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ABSTRACT

This report represents the National Science Foundation's fourth projection analysis of science and engineering doctorate supply and utilization through 1987. The 1979 study incorporates the effect of the domestic market for highly trained science and engineering (S/E) personnel upon the numbers of S/E doctorates awarded by American universities. This report consists of four chapters. Chapter one describes the method used to project the 1982 and 1987 supplies of doctoral scientists and engineers in five fields. Chapter two briefly describes the utilization of doctoral scientists and engineers in 1977, and explains how 1982 and 1987 utilization estimates were derived by summing eight categories of S/E-related employment. Chapter three presents the 1982 and 1987 balances between full-time supply and utilization in the market for scientists and engineers. Chapter four presents a summary of projection methods and assumptions. Appendices which include technical notes and a bibliography are also included. (HM)

PROJECTIONS of SCIENCE and ENGINEERING DOCTORATE SUPPLY and UTILIZATION 1982 and 1987

National Science Foundation
NSF 79-303

FOREWORD

Recent changes in the supply-demand balance for scientists and engineers have increased interest in projections. By the early seventies warnings that a significant number of new science and engineering doctorates would be unable to find employment related to their education displaced the concerns of the preceding decade that the United States would have too few of these highly trained people to meet national goals. Coming near the start of a new decade, this latest NSF study projects to 1982 and 1987 the balance between the supply of doctoral scientists and engineers and their science and engineering-related utilization.

As indicators of possible futures, these projections are intended to be used by planners and policymakers as tools to anticipate potential problems and opportunities. They can also be used by students as general indicators of the types of future opportunities available in broad fields of science and engineering. The analysis supporting the projections may also help the reader develop a better understanding of the dynamics of the doctoral labor market. It should be recognized, however, that projection models produce forecasts that are sensitive to assumptions and methodological limitations. Therefore, users should focus on broad features of the projections and not attribute a false sense of precision to numerical values.

The current projections are the fourth in a series initiated by the National Science Foundation in 1969. Throughout this decade, successive NSF projections have reflected continuous improvements in both methods and data bases. This report incorporates a significant number of technical changes. The most important one involves feedback from the doctoral labor market to the production of new doctorates. Although there have been changes in methods and certain data trends—especially those involving the availability of R&D funds—it is notable that the overall results of the new NSF projections are generally consistent with those produced four years ago and are also consistent with more recent projections developed by the Bureau of Labor Statistics.

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SUMMARY OF FINDINGS

- Projections presented in this report indicate that about 17 percent (or 70,000) of all science and engineering (S/E) doctorates in the 1987 full-time labor force may not be employed in S/E positions. (The Bureau of Labor Statistics projects an equal gap between supply and "traditional" utilization of S/E doctorates. See appendix A-3.) On the basis of current labor force statistics, however, it is expected that nearly all of the 70,000 will be employed. By comparison, only 25,000, or 9 percent of the full-time S/E Ph.D. labor force, held non-S/E jobs or were unemployed in 1977.[1] Non-S/E utilization is projected in this report to range in 1987 from about 9 percent in the physical sciences to a high of 21 percent in mathematics. Non-S/E utilization in engineering and the social sciences is projected to be 19 percent in that year, whereas the estimated figure for the life sciences is 16 percent (table 1).

Table 1. Proportions of full-time S/E doctorates who are projected to be in non-S/E-related positions in 1987

Field	Percent
Total	17
Physical sciences	9
Engineering	19
Mathematics	21
Life sciences	16
Social sciences	19

