 3, pp. x and xi.

jections for individual fields follow similar patterns, as can be seen from figures 3-12, 3-13, and 3-14 which show the hiring trends for the physical sciences, the life sciences, and the social sciences under the two scenarios most consistent with past experience.

Figure 3-10.—Annual Hiring, Science and Engineering Faculty, Extreme Cases



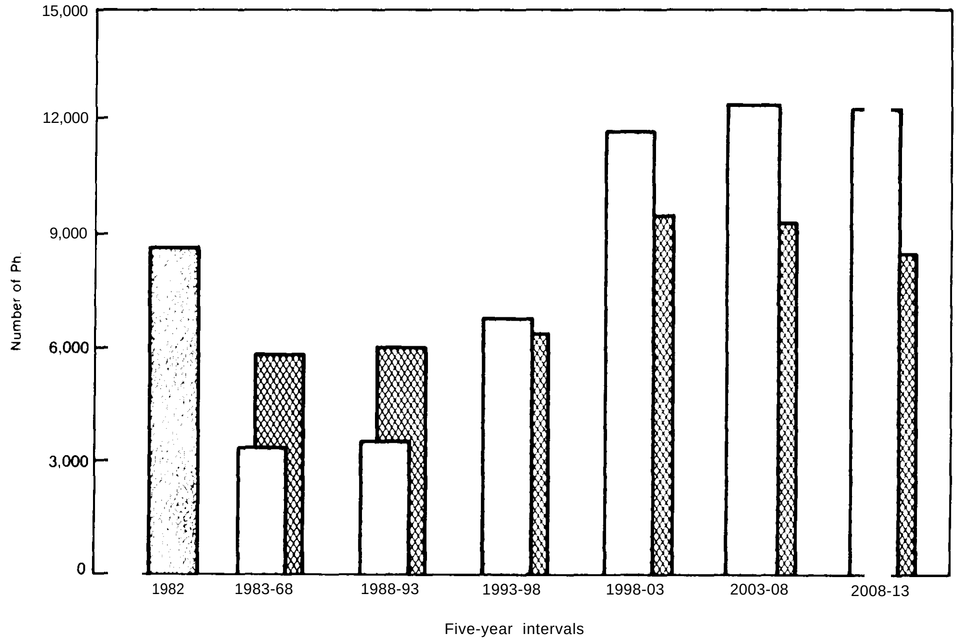
SOURCE Office of Technology Assessment

INDUSTRIAL EMPLOYMENT OF SCIENCE AND ENGINEERING PH.D.s

The trends discussed above in the academic employment of science and engineering Ph.D. s must be placed in the context of the availability of alternative careers for those professionals. As tables 3-1 and 3-2 show, educational institutions employ only 52 percent of all Ph.D. scientists and engineers, and less than 48 percent of those who received their doctorate after 1977. The variation from field to field is substantial, with mathematics, social science, and biology having two-thirds or more of their Ph.D.s employed in academia, while chemistry and engineering are at one-third or less academic employment. By comparison, in the humanities 83 percent of all Ph. D.s are employed at educational institutions .29 Of course, the principal alternative market for science and engineering Ph.D. s is industry, which has in-

[29]National Research Council, *Science, Engineering and Humanities Doctorates in the U. S.: 1983 Profile* (Washington, DC: National Academy Press, 1983), pp. 36, 37, and 74.

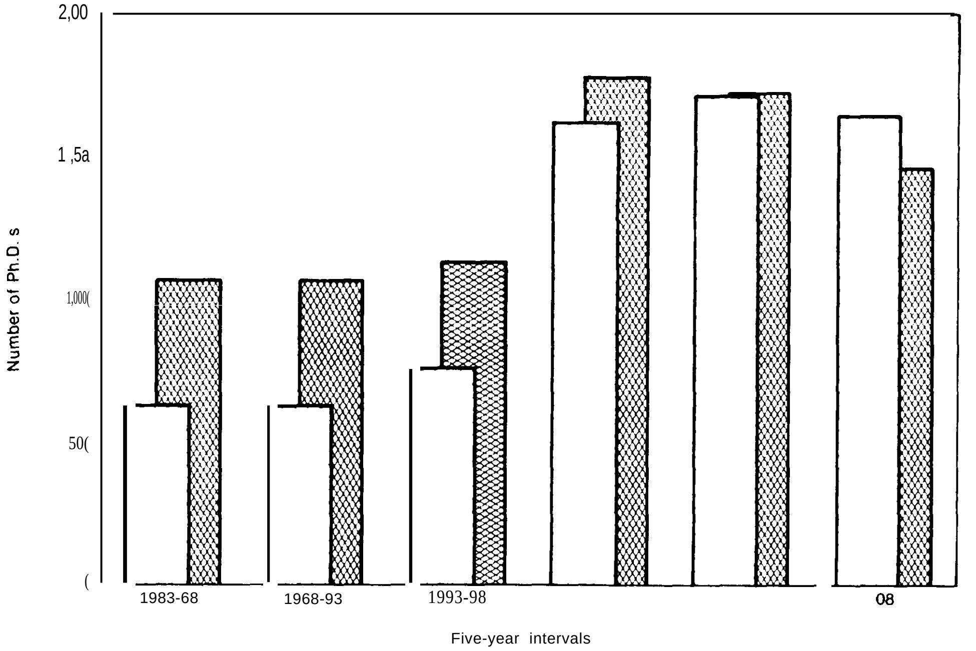
Figure 3-11 .—Annual Hiring, Science and Engineering Faculty, Middle Cases



Historic assumption ❑ 1982 hiring level Middle assumption

SOURCE Of fice of Technology Assessment

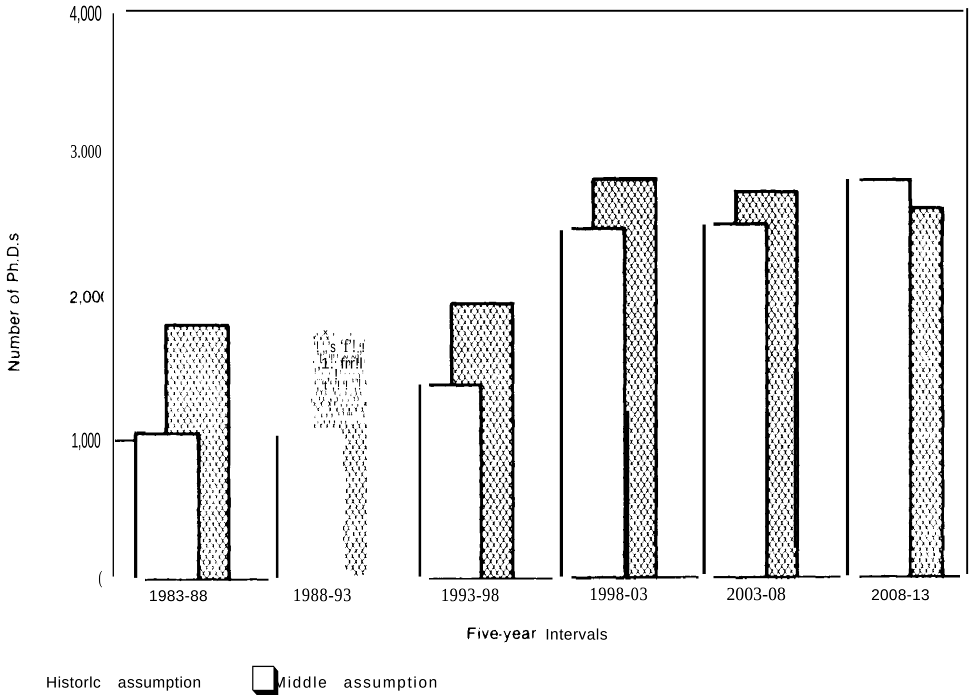
Figure 3-12.—Projected Annual Hiring: Physical Scientists



❑ Historic assumption ❑ Middleclass assumption

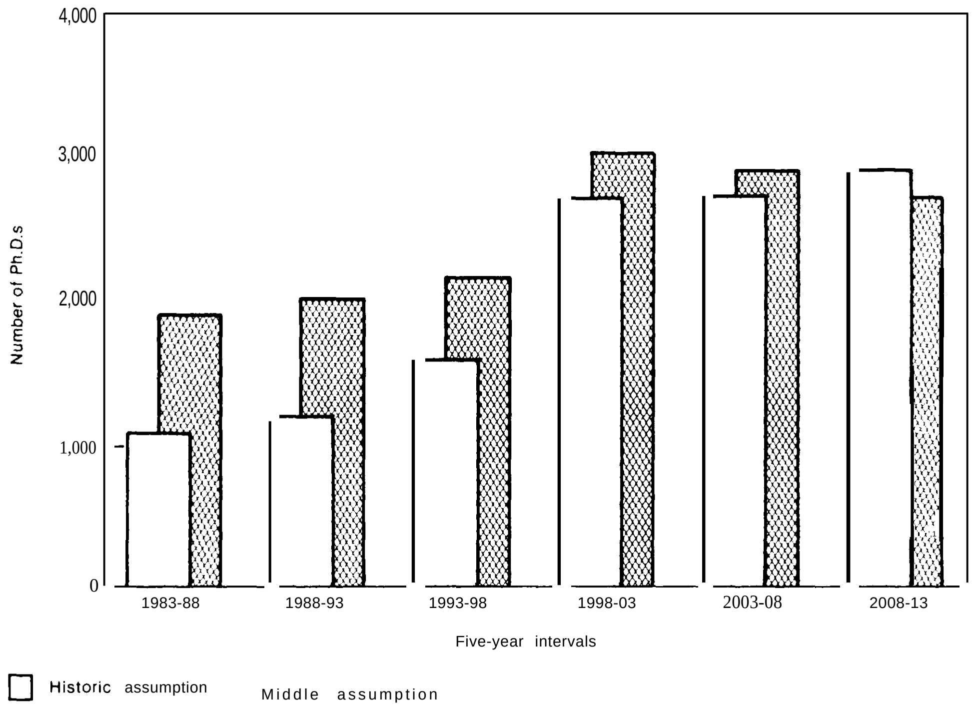
SOURCE Of Office of Technology Assessment