Source National Science Foundation

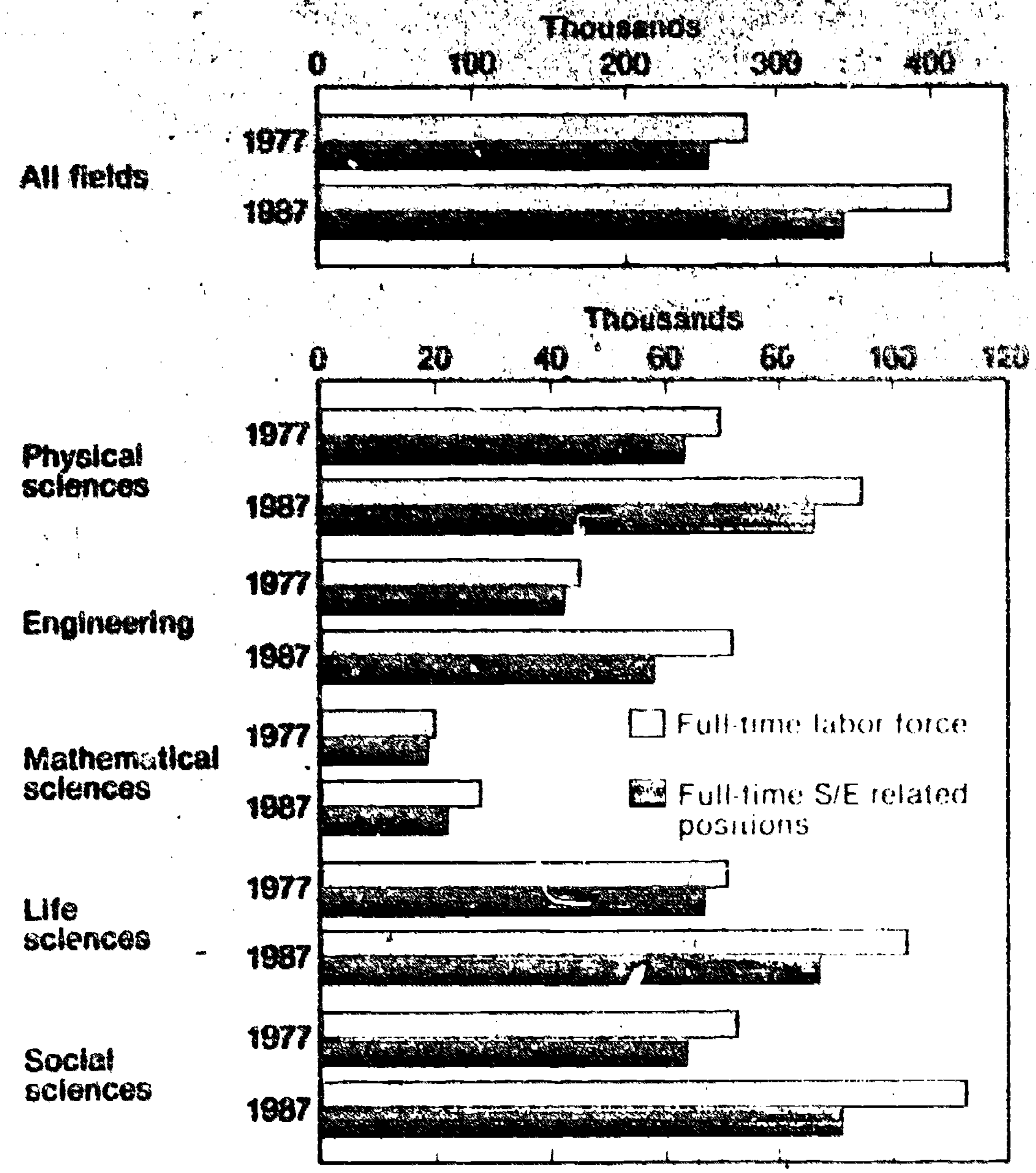
- These projections reinforce the conclusion of an earlier NSF study[2] that a substantial number of new S/E doctorate recipients through the mid-eighties are unlikely to find work in areas related to their training. This new study concludes that about 25 percent of 1977–87 S/E doctorate recipients may not be employed in S/E-related activities in 1987.[3]

[1] This includes about 3,000 who were unemployed. Data from the 1975 Survey of Doctoral Scientists and Engineers indicate that about 90 percent of S/E doctorates holding non-S/E jobs did so on a voluntary basis.

[2] National Science Foundation, *Projections of Science and Engineering Doctorate Supply and Utilization, 1980 and 1985* (NSF 75-301) (Washington, D.C. 20402: Supt. of Documents, U.S. Government Printing Office).

[3] This projected 1987 rate of non-S/E utilization assumes that all S/E doctorates who are currently employed in S/E jobs will remain in S/E jobs or leave the labor force. The projected non-S/E utilization rate will be smaller if some of these currently employed S/E doctorates move to non-S/E jobs.

Supply and S/E-related utilization of doctorates[a]



[a]Includes postdoctorates

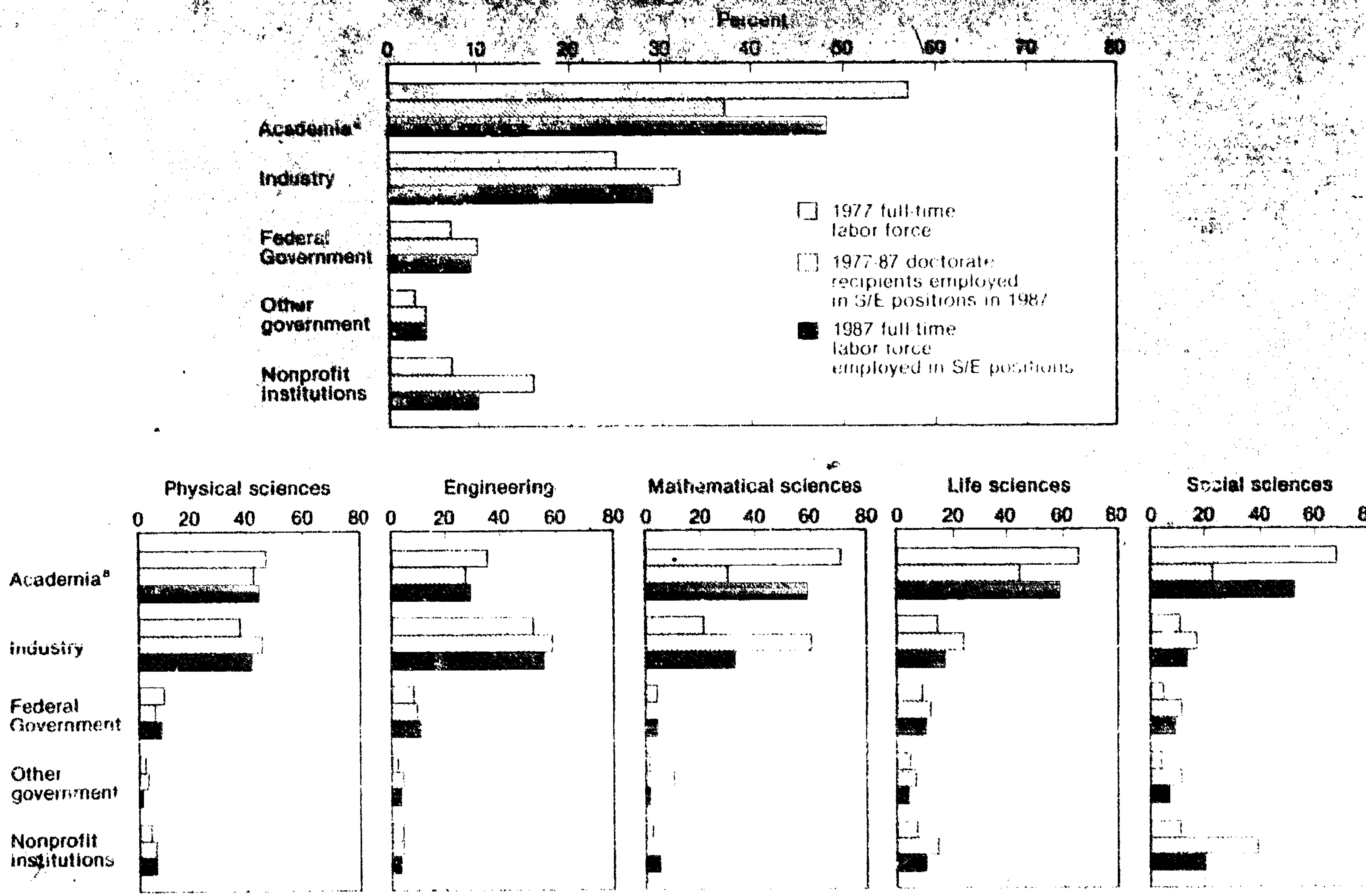
SOURCES: National Science Foundation and National Research Council.