Figure 3-13.—Projected Annual Hiring: Life Scientists



SOURCE Off Ice of Technology Assessment

Figure 3-14.—Projected Annual Hiring: Social Scientists



SOURCE: Office of Technology Assessment

Table 3-1.—Type of Employer of Doctoral Scientists and Engineers (1940-82 Graduates) by Field of Ph. D., 1983 (in percent)

	Field of doctorate											
Type of employer	All fields	Mathematics	Computer science	Physics astronomy	Chemistry	Earth/ environment	Engineering	Agriculture	Medicine	Biology	Psychology	Social science
Employed population[a]	350,900	18,500	2,500	28,100	44,900	12,000	55,000	16,900	12,900	57,600	47.500	55.000
Educational institutions	52.2	73.0	46.5	47.5	326	454	349	578	565	64.1	47.1	718
Business/Industry[b]	31 7	19,2	47,7	363	573	300	542	224	242	180	275	128
U S Government	7 6	51	4 2	108	5,8	179	71	140	7 3	8 7	3 7	7 2
State/local government	2 0	02	01	03	07	33	06	25	28	21	47	30
Hospital /clinic	2 8	03	–	0.9	09	01	02	02	5.8	32	127	04
Other nonprofit organization	3 1	1 8	1.4	4 1	2 2	2 9	2.6	2 2	3 1	3.6	4 1	3 3
Other	0.3	–	–	—	—	01	01	05	01	02	—	13
No report	0 2	0 4	0.1	02	03	0.4	02	04	04	02	02	02

[a] Includes full and part time employed only
[b] Includes self employed

SOURCE National Research Council *1983 Profile* pp 36 37

Table 3-2. —Type of Employer of Doctoral Scientists and Engineers (1977"82 Graduates) by Field of Ph. D., 1983 (in percent)

	Field of doctorate											
Type of employer	All fields	Mathematics	Computer science	Physics/ astronomy	Chemistry	Earth/ environment	Engineering	Agriculture	Medicine	Biology	Psychology	Social science
Employed population[a]	80,800	3,600	1 .20F	4,300	7,000	3.000	11,500	3800	3,800	11,100	15,900	15.600
Educational Institutions	47.8	707	51 8	357	184	428	321	557	553	59.2	423	648
Business/Industry[b]	341	21 6	44.3	440	736	353	572	291	232	228	272	171
U S Government	6 6	5 8	3 0	132	3 8	148	5 8	8 6	7 8	77	32	78
State/local government	3 1	01		—	09	3.5	10	23	22	27	61	49
Hospital/clinic	4 3	0 8	—	0 9	11	—	0.5	–	73	30	164	06
Other nonprofit organization	3 7	11	0 9	5 7	2 2	3 0	3 4	2 5	3 7	4 5	44	4.3
Other	0 1	—	—	—	—	0.4	–	09	–	—		04
No report	02	–		06	–	02	–	09	04	02	04	02

[a] Includes full and part time employed only
[b] Includes self employed

SOURCE National Research Council *1983 Profile* pp 36 37 creased its share of the employed doctorates in those fields by 10 percent in recent years. In physics, chemistry, and biology the industrial share of employed doctoral scientists is 20 percent higher among recent Ph. D.s than it is in the overall population of doctoral degree holders.

The increasing share of science and engineering Ph .D. s employed in industry is an important phenomenon that deserves closer scrutiny. In 1973, there were 53,400 Ph.D. scientists and engineers employed in industry, as compared to 129,300 in academia, according to the National Science Foundation .30 By 1983 the number of industrial scientists and engineers had more than doubled, to 113,500, while the number in academia had increased by only 50 percent, to 196,100. The rate of growth in industry was about 8 percent per year over the decade while that of academia was more like 4 percent per year.

Among the different science and engineering fields, computer scientists, psychologists, and social scientists showed the most dramatic growth in industry between 1973 and 1983, increasing by 300 to 500 percent (see table 3-3).[31] Of course, all three fields started from very low levels in 1973—3,000 or less. Engineering and physical science continued to employ the largest numbers of doctoral scientists and engineers—34,500 and 29,000 respectively in 1983—but their growth rates over the decade were lowest, at 100 and 46 percent respectively. The number of industrial Ph.D. scientists and engineers whose primary work activity was research and development doubled over the decade, but the numbers in consulting, sales and professional services, and "other" all quadrupled or quintupled. Fifty percent of the growth over the decade was in these three non-R&D related activities.

Even more dramatic, however, was the change in the relative demand for *new* Ph.D. scientists and engineers between industry and academia. Between 1973 and 1975 the number of academic Ph.D. scientists and engineers increased by 19,700, while the number of industrial Ph.D. scientists and engineers increased by only 11,200. Between 1981 and 1983, by contrast, the corresponding increases were 9,000 for academia and 14,300 for industry.[32] Thus the demand for *additional* science *and* engineering Ph. D.s in industry increased from 55 percent of the academic demand in the early 1970s, to 160 percent of the academic demand by the early 1980s.

To get a complete picture of the academic and industrial markets for science and engineering Ph.D,s we would need to add the *replacement* demand to the growth demands calculated above. The replacement demand in academia can be easily calculated with the OTA model described above, and it comes to 8,000 additional science and engineering Ph. D.s needed in 1981 to 1983. There is no data on the replacement rate for industrial Ph.D. scientists and engineers, but if we assume it to be equal to that of academia, or about 2 percent per year, that would generate demand for an additional 4,000 of those professionals between 1981 and 1983. The total industrial demand for new Ph.D. scientists and engineers would about 18,000 between 1981 and 1983, while the academic demand was 17,000.

There is evidence, however, that the industrial demand for new doctoral scientists and engineers is not wholly supplied by recent Ph. D.s. Based on a comparison of NSF[33] and NRC[34] data for the 1977-83 time period, it appears that only two-thirds of the additional industrial science and engineering Ph. D.s reported between 1977 and 1983 came from the pool of recent graduates. The rest were undoubtedly experienced Ph, D.s coming from academia and the government, and immigrants.

It is difficult to predict the future industrial market for science and engineering Ph. D.s with any degree of certainty in the absence of an understanding of the causes of the dramatic growth of the past decade, It is clear, however, that if the recent growth rate were to continue for another decade it would generate substantial employment

[30] *Science and Engineering Personnel: A National Overview,* NSF 85-302 (Washington, DC: National Science Foundation, 1985), table B-12a, p. 113.

[31] *Characteristics of Doctoral Scientists and Engineers in the United States: 1983,* op. cit., table 4, p. xii-xiii.

[32] Ibid., tables 3 and 4, pp. x-xiii.

[33] *Science and Engineering Personnel: A National Overview,* op. cit., table B-12a, p. 113.

[34] National Research Council, *Science, Engineering, and Humanities Doctorates in the United States: 1983 Profile,* op. cit., table 2-8, p. 37.

Table 3.3.—Selected Characteristics of Doctoral Scientists in Business and Industry

Characteristics	1973 Number	1973 Percent	1973 Percent of total employed	1973 Median annual salary	1983 Number	1983 Percent	1983 Percent of total employed	1983 Median annual salary
Total-:.	53,403	loo.o	24.2	23,300	113,463	100.0	30.7	47,000
Field:								
Scientists	35,631	66.7	19.3	23,300	76,963	69.6	25.7	45,500
Physical scientists	19,665	36.8	40.5	22,700	28,748	25.3	44.9	45,900
Chemists	15,759	29.5	51.2	22,500	22,525	19.9	54.5	45,600
Physicists/astronomers	3,906	7.3	22.0	23,600	6,223	5.5	27.4	48,300
Mathematical scientists	864	1.6	7.1	24,100	2,027	1.8	12,4	42,700
Mathematicians.	657	1.2	6.2	23,900	1,512	1.3	11.1	43,600
Statisticians.	207	0.4	14.1	25,100	515	0.5	18.5	40,000
Computer/information specialists	1,007	1.9	37.1	22,300	6,819	6.0	56.1	42,700
Environmental scientists	2,204	4.1	21.4	22,600	5,154	4.5	31,3	48,500
Earth scientists	2,085	3.9	24.4	22,500	4,596	4.1	36.7	49,200
Oceanographers	94	0.2	8,3	(a)	217	0.2	12.5	(a)
Atmospheric scientists	25	(b)	3.9	(a)	341	0.3	15.5	48,600
Life scientists	7,147	13.4	12.6	23,300	16,444	14.5	17.7	43,700
Biological scientists	3,309	6.2	9.0	22,800	7,730	6.8	14.0	41,800
Agricultural scientists	1,718	3.2	18.7	21,600	3,583	3,2	24,6	40,100
Medical scientists .,	2,120	4.0	19.9	26,300	5.131	4.5	22.2	50,700
Psychologists	3,081	5,8	12.4	30,000	13,020	11.5	27.9	48.000
Social scientists	1,663	3.1	5.7	27,200	6,751	5.9	11,4	45,400
Economists	1,031	1.9	10.7	29.200	2,779	2,4	16.4	52,100
Sociologists/ anthropologists	125	0.2	1.9	(al	801	0.7	6.6	36,300
Other social scientists	507	0.9	3.8	25,200	3,171	2.8	10,5	35,600
Engineers	17,772	33.3	49.7	23,200	34,500	30,4	56,1	49,900
Aeronautical/astronaut local engineers	639	1.2	38.3	25,300	1,928	1.7	52,3	47.700
Chem!al engineers	3,246	6.1	72.8	22,700	4,788	4.2	68.5	52,400
Civil engineers	883	1.7	28.5	21.500	1,895	1.7	35,6	47,600
Electrical/electronic engineers	3,424	6.4	48.5	23,600	7,615	6.7	60.0	51,200
Mechanical engineers	1,366	2.6	41.9	22,300	2,596	2.3	45.9	48.100
Nuclear engineers	666	1.2	52.7	23,100	1,380	1.2	59,3	46,000
Other engineers	7,548	14.1	50.4	23,600	14,298	12.6	57,5	48,700
Sex:								
Men	52,040	97.4	25.6	23,300	103,272	91.0	32.2	47,900
Women	1,363	2.6	8.1	20200	10,191	9,0	20.9	38,900
Race:								
White	48,926	91.6	24.2	23,600	97.673	86.1	29,7	48,000
Black.	298	0.6	14.6	23,000	675	0.6	136	43.900
Asian/Pacific Islander	3,099	5.8	30.0	20.800	13,431	11.8	45,2	44,800
American Indian/Alaskan native	5	\hl	3.5		69	0.1	16,5	ial
Other	31	0.1	15,8	'	76	0.1	37,6	Id)
No report	1,044	20	19.3	23000	1.539	14	277	39,800
Ethnicity:								
Hispanic ....,	264	0.5	16.8	21200	1,497	13	27.9	47,200
Nonhispanic	16,859	31.6	20,2	24200	97,974	86.3	30.9	47,200
No report	36,280	679	26.8	229OO	13,992	12.3	296	45,200
Age:								
Under 30. .	1,999	3.7	20,6	17800	2,037	1.8	31,5	36,400
30-34	12,267	230	24.7	20,100	16,432	14,5	34,1	38,700
35-39,	10,435	19,5	24.8	22,500	25,491	22,5	33,6	44,100
40-44	8,520	16.0	24.1	24,900	26,059	23.0	32.5	50,100
45-49	7.098	13.3	23.7	26800	15,900	14.0	30.7	50,900
50-54	6,288	11,8	26.1	27,800	10,656	9,4	26.8	53,100
55-59,	3,874	7.3	24.9	27600	7,451	6.6	23.4	55.800