- The full-time S/E doctoral labor force (supply) is projected to increase during the 1977–87 projection period by almost 50 percent to about 410,000.

- The number of full-time S/E-related positions (utilization) held by doctorates is projected to grow over the same period by 35 percent to about 340,000. Industrial R&D utilization of S/E doctorates is projected to expand by 1987 to almost 70,000—39 percent over 1977, primarily as a result of expected growth in R&D funding. In contrast, S/E doctoral faculty utilization over the same period is projected to grow only 11 percent to about 145,000.

- New (1977–87) doctorates in all broad fields in S/E positions are expected to be less concentrated in academia than were S/E doctorates in the 1977 labor force—57 percent for the latter vs. 35 percent for the former. New S/E doctorates are projected to be more concentrated in nonprofit organizations—7 percent for the 1977 labor force vs. 16 percent for new doctorates, and in industry—25 percent of the 1977 labor force vs. 32 percent of new doctorates.

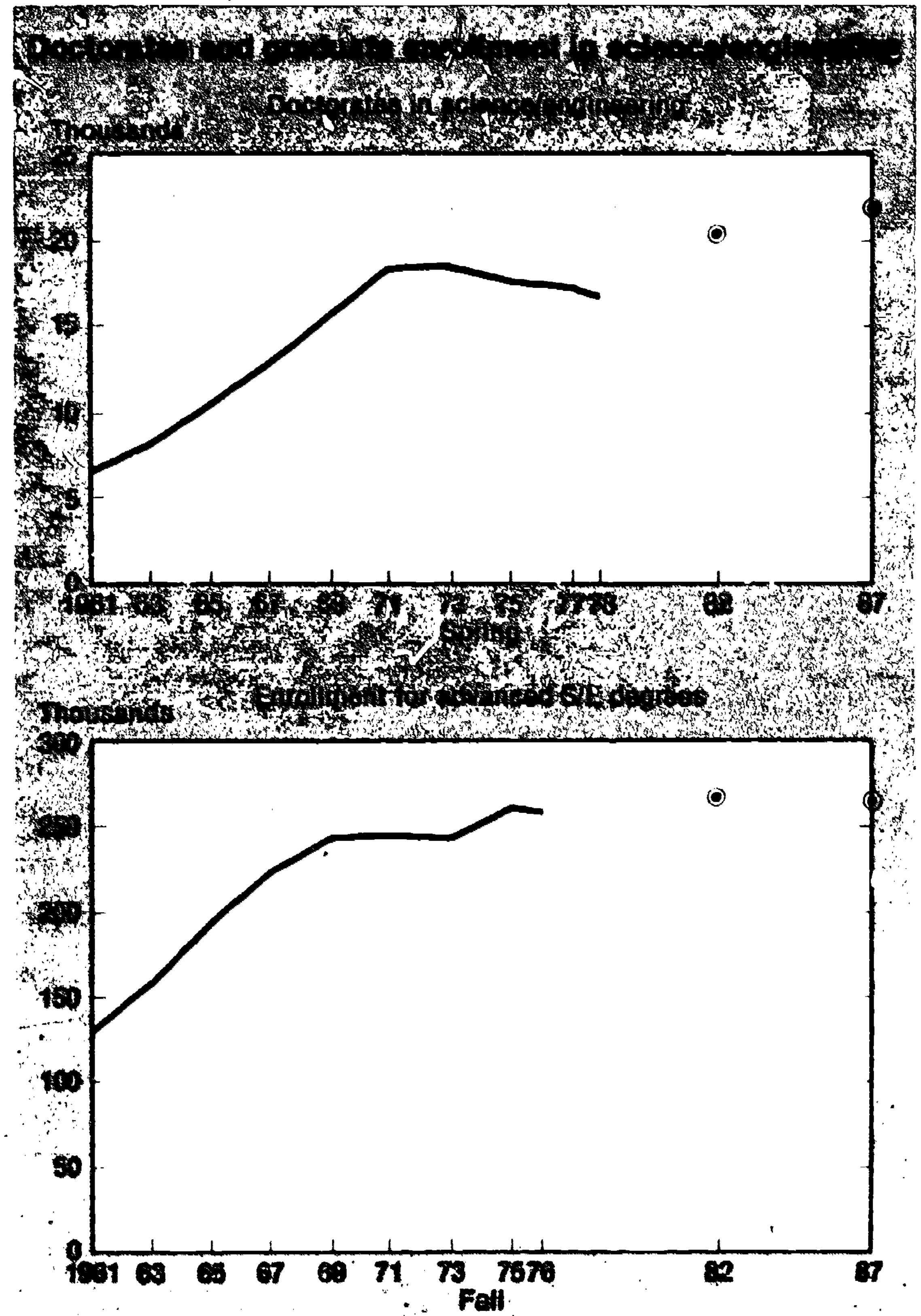
Science [illegible]