Table 3-3.—Selected Characteristics of Doctoral Scientists **in Business and Industry—Continued**

	1973				1983			
Characterstics	Number	Percent	Percent of total employed	Median annual salary	Number	Percent	Percent of total employed	Median annual salary
60-64	1,957	3.7	21.7	27,900	6,153	5.4	27,3	53,800
65 and over	932	1,7	19.1	25,800	3,218	2.8	26,5	60.300
No report	33	0.1	33.0	~a)	66	0.1	26.1	la)
Type of employment								
Science/engineenng	**49,398**	**92.5**	23.9	**23,100**	98,407	86.7	**30.1**	46,700
Other/unknown field	**4,005**	**7,5**	28.5	**25.700**	15,056	13.3	**35,9**	50,400
Primary work activity:								
Research and development	**23,758**	**44.5**	33.2	**21,300**	46.525	41.0	37.3	43,600
Basic research	**3,525**	**6.6**	10.3	**21,600**	6,731	5.9	11.8	42,100
Applied research	**13.212**	**24.7**	46,0	**21,300**	23,463	20.7	49,5	44.100
Development/design	**7,021**	**13,1**	82.6	**21,100**	16,331	14.4	80.5	43,600
Management/ administration	**19,840**	**37.2**	43.0	27,000	25,528	22.5	**41.3**	55,900
Of R&. D	**14,242**	**26.7**	54.3	26,300	20,066	17.7	**63.9**	55,600
Of other	**5,598**	**10.5**	28.1	29,400	5,462	4,8	**18.0**	60,000
Teaching	**191**	**0.4**	0.2	la)	1,301	1.1	**1.2**	41,700
Consul tang	**2,781**	**5 2**	68.6	25,100	10,673	9.4	**83.7**	48.300
Sales/professional services	**3,001**	**5.6**	37.2	25,400	15,581	13.7	**52.3**	48,400
Other	**2,988**	**5,6**	43.0	21.700	12,303	10,8	**50,9**	44,500
No report	**844**	**1 6**	22,9	23,200	1,552	1,4	**20.0**	50,000

[a] No median computed for groups with fewer than 20 individuals
t Less than 0.05 percent

NOTE Percents may not add to 100 because of rounding

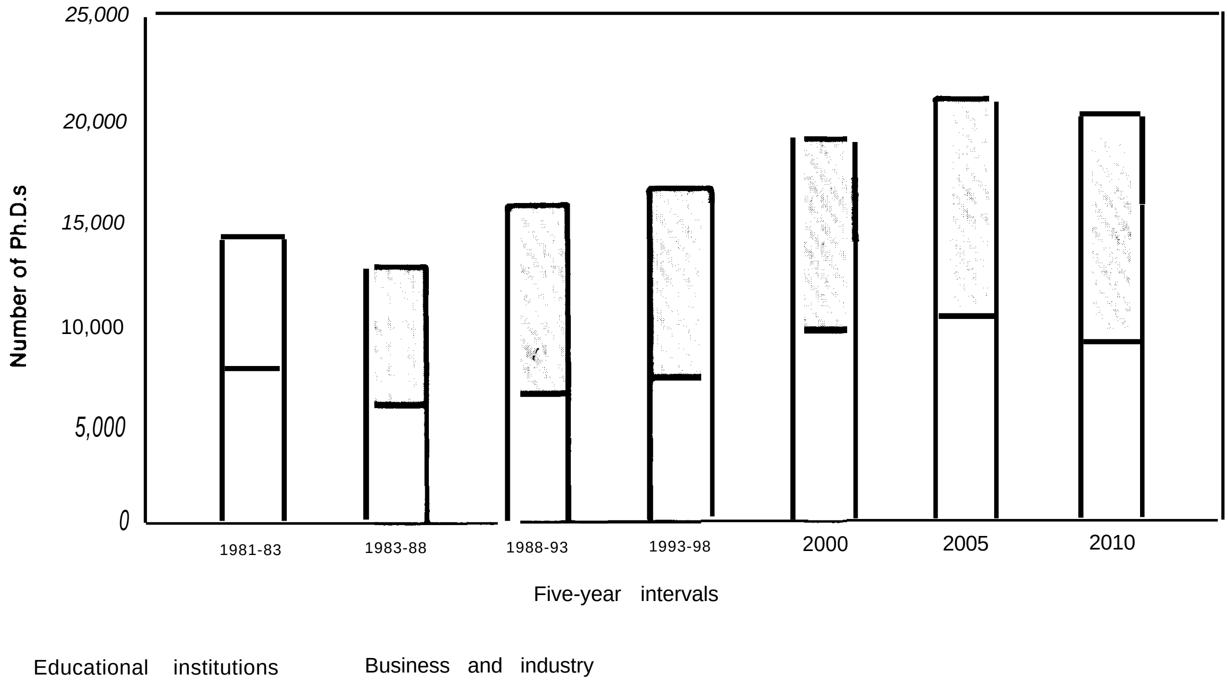
SOURCE *Characteristics of Doctoral Scientists and Engineers in the United States* 1983 (Washington DC National Science Foundation 1985) pp x ii and x iii

opportunities for doctoral scientists and engineers. Assuming that the 7.8-percent growth rate experienced in the 1970s continues through the 1980s, and that new science and engineering Ph. D.s continue to account for two-thirds of that growth, as they did in 1977 to 1983, there would be about 7,000 new doctoral scientists and engineers hired by industry each year between 1983 and 1988, and 10,000 hired each year between 1988 and 1993, Both of those figures exceed the projected academic demand for those years by a considerable amount. When added to the projected academic demand for the two time periods, they lead to the combined demand for new science and engineering Ph. D.s in the two sectors between 1983 and 1993 shown in figure 3-15. As can be seen, the totals for 1983 to 1993 are quite close to that of the 1981-83 time period. Thus, the decline in academic hiring over the next decade could be completely compensated for by the increase in industrial demand.

Beyond the next decade, predictions of industrial demand for Ph.D. scientists and engineers become even more speculative. The continuation of the 7.8-percent growth rate for more than another decade seems unlikely for two reasons. First, the numbers of new Ph.D. scientists and engineers required for 8 percent per year growth for another decade become so large they are impossible to believe (the industrial sector alone would require twice as many new Ph .D. s per year as all sectors required in 1983). Second, the surge in growth in industrial science and engineering Ph. D.s is a relatively recent phenomenon. Statistics published by NRC[35] show that the percent of new Ph. D.s planning employment in business and industry declined steadily for all the science fields through the 1960s, and only began to increase in 1973. “Until recently the trend has been downward for employment of new science Ph. D.s in business and industry” NRC wrote in 1978. “Is a change coming?” it wondered. If the trend reversed itself in 1973 it seems entirely possible it could change again in another decade.

“National Research Council, *A Century of Doctorates* (Washington, DC: National Academy of Sciences, 1978), p. 81.

Figure 3-15.— New Ph.D. Hiring: Science and Engineering



SOURCES. Office of Technology Assessment.

The simplest assumption for the 1993-2003 time frame is that the rate of industrial hiring of new science and engineering Ph. D.s remains constant at its 1993 level. Using that assumption, the combined academic and industrial demand increases substantially above the 1983 level between 1993 and 1998 and grows to exceed the current annual supply of new science and engineering Ph. D.s between 1998 and 2003.

The American Institute of Physics (AIP) has recently completed an in-depth analysis of the long-term market for physics Ph. D.s that tends to support the analysis 'presented above. The AIP projects that the total industrial, government, and academic demand for new physics Ph. D.s could exceed the projected supply by the year 2000 under the most likely scenarios.[36] (See figure 3-16.)

[36] U. S. Congress, House, "Testimony by Daniel Kleppner, Professor of Physics, Massachusetts Institute of Technology, " Committee on Science and Technology, Task Force on Science Policy (Washington, DC: U.S. Government Printing Office, July 9, 1985), pp. 2-37.

POSTDOCTORAL APPOINTMENTS

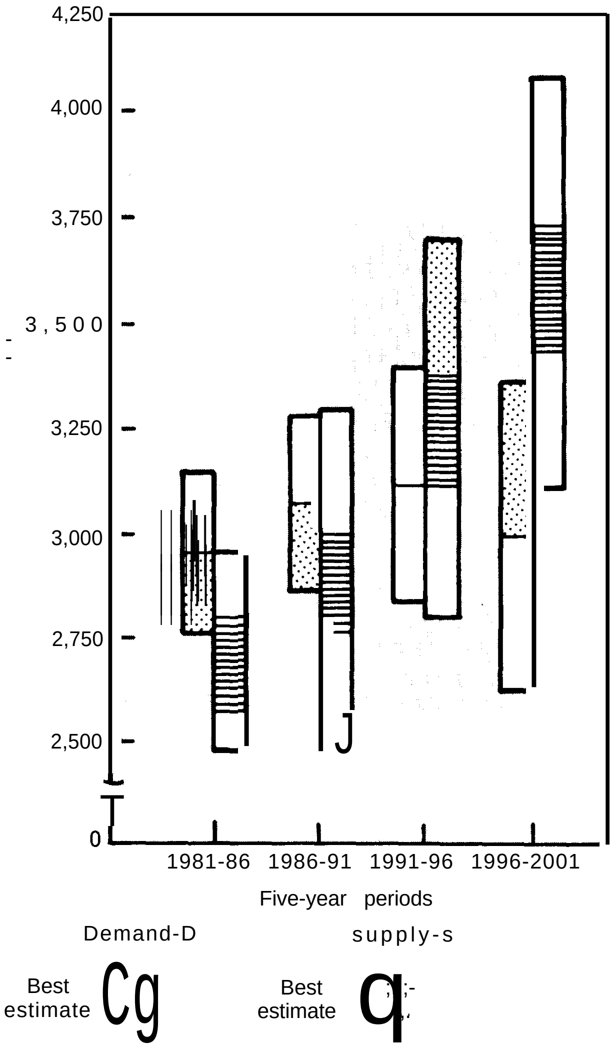
Among new science and engineering Ph. D.s who do not obtain a faculty position or enter industry, the principal alternative mode of employment is the postdoctoral appointment. The National Research Council defines a postdoctoral as a "temporary" appointment the primary purpose of which is to provide for continued education or experience in research usually, though not necessarily, under the supervision of a senior mentor.[37] NRC gives a number of rationales for the increasing percentage of Ph. D.s taking postdoctoral appointments:[38]

> In many areas of science and engineering, especially the interdisciplinary and transdisciplinary

[37] National Research Council, *Postdoctoral Appointments and Disappointments* (Washington, DC: National Academy Press, 1981), p. 11.

[38] Ibid., pp. 80-82.

Figure 3.16.—Possible Levels of Supply and Demand for Physicists Within Each Five-Year Period, 1981-2001



SOURCE American Institute of Physics, in Testimony by Daniel Kleppner to the House Committee on Science and Technology, July 9, 1985, p 52-37

ones, the nature of research has become increasingly complex, and has required young investigators to develop highly specialized skills, Frequently these skills can be acquired more effectively through an intensive postdoctoral apprenticeship than through a graduate research assistantship . . . .

From the perspective of the young investigator the postdoctoral appointment . . . provide[s] a unique opportunity to concentrate on a particular research problem without the burden of either the teaching or the administrative responsibilities usually given to a faculty member . . . . As the competition for research positions has intensified . . . . the opportunity as a postdoctoral to establish a strong record of research publications has become increasingly attractive to many young scientists interested in careers in academic research . . . .

However, there is now considerable evidence, and concern, that the postdoctoral appointment has become something of a holding pattern for new Ph. D.s who cannot find immediate faculty or industrial positions. A recent Higher Education Research Institute survey of doctoral degree holders who had taken postdoctoral appointments found that the number of respondents reporting "employment not available elsewhere" as the reason for taking a postdoc increased from 5.6 percent of the 1960 to 1967 graduates to 36.8 percent of the 1970 to 1973 graduates. The number citing "to become more employable" as a reason jumped from 19.4 percent in the former period to 39. o percent in the latter.[39]

The number of science and engineering Ph.D.s with plans or firm commitments for postdoctoral study immediately following receipt of the degree has increased dramatically over the past quarter century. Figure 3-17 shows the "percent of Ph.D. recipients from U.S. universities planning postdoctoral study immediately after receiving the doctorate" between 1958 and 1982, by field.[40] It can be seen that in the biosciences, chemistry, physics, and astronomy the percent reporting postdoctoral plans has increased from approximately 10 percent in 1958 to between 40 and 60 percent in 1982. (It should be noted that data from i958 to 1969 are not completely comparable to those from 1969 to 1983 because of a change in surveying procedures at NRC.) In biochemistry the percentage today exceeds 70 percent, while in most other science and engineering fields it is relatively low (10 to 20 percent).

According to NRC, postdoctoral appointees represented 3 percent of the U.S. doctoral scientific and engineering labor force of 365,000 in 1983, or 11,000 individuals.[41] This was an increase of 5 percent from the 10,5OO reported by NRC for 1979.[42] More than 6,600 of the 1983 postdoctoral appointees, or 60 percent, were life scientists. They represented about 44 percent of the 15,OOO Ph. D.s awarded in the life sciences in the 1981-83 period. (The average postdoctoral appointment lasts 3 years.) The next largest group, 2,2oo, or 20 percent, were in the physical sciences. They represented about 22 percent of the physical science Ph. D.s over the 1981-83 period. The social scientists at 1,2oo were the third largest group, Engineers and mathematicians were far behind at 280 and 120 postdoctoral respectively.

Postdoctoral appointees with Ph.D.s from U.S. graduate schools—the population discussed above —represent only half of the total postdoctoral appointees in the United States. According to NSF[43] the total number of postdoctoral appointees in 1983, including those with foreign Ph. D.s and first professional degrees from U.S. schools, was 20,800, up 13 percent from a total of 18,500 in 1976.[44] Of these postdoctoral appointees, 15,000, or 73 percent, were supported by the Federal Government, with 10,000 or *50* percent on research grants. Since this chapter is concerned primarily with the fate of scientists and engineers who receive Ph. D.s from U.S. universities, the 11,000 postdoctoral appointees surveyed by NRC is the more relevant population.

In 1981 NRC completed a comprehensive study of "Postdoctoral in Science and Engineering in the United States, " which examined in depth the role of the postdoctoral appointment in the transition from graduate school to the workplace .45 It found that between 1973 and 1979, 29 percent of the science and engineering Ph. D.s who entered the labor force each year (4,3oo out of 15,000) took postdoctoral appointments, In the biosciences, 55 percent of the new Ph.D.s who entered the labor force each year (2,000 out of 3,600) took an immediate postdoctoral appointment. In physics and chemistry, the fields with the next highest proportions of postdoctoral appointments, the corresponding percentages were 46 and 40 percent.

NRC also found that in the biosciences, the duration of the postdoctoral appointment had increased appreciably. Fifty-seven percent of the bioscientists who received their degree in 1976 and reported plans for postdoctoral study to NRC held appointments for longer than 2 years, up from 34 percent among 1969 doctoral degree recipients

"William Zumeta, "Anatomy of the Boom in Postdoctoral Appointments During the 1970s: Troubling Implications for Quality Science?" *Science, Technology and Human Values, vol. 9, No. 2,* spring 1984, pp. 23-37.

[40]William Zumeta, *Extending the Educational Ladder: The Changing Quality and Value of Postdoctoral Study* (Lexington, MA: D.C. Heath & Co., 1985), p. 7.

[41]National Research Council, *Science, Engineering and Humanities Doctorates in the U. S.: 1983 Profile,* op. cit., pp. 28-29.