[a][illegible]

SOURCES: National Research Council and National Science Foundation.

- The number of new S/E baccalaureates and doctorates produced during the 1977–87 period are projected to be 20 percent and 23 percent larger, respectively, than corresponding totals of the preceding 11-year period, 1966–76. The projections of doctoral degrees presented in this report were produced with an econometric model that relates the number of doctoral awards to labor market conditions.



SOURCES: National Center for Education Statistics and National Science Foundation

INTRODUCTION

This report provides projections of the supply and utilization of doctoral scientists and engineers through 1987. The study, the fourth in a series that began in 1969, uses a new approach that explicitly incorporates the effect of the domestic market for highly trained S/E personnel upon the numbers of S/E doctorates awarded by American universities. In this improved approach, market conditions are assumed to affect the projected proportions of both S/E baccalaureates who enter graduate school and graduate enrollees who earn doctorates.

The projected 1982 and 1987 supplies of doctorates in each broad S/E field[1] are the summation of three components. The first is composed of those members of the 1977 doctoral labor force who are projected to be still employed at the later dates. The second component, about equal in size to the first, is doctorate recipients for 1977 through 1982 and 1983 through 1987. Before their inclusion in the projected supply, these estimates of future degree-recipients are adjusted to reflect the emigration of non-U.S. residents and any field-switching of the remaining new doctorates as they take their first jobs after graduation. The third, and smallest, component is the estimated number of future Ph.D. immigrants.

Estimates of future utilization, disaggregated both by sector of employment and S/E field, are based primarily upon projection equations which link demand factors (R&D spending and S/E bachelor's degrees[2]) to the utilization of scientists and engineeers. The parameters of these equations are estimated using multiple regression techniques. The projected balance between supply and utilization in 1982 and 1987 is obtained by comparing estimated future supplies with projected numbers of S/E-related jobs available in each of these two years.

Several factors which have changed since the last report, prepared four years ago, strongly affect the current projections. For example, industrial R&D expenditures have begun to grow again after having been fairly constant in real terms from 1970 to 1976. Other changes include a sharp fall in undergraduate degrees in the social sciences and an acceleration in the long-term upward trend in life sciences baccalaureates. In addition, information from a recent survey, supported by NSF and completed since

[1] The five broad S E fields discussed in this report are engineering, the life sciences, the mathematical sciences, the physical sciences, and the social sciences. See appendix A 4 for the composition of these broad fields

[2] Bachelor's degrees serve in the model as an index of teaching loads

the last supply and utilization report, allows more reliable estimation of the proportion of new S/E hires in academia who will have doctorates.[3]

Limitations

In interpreting the information presented in this report, it should be remembered that projections are conditional forecasts incorporating a number of assumptions about the future. If these assumptions are changed, the results of the projections would be altered.

The analysis in this report combines trend extrapolation, when justified by expectations that factors determining past trends are likely to remain unchanged during the projection period, with econometric models. An obvious hazard of trend extrapolation is that past tendencies may not continue because of unexpected events. In the econometric models, statistical relations between dependent and independent variables, such as between employment of scientists and engineers and industrial R&D spending, are derived from regression analysis. The use of such analyses presents difficulties similar to those of trend extrapolation. For example, pertinent factors may be omitted from regressions either through lack of knowledge or because of data limitations, thereby causing possible bias in the estimated parameters.