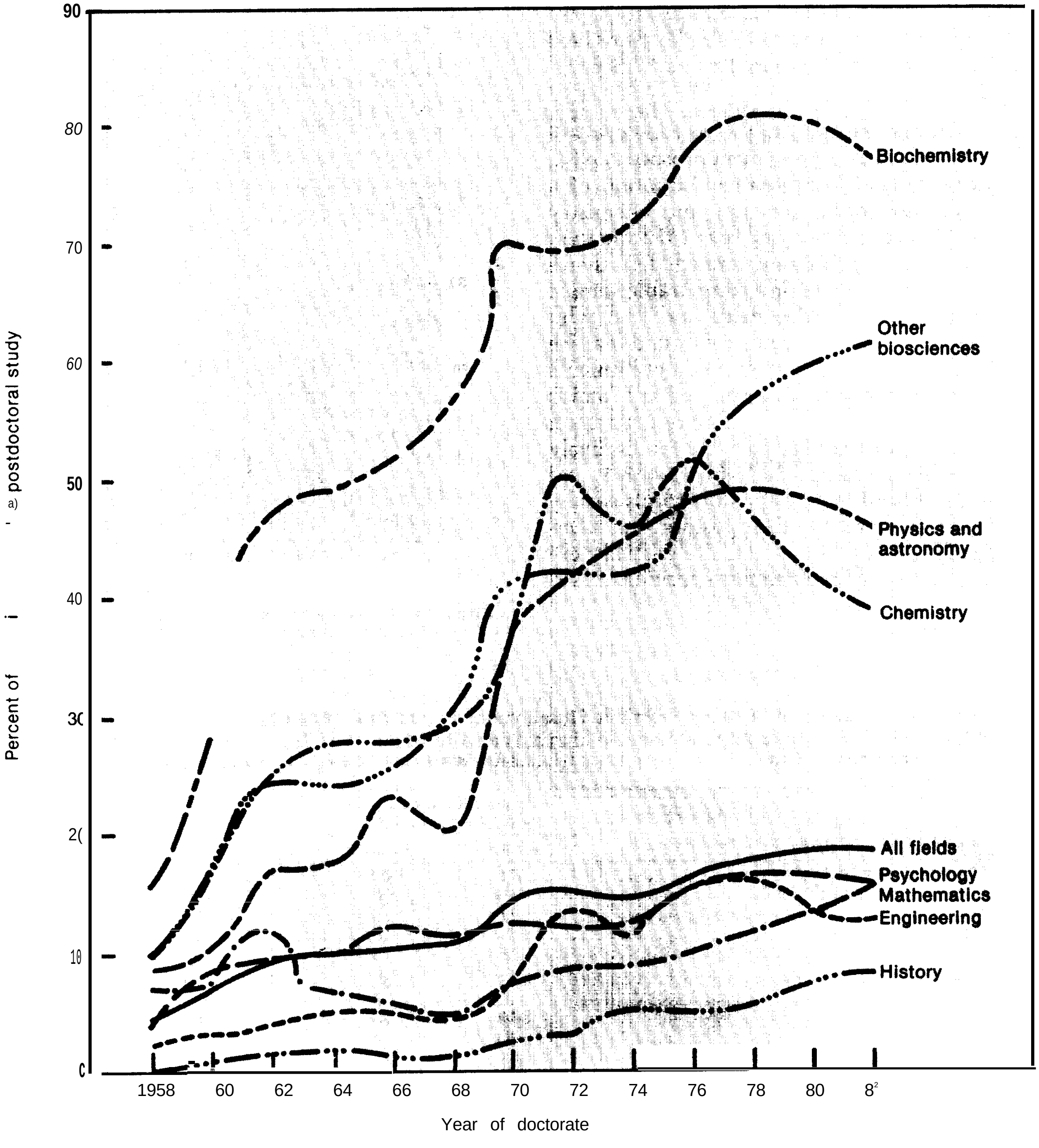
"'National Research Council, *Postdoctoral Appointments,* op. cit., p. 13.

[43]*Academic Science/Engineering: Graduate Enrollment and Support, Fall* 1983, NSF 85-300 (Washington, DC: National Science Foundation, 1985), table A-33, p. 52.

[44]Ibid., table C-35, p. 138.

[45]National Research Council, *Postdoctoral Appointments,* op. cit.

Figure 3-17.—Percent of Ph.D. Recipients From U.S. Universities Planning Postdoctoral Study Immediately After Receiving the Doctorate, Selected Disciplines, 1958-82



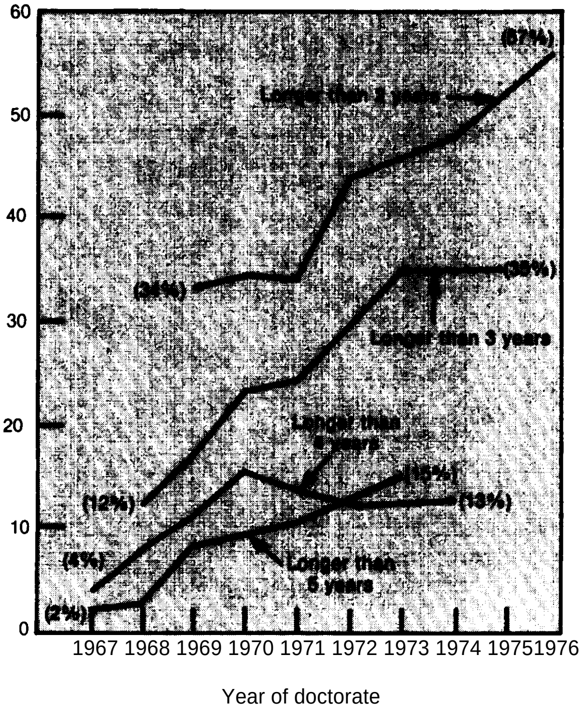
NOTE Data were reported only for even-numbered years Data for intervening years were interpolated

SOURCE William Zumeta, *Extending the Educational Ladder The Changing Quality and Value of Postdoctoral Study* (Lexington, MA DC Heath & Co 1985) p 7 reporting planned postdoctoral study. Thirty-five percent of the 1975 Ph.D. recipients reporting planned postdoctoral study, as opposed to 12 percent of the 1968 recipients with similar 'plans held appointments for more than 3 years.[46] (See figure 3-18.)

To determine the effect of the postdoctoral appointment on future employment prospects, NRC compared the 1979 employment situation of a sample of bioscience, physics, and chemistry Ph.D.s who received their degree in 1972 and took a postdoctoral appointment immediately thereafter, with the situation of a comparable sample of Ph. D.s from the same fields and year who never held such an appointment. It found that the group that had taken postdoctoral appointments was far more likely to be employed at a major research university and involved in research than its nonpostdoctoral counterpart, but far less likely to have received tenure. (See tables 3-4, 3-5, and 3-6.) It also found that nonpostdoctorals earned 3 to 10 percent more than their postdoctoral counterparts. These last two effects are partially explained by the delay in obtaining a position caused

[46] Ibid., pp. 85-108.

Figure 3-18.— Percent of Bioscientists Planning Postdoctoral Study Who Had Held Appointments Longer Than 2 to 5 Years, by Year of Doctorate



SOURCE National Research Council *Postdoctoral Appointments and Disappointments* (Washington DC National Academy Press 1981) p 89

Table 3-4.—Comparison of 1979 Employment Situations of Fiscal Year 1972 Bioscience Ph.D. Recipients Who Took Postdoctoral Appointments Within a Year After Receipt of Their Doctorates With the Situations of Other Fiscal Year 1972 Graduates Who Have Never Held Appointments

Employment position in 1979	Took postdoctorate within year after graduation		Never held postdoctorate	
	Number	Percent	Number	Percent
Total 1972 bioscience Ph. D.s[a]	1,571	100	1,472	100
Major research universities[b]	446	28	230	16
Tenured faculty	77	5	130	9
Nontenured faculty	281	18	69	5
Nonfaculty staff	88	6	31	2
Other universities and colleges	548	35	649	44
Tenured faculty	116	7	410	28
Nontenured faculty	369	24	195	13
Nonfaculty staff	63	4	44	3
Nonacademic sectors	537	34	580	39
FFRDC Laboratories	30	2	12	1
Government	171	11	243	16
Business/industry	183	12	214	14
Other sectors	153	10	111	8
Unemployed and seeking job	40	2	13	1

[a] Excludes graduates not active in the labor force in 1979
[b] Included are 59 Universities whose total R&D expenditures in 1977 represented two-thirds of the total expenditures of all universities and colleges
NOTE Percentage estimates reported in this table are derived from a sample survey and are subject to an absolute sampling error of less than 5 percentage points
SOURCE National Research Council, *Postdoctoral Appointments and Disappointments* (Washington DC National Academy Press, 1981), p 92

Table 3.5.—Comparison of 1979 Employment Situations of Fiscal Year 1972 Physics Ph.D. Recipients Who Took Postdoctoral Appointments Within a Year After Receipt of Their Doctorates With the Situations of Other Fiscal Year 1972 Graduates Who Have Never Held Appointments

	Took postdoctorate within year after graduation		Never held postdoctorate	
Employment position in 1979	Number	Percent	Number	Percent
Total 1972 physics Ph. D.s[a]	557	‘100	632	100
Major research universities	115	21	46	7
Tenured faculty	28	5	19	3
Nontenured faculty	53	10	19	3
Nonfaculty staff	34	6	8	1
Other universities and colleges	132	24	166	26
Tenured faculty	49	9	113	18
Nontenured faculty	63	11	41	6
Nonfaculty staff	20	4	12	2
Nonacademic sectors	308	55	418	66
FFRDC Laboratories	91	16	82	13
Government	71	13	107	17
Business/industry	126	23	186	29
Other sectors	20	4	43	7
Unemployed and seeking job	2	0	2	0

[a]Excludes graduates not active in the labor force in 1979
[b]Included are 59 universities whose total R&D expenditures in 1977 represented two-thirds of the total expenditures of all universities and colleges
NOTE Percentage estimates reported in this table are derived from a sample survey and are subject to an absolute sampling error of less than 5 percentage points
SOURCE National Research Council, *Postdoctoral Appointments and Disappointments* (Washington DC National Academy Press 1981) p 92

Table 3.6.—Comparison of 1979 Employment Situations of Fiscal Year 1972 Chemistry Ph.D. Recipients Who Took Postdoctoral Appointments Within a Year After Receipt of Their Doctorates With the Situations of Other Fiscal Year 1972 Graduates Who Have Never Held Appointments

	Took postdoctorate-within–year after graduation		Never held postdoctorate	
Employment position in 1979	Number	Percent	Number	Percent
Total 1972 chemistry Ph.D.s[a]	941	100	615	100
Major research universities	142	15	18	3
Tenured faculty	42	4	18	3
Nontenured faculty	64	7	0	0
Nonfaculty staff	36	4	0	0
Other universities and colleges	119	13	166	27
Tenured faculty	25	3	117	19
Nontenured faculty	79	8	41	7
Nonfaculty staff	15	2	8	1
Nonacademic sectors	680	72	416	68
FFRE)C Laboratories	38	4	0	0
Government	78	8	86	14
Business/industry	501	53	287	47
Other sectors	63	7	43	7
Unemployed and seeking job	0	0	15	2

[a]Excludes graduates not active in the labor force In 1979
[b]Included are 59 universities whose total R&D expenditures in 1977 represented two-thirds of the total expenditures of all universities and colleges
NOTE Percentage estimates reported in this table are derived from a sample survey and are subject to an absolute sampling error of less than 5 percentage points See app G for a description of the formula used to calculate approximate sampling errors
SOURCE National Research Council *Postdoctoral Appointments and Disappointments* [Washington, DC National Academy Press 1981) p 92

by the time spent at the postdoctoral level. The magnitude of the effect was so large in the biosciences, however, that NRC expressed concern over "whether the postdoctoral-experience has been advantageous to those pursuing careers in research. " It reported "frustrations" among young bioscientists caught in a "postdoctoral holding pattern, " as exemplified by the following quote :47

> Frankly, many of us are concerned about our future prospects in these times, after many years of training, We are becoming increasingly discouraged by the decline of tenure-track positions and the increasing difficulty in obtaining grant support. An opinion that is often expressed is that we postdocs provide a cheap labor source for "established" investigators. Especially in recent years many of us have been completely bypassed by the economic trends, so that we have been unable to purchase homes, have families, etc., while pursuing advanced training necessary to secure a " respectable position. " For many of us it is becoming reasonable to ask: "Is it worth it?"

"Ibid-.; ;- 93.

In summary, NRC found that "postdoctoral continue to play an important role in the nation's research enterprise, " and are "an invaluable mechanism for strengthening and confirming the research potential of the young investigator. " However, NRC found "some serious concerns . . . regarding the present and future role of postdoctoral in the research community. " These were:[48]

1. the lack of prestige and research independence in postdoctoral appointments for the most talented young people;
2. the mismatch between the important role that postdoctoral play in the Nation's research enterprise and the lack of opportunities that they find for subsequent career opportunities in research;
3. the lack of recognized status of postdoctoral appointments in the academic community; and
4. the underutilization of women and members of minority groups in scientific research.

[48]Ibid.

SUPPLY OF AND DEMAND FOR ENGINEERING FACULTY

Unlike the rest of academia where the demand for new faculty has been and will continue to be weak, engineering departments appear to be suffering from a surplus of unfilled faculty slots. Those concerned with engineering education and the health of American engineering feel that the lack of sufficient faculty is the most important deterrent to increasing the quality, scope, and number of engineering programs. For several years, the engineering community has been referring to the growing faculty shortage problem as the most immediately pressing problem facing engineering education. Undergraduate engineering enrollments have more than doubled in the past decade. In addition, graduate enrollments have nearly doubled. Meantime, full-time engineering faculty rose 14 percent and part-time engineering faculty rose 20 percent .[49] These trends have raised the student faculty ratio from 12:1 to 20:1, after adjusting for faculty research commitments. (In 1973 there were 235,000 full-time equivalent engineering undergraduate and graduate students and 19,400 FTE engineering faculty not involved exclusively in research. By 1983 those numbers had increased to 486,400 FTE students and 24,800 FTE faculty. [50]) If the number of engineering majors stays constant or slows in its increase, the alleged shortage will eventually abate. Engineering enrollment was actually down 2.8 percent in 1984 from 1983.[51]

"*American Association of Engineering Societies, *Engineering and Technology Enrollments, Fall 1983 (New* York: American Association of Engineering Societies Publications, 1984). Data was derived from the 16th annual survey of engineering and technology enrollments conducted by the Engineering Manpower Commission of AAES.

[50]*Academic Scjence/Engineering: Scientists and Engineers*, NSF *84-309* (Washington, DC: National Science Foundation, 1983), table B-1, p. 6 for faculty. All figures multiplied by 0.78 to eliminate FTEs devoted purely to research (same source, table AlA, p. 78); U.S. Congress, House, "Testimony of David R. Reyes-Guerra, P. E., Executive Director, Accreditation Board for Engineering and Technology, " Committee on Science and Technology (Washington, DC: U.S. Government Printing Office, July 24, 1985), chart D for enrollments.

[51]U. s. Congress, House, "Testimony of David R. Reyes-Guerra, " op. cit., chart D.

Many in the engineering community argue that the increase in the student to faculty ratio has significantly reduced the quality of engineering education and may be forcing faculty to pursue nonacademic positions. Surveys conducted by the Engineering Manpower Commission for the Engineering College Faculty Project reported that faculty shortages had resulted in higher teaching loads and some curtailment of course offerings.[52] It is important to note that there is no consensus that the rising student to faculty ratio has had a major impact on the quality of engineering B.S. recipients, Robert Armstrong of DuPont has publicly stated that industry does not see this as a problem, as have others.[53]

The extent of the shortage varies, depending on the manner in which it is calculated. According to NSF there are nearly 29,000 engineers employed full-time at universities and colleges and an additional 8,800 employed part-time.[54] A 1983 survey of engineering faculty and graduate students by the American Society for Engineering Education (ASEE) reported that 8.5 percent of the authorized full-time faculty positions were unfilled in the fall of 1983 as compared to 7.9 percent in 1982.[55] However, Edward Lear, executive director of the ASEE, estimates that the shortage is actually about 20 to 25 percent. He claims that to restore the ratio of faculty to students that existed in the late 1960s would require an additional 6,000 faculty in the engineering colleges. " Lear claims that the true shortage is understated because administrators will not authorize positions, even if they are needed, if there *is* no prospect of their being filled.

On the other hand, Sue Berryman, a social scientist at the Rand Corp., analyzed NSF data on academic engineering and found a possible shortage of computer science faculty but not of electrical engineering faculty. She bases this finding on an examination of comparative salaries, tenure rates, and rates of resignation among the different science and engineering fields. Even if there is a shortage of computer science faculty, Berryman points out, the implications of such a shortage are uncertain. She notes that many of the academic requirements for computer science can be fulfilled in courses other than computer science.[57]

Another finding that raises questions about the seriousness of the engineering faculty shortage problem comes from the NRC survey of doctorate recipients. According to that survey, the number of engineering doctorate recipients reporting definite postgraduation plans for academic employment declined between 1973 and 1979 and has only returned to its earlier level in 1983. If engineering doctorate recipients are as much in demand by engineering departments as the engineering professions claim, the number reporting definite academic plans should have increased substantially.

The ,NRC data also reveals that the proportion of engineering doctorate recipients without firm plans at the time of receipt of the doctorate is about the same as that for all other fields and has remained constant *over* the past decade. In 1983, 27.6 percent of the engineers reported that they were still seeking appointments as their doctoral studies were completed, the same percentage as in 1973, while 27,1 percent of all doctorate recipients made the same report. If the competition for engineering Ph. D.s between academia and industry were as strong as some claim, the proportion of engineers without definite employment plans should be lower than that for all other fields and should be decreasing.[58]

Setting aside considerations of the magnitude of the shortage problem, administrators claim that engineering departments are increasingly dependent on hold-over retirees who *will* soon leave the system entirely, on part-time personnel chosen

[52] McPherson, The State of Academic Labor Markets, " op. cit., pp 18-IQ

[53] National Research Council, *Labor Market Conditions for Engineers Is There a Shortage? (* Washington, DC: National Academy Press, 1984), ch. 1, p. 122

[54] *Academic Science* Engineering *scientists and Engineers,* op. cit., p. 83, and table B-I, p. o.

[55] Paul Doigan, 'ASEE Survey of Engineering Faculty and Graduate Students, Fall 1 983,' *Engineer-ing Education* October 1 984, p 50.

[56] National Research Council, *Labor Market Conditions*, op. cit., p 115.

[57] Sue E, Berryman, "The Adjustments of Youth and Educational Institutions to Technologically-Generated Changes in Skill Requirements, ' National Commission for Employment Policy, May 1985.

[58] National Research Council, *Summary Report 1983: Doctorate Recipients From United States Universities* (Washington, DC: National Academy Press, 1983), p. 19.

more for their availability than for their expertise, and on foreign nationals (some of whom are thought to be underqualified because of alleged language and cultural problems). Universities claim that the reasons they cannot recruit the best engineers to teach are the relatively lower salaries of faculty versus those found in business and the lack of state-of-the-art equipment for research. Daniel Drucker of the University of Florida claims that the fundamental problem is one of quality. Not enough of the top-quality engineering undergraduates are pursuing the Ph. D., and of those who do, not enough want to teach.[59]

There are signs, however that the situation is improving. The ASEE Report in 1983 showed that 35.8 percent of institutions reported an increase in their ability to recruit and retain faculty—up from 16.5 percent in 1981.[60] Unfilled engineering faculty positions at the professor level in 1982 were only 2,9 percent, below the estimated academic norm. The biggest problem seemed to exist at the assistant professor level where 24.4 percent of the budgeted positions were reported vacant. At higher levels there actually appears to be a net flow of engineers into the universities; i.e., more engineers leaving industry for academia than *vice-versa*. Electrical engineering experienced the greatest influx of new faculty members from industry, with the gain exceeding the loss by more than 150 percent.[61]

Increasingly, the rewards for university positions are becoming more attractive. The Survey of Deans conducted by AAES/ASEE documented that many universities were providing differential salary treatment for engineering faculty for purposes of recruitment and retainment. Increases awarded to engineering faculty were over and above normal, regularly scheduled university-wide salary adjustments. Engineering faculty salaries have risen 7 to 10 percent per year recently, while nonacademic engineers have received raises on the order of 2.8 percent per year.[62]

[59]National Research Council, *Labor Market Conditions*, op. cit., p. 113.

[60]Doigan, op. Cit., p. 52.

[61]American Association of Engineering Societies/ American Society for Engineering Education, *Final Report: Engineering College Faculty Shortage Project* (Washington, DC: American Society for Engineering Education, November 1983), p. 10.

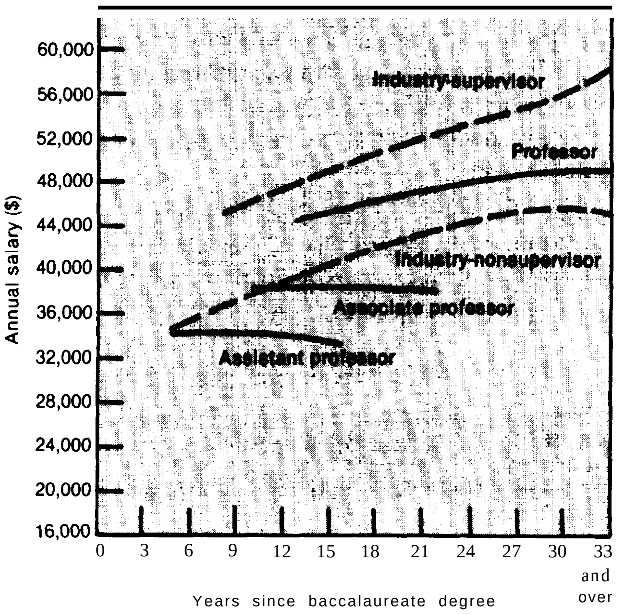
[62]National Research Council, *Labor Market Conditions*, p. 118.

The relationship of academic salaries to nonacademic salaries is illustrated in figure 3-19 showing academic and industrial salaries for engineering Ph.D.s. The figure shows that only supervisory engineers receive higher salaries than their academic counterparts at the full professor level, but that junior academics do not fare nearly as well as junior industrial engineers. Figure 3-19 displays median academic salaries for a 9-month period, augmented by a 2-month summer grant, which is received by most faculty. These data may be deceiving, as they do not include compensation received by faculty for consulting. Robert Weatherall of MIT reports that electrical engineering graduates who received Ph. D.s in 1967 and joined faculties were receiving more financial compensation from all sources, including consulting, than their counterparts in industry. Weatherall concludes that graduate students are disturbed more by a lack of equipment and resources than by salary differentials.[63]

A survey conducted by the College and University Personnel Association found that engineer-

[63]Ibid., pp. 118-119.

Figure 3-19.—Comparison of Academic-Industry Engineering Ph.D. Salaries (All Professorial Salaries Adjusted to n-Month Basis)



SOURCE Engineering Manpower Commission, AAES, 1983 ing faculty earned higher salaries in public institutions than in private institutions during the 1983-84 school term.[64] Yet, according to the ASEE survey reported above, there were *more* unfilled vacancies in the public schools than in private schools. This finding also calls into question the claim that the salary differential is the principal disincentive to a career in academia.

Many in the engineering community believe that the number of doctorate awards must be increased in order to reduce the impacts of shortages of engineering faculty. Fortunately, the number of doctorates awarded annually in engineering has been rising steadily since 1980. ' Engineering doctorate degrees increased by 4.8 percent in 1984, '5 when all other disciplines, except for the physical sciences, experienced declines." Full-time enrollment of U.S. graduate students in engineering has risen for the past 3 years. '7

Some question the extent to which undergraduate engineering education is necessarily dependent on doctoral level faculty to accomplish its mission. The Panel on Engineering Graduate Education and Research of the National Research Council Committee on the Education and Utilization of the Engineer concluded in their 1985 report that schools that emphasize undergraduate education can safely utilize faculty without the doctorate. However, the "faculty in research universities should, in the overwhelming majority, have doctor's degrees. "[68]

"Scientific Manpower Commission, *Afar-power Comments, vol.* 21, No. 3, April 1984, p. 16.

● The percentage of foreign nationals enrolled in doctoral engineering programs has remained constant at approximately 41 percent during this time period.

"'Patrick Sheridan, "Engineering Enrollments, Fall 1983, " *Engineering Education*, October 1984, p. 46.

[66]National Research Council, *Doctorate Recipients, 1983,* op. cit., see table A and figure 2.

[67]Doigan, op. cit., p. 54.

In conclusion, there appears to some disagreement about the actual need for academic engineers. Documented shortages are much lower than shortages determined on the basis of some ideal quality of education. In addition, the shortages are more apparent at some faculty levels, particularly entry levels, and in particular disciplines, such as computer science. These shortages have occurred more because of skyrocketing undergraduate enrollments in engineering than because of the decline in the number of engineers seeking Ph.D,s and subsequent academic appointments. If universities and colleges continue to allow high enrollments in engineering in response to perceived market signals, then faculty shortages will continue, particularly if academe continues to rely only on field-specific, U.S. educated doctorate recipients as their primary source for academic faculty. Some academic institutions have already begun to cap their undergraduate engineering enrollments in an attempt to relieve the faculty shortage.

In addition, the literature suggests that one means of drawing more doctorate recipients into academe is through improvement of research facilities and equipment. The salary differential does not appear to be as important a disincentive as some would suggest; many young Ph. D.s prefer to conduct their research in industry because the facilities and equipment there are at the leading edge.

[68]National Research Council, *Engineering Graduate Education and Research* (Washington, DC: National Academy Press, 1985), p. 103.

U.S. EDUCATION AND UTILIZATION OF FOREIGN SCIENTISTS AND ENGINEERS

Both as students and as faculty members, foreign nationals are a significant portion of the academic population, particularly in engineering, computer science, and the physical sciences. Foreign students comprised 6.2 percent of the undergraduate enrollment in engineering, and 35 percent of the graduate enrollment. Their overall participation in all of higher education enrollment is less than 3 percent, demonstrating their disproportionate participation in engineering *education*. [69] One-fourth of all graduate students who

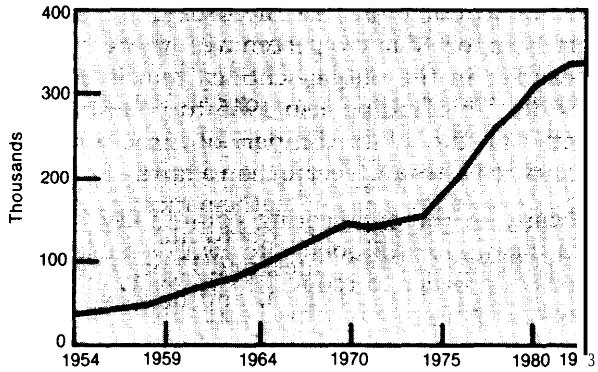
"*Participation of Foreign Citizens in U.S. Science and Engineering* (Washington, DC: National Science Foundation, January 1985).

are foreign nationals are enrolled in engineering programs.

There has been a steady increase in enrollment of foreign students since 1964, when total foreign enrollment in U.S. institutions of higher education was 1.5 percent .70 (See figure 3-20.) A Report of the Institute of International Education concluded that foreign students enroll proportionately more often in engineering and the medical sciences, and less often in the humanities and social sciences. This can be attributed to the unavailability in developing countries of costly training facilities necessary for engineering and medical science education. [71] Since 1979, the regional origin of engineering students has changed dramatically. The proportion of South and East Asians nearly doubled between 1979 and 1984, while the proportion of students from the Middle East declined by 17 percent. Data from 1984 show that South and East Asians constitute nearly 60 percent of foreign *graduate* engineering students, and 32 percent of foreign *undergraduate* engineering students. Middle Easterners comprise 18 percent of the foreign *graduate* engineering population and 38 percent of the foreign *undergraduate* engineering population. 72 Table 3-7 shows world region of origin of foreign students in the sciences and engineering undergraduate and graduate levels combined.

Data for 1983 from AAES show that at the Ph.D. level, 41.5 percent of total full-time engi-

Figure 3-20.—Total Foreign Enrollment in U.S. Institutions of Higher Education



Foreign enrollment as a percent of total enrollment	1.5	1.7	1,6	2.5	2.7

NOTE" Includes students at all levels
SOURCE Institute of International Education and National Center for Education Statistics

[70] Ibid., p. 7.
[71] Elinor G. Barber (ed.), *Foreign Student Flows,* IIE Research Report No. 7 (New York: Institute of International Education, 1985), pp. 40-42.

[72] Marianthi Zikopoulos and Elinor G. Barber (eds.), *Profiles: Detailed Analyses of the Foreign Student Population, 1983 1984* (New York: Institute of International Education, *1985),* pp. *30-39.*

Table 3-7.–Origin of Foreign Students Within Fields of Study, 1983-84

	World region								
	Africa	Europe	Latin America	Middle East	North America	Oceania	South and East Asia	Total	Number of students reported
Agriculture	26.6	5.5	27.9	8.7	4.1	1,0	26.3	100,1	4,993
Business and management	16.1	8,6	17.8	12.3	4.2	1.3	39.7		37,939
Education	16.5	9.7	17.1	13.2	10.8	4.1	28.7		7,944
Engineering	7.0	6.5	12.2	30,1	1.8	0.2	42.2		43,261
Fine and applied arts	15.8	6.5	21.2	16.5	4.8	0.5	34.5		4,185
Health sciences	16.5	9.9	18.8	14,3	9.8	2.3	28.4		8,814
Humanities	9.6	21.4	14.4	6.8	9.7	2.5	35.6		8,490
Math/computer science	6.4	7.1	13.0	17.2	1.5	0.7	54.1		18,993
Physical/life sciences	10.6	11,4	12.8	14.3	4.3	0.9	45,7		15,888
Social sciences	6.8	16.4	18.2	10.7	11.0	2.1	34,8		7,739
Other	14.4	12.9	17.8	11,1	7.5	1.6	34.7		7,400
Intensive English language	2.9	5.4	22.5	26.5	0.5	0.0	2,0		3,296
Undeclared	10.3	16.1	19.1	12.8	9.3	1,3	31.2		8,108
All fields	11.4	9.6	15.8	17.4	4.8	1.2	39.9		177,050

SOURCE National Science Foundation

neering candidates were foreign nationals, up slightly from 41 percent in 1982. * The National Research Council Survey of Doctoral Recipients (1983) shows that the percentage of engineering doctoral recipients listing U.S. citizenship has declined from 82 percent in 1965 to just under 48 percent in 1983.[73] In comparison, in 1983, non-U.S. citizens received more than a third of the doctoral degrees awarded in mathematics, 28 percent of physics and astronomy doctorates, 21 percent of the chemistry doctorates, and 12 percent of the doctorates in the biological and health sciences (down from 14 percent in 1975).

In the doctoral population, available information from various sources indicate that between 20 and 50 percent of foreign doctoral students in the sciences are principally supported through research or teaching assistantships. In engineering, the proportion is nearly 60 percent.[74] It is uncertain whether this deprives qualified U.S. students of research training and financial support. Analysts Lewis Solmon and Ruth Beddow found that, “foreign students probably pay more than their education costs, and they might be paying substantially more. ”[75] Solmon and Beddow did not include U.S. research assistantship or fellowship support in their analysis, however.

Proponents of U.S. education assistance to foreign nationals justify it with the following reasons; it is a means of helping persons from less fortunate nations to obtain the benefits of a U.S. education; the political advantage of having future leaders of other countries educated in the United States, rather than elsewhere will pay off in the long run; it is to the cultural and sociological advantage of U.S. students to be exposed to persons from other parts of the world; and the United States can utilize the skills and training of those individuals who stay on in this country after their educational training has ended. Opponents are concerned that the training and employment of foreign nationals in the United States constitutes a “brain-drain” from the home country if they remain here, and could pose a threat to our national security, if they return home. Restricting access to “sensitive” research at U.S. universities may provide additional problems to those research institutions with large numbers of foreign students and faculty members.

There is disagreement between various groups in this country as to whether individuals admitted to the United States as students who complete a graduate degree here should be allowed to remain after completion of the degree (and perhaps a short period of further training). Increasing proportions of those earning doctorate degrees (56 percent in 1983) are remaining in the country after graduation.[76] Many employers, both in industry and in academic institutions, say that they cannot fill certain research and faculty positions with U.S. citizens, and available data verify this. ” In 1984, major changes in immigration rules were proposed in legislation passed separately by both houses but not signed into law, both of which included an exception to the general rule that all foreign nationals in this country on a student visa be required to return to their native countries after graduation for 2 years before attempting to reenter the United States on a permanent visa. The exceptions would have allowed some scientists and engineers, as well as some other specialists, to accept employment and remain here. Universities and some industries felt sufficiently dependent on the foreign national population with U.S. graduate degrees that they lobbied Congress to include the exception allowing scientists and engineers to stay and accept employment in the United States. ’g

Others are concerned that the increasing number of foreign engineers earning degrees in this country are taking jobs at low pay in order to remain here, thus driving down salaries and reducing opportunities for U.S. members of the engi-

*In base numbers, in 1982 there were 6,741 foreign nationals among the 16,442 engineering doctorate enrollees; in 1983, 7,687 of the total 18,540 doctoral candidates were foreign nationals.

“’National Research Council, *Summary Report 1983: Doctorate Recipients From United States Universities* (Washington, DC: National Academy Press, 1983), see table D.

“’Betty Vetter, “U.S. Education and Utilization of Foreign Scientists and Engineers, ” contractor report prepared for the U.S. Congress, Office of Technology Assessment, 1985.

‘Lewis C. Solmon and Ruth Beddow, ‘‘Flows, Costs and Benefits of Foreign Students in the United States: Do We Have a Problem?” in Elinor Barber, op. cit., pp. 121-122.

[76] *Participation of Foreign Citizens*, op. *cit.*, p. v.

[77] Michael G. Finn, “Foreign National Scientists and Engineers in the U.S. Labor Force, 1972- 1982, a report to the National Science Foundation, March 1985 draft.

[78] Vetter, op. cit. , P, 16.

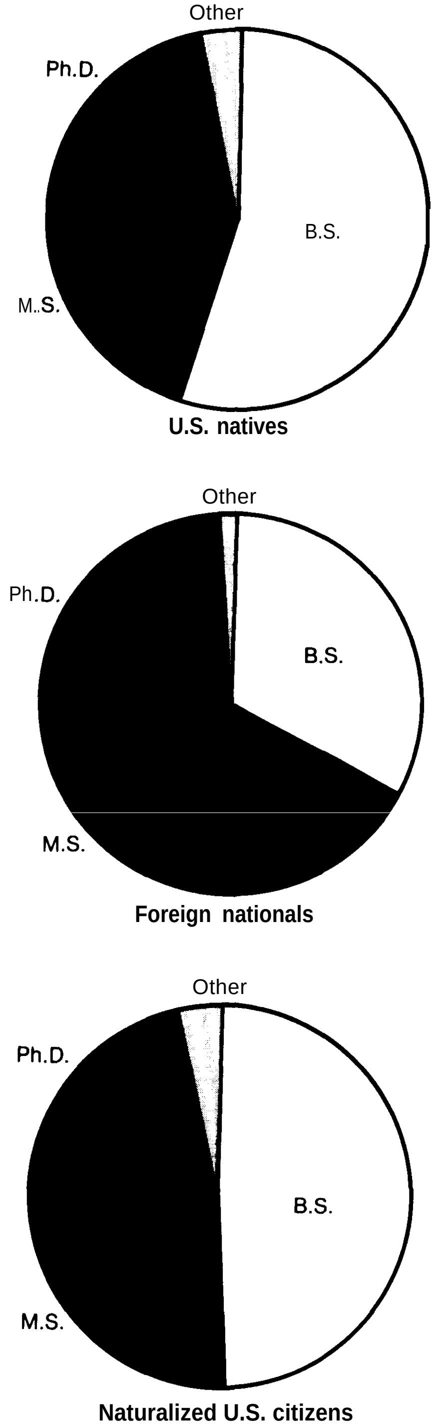
neering profession. There is no statistical evidence that foreign engineers are paid less than comparably trained and experienced U.S. engineers.[79]

Foreign nationals are employed proportionately more often in educational institutions, specifically higher education, than U.S. citizens. This may be explained by the fact that scientists and engineers who are foreign nationals tend to have higher levels of educational attainment than U.S. scientists and engineers, as shown in figure 3-21. The proportion of foreign nationals engaged in research, development, and design is about the same as for U.S. scientists and engineers. The proportion of foreign nationals in management positions in R&D firms, however, is less than their U.S. counterparts. This may be a reflection of the fact that foreign nationals in the U.S. science and engineering labor force tend to be younger than the average U.S. scientist or engineer. Management positions traditionally go to senior employees.[80]

Many foreign nationals choose to enter the academic market after graduation. Because there is a shortage of faculty in engineering and in computer science and because an increasing proportion of U.S. doctoral graduates in these fields are foreign citizens, U.S. faculties include a large and increasing proportion of foreign nationals and foreign born but U.S. educated citizens. The current shortages of faculty in engineering schools would be far higher had they not been able to employ foreign engineers with U.S. Ph.D.s. A 1982 survey found that 18 percent of all full-time engineering faculty members earned their B.S. degrees from an institution outside the United States. The highest percentage of foreign born faculty is in computer science/engineering—20. 7 percent. More than one-fourth (26 percent) of all assistant professors in engineering in 1982 earned their B.S. degrees outside the United States.[81]

Several authors have made reference to the "growing problem" of foreign nationals on engineering faculties. They contend that the drawbacks of an increasingly foreign born faculty are

Figure 3-21.—Educational Attainment of Scientists and Engineers, by Immigrant Status, 1982



SOURCE. ORAU, based on 1982 Postcensal survey (Finn)

[79] Vetter, op. cit., p. 17.
[80] Finn, op. cit., p. 12.
[81] Vetter, op. cit.

the limitations in their communications skills and the implications for education. Some studies have found that a number of problems for women are greatly exacerbated when they deal with foreign faculty and foreign students .82 The classroom climate for women who must deal with foreign male faculty and graduate students is particularly difficult when such faculty and students come from countries where women, by statute or custom, have a very restricted role. These difficulties are further emphasized by the fact that 92.5 percent of all foreign students in engineering are male.

In conclusion, there is no apparent national policy in regard to either the education or the utilization of foreign students and graduates, against which either current or proposed regulations for the temporary or permanent entry of foreign science and engineering students or foreign scientists and engineers might be tested. Foreign students make up a significant fraction of graduate enrollments in U.S. universities, where they serve as research assistants, and to *a* lesser degree, as teaching assistants. As these students obtain advanced degrees, many seek to remain in the United States and to enter the U.S. labor force, which appears to be problematic only in academe, where communication skills are essential. There is no doubt that foreign born scientists have enriched U.S. accomplishments and achievements in science and technology. As these individuals increasingly enter American industry and academe, following an education in American colleges and universities, a new set of policy issues arise. Issues of interest to policy makers are the purposes of educating students from other nations, whether the education of American students suffers from the participation of foreign nationals, and the cost, if any, to the taxpayers of educating foreign students.

[82] Scientific Manpower Commission, *The International Flow of Scientific and Technical Talent: Data, Policies and Issues,* proceedings of a joint meeting of the Scientific Manpower Commission and the Engineering Manpower Commission on May 7, *1985,* in preparation for publication, 1985.