In view of these limitations, a false sense of precision should not be attributed to the numerical values presented in this report. Despite these caveats, the general supply/utilization relationships projected are believed to be representative of what would occur under the assumptions stated in the text. The projection results are similar to those derived by the Bureau of Labor Statistics.[4]

A final caveat concerns the high degree of aggregation in the reported projections. Each major area of science and engineering includes specific disciplines (e.g., physics, economics, electrical engineering) that can differ in their supply and utilization balance from the aggregate balance. Thus, it must not be assumed that projections for a broad area of science (e.g., physical sciences) are necessarily applicable to individual disciplines.[5]

[3] Frank J. Atelsek and Irene L. Gomberg, *New Full-Time Faculty 1976-77: Hiring Patterns by Field and Educational Attainment* (Washington, D.C.: American Council on Education, March 1978.)

[4] Douglas Braddock, "Oversupply of Ph.D.s to Continue through 1985," *Monthly Labor Review*, Oct. 1978, pp. 48-50

[5] NSF projects by broad S/E field because too little is currently known about interfield mobility to make further breakdowns by individual S/E fields very meaningful

Chapter I. SUPPLY OF SCIENCE/ENGINEERING DOCTORATES

This chapter describes the method used to project the 1982 and 1987 supplies of doctoral scientists and engineers in each of the five fields. The basic projection method consists of adjusting 1977 doctoral S/E stocks for projected flows into and out of those stocks. The following steps summarize the procedures for estimating the 1987 supply of doctorates by field:

1977 doctoral labor force
plus
1977–87 doctoral awards
less
1977–87 emigration
plus
1977–87 immigration
plus
adjustments for 1977–87 field mobility
less
1977–87 deaths and retirements
equals
1987 doctoral labor force

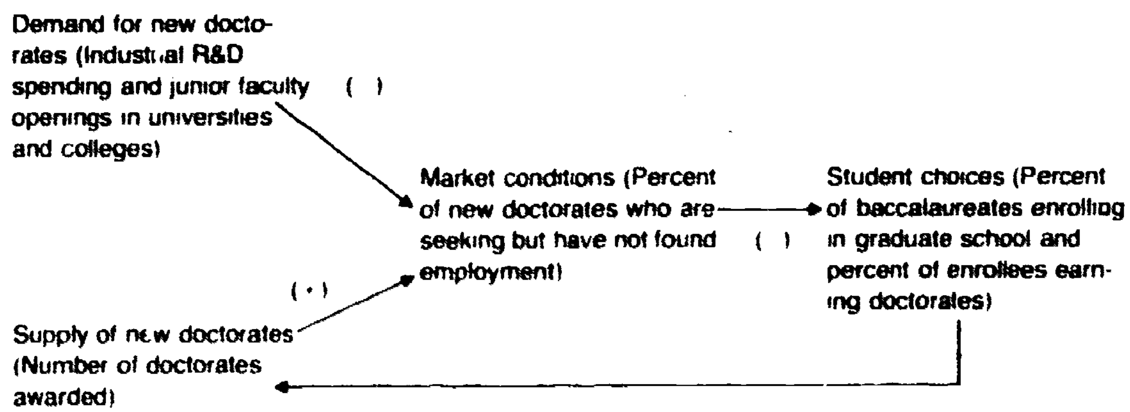
The 1982 stock is estimated with comparable procedures.

The first section concerns doctoral awards which are projected using a model that links student decisions regarding graduate school attendance and completion to employment opportunities for new doctorates. Appendix A-2 provides more detail on the model and presents the equations which comprise the projection model. The remaining sections deal with (1) projections of international mobility, (2) adjustments for differences between field of degree and field of employment for some doctorates, and (3) estimation of future doctoral deaths and retirements.

Doctoral Degrees

Projections of new degrees are based on analysis of historical data linking the supply of S/E doctoral graduates by broad field to labor market conditions. As economic theory suggests, improved opportunities for obtaining employment elicit greater participation in doctoral study, although a lag of several years may separate responses in the number of graduates from market changes.[6] The historical links between market conditions, student behavior, and graduate school output provide the basis for this report's projections of S/E doctoral degrees through 1987. It is assumed that these links will continue to have the values they have had in the past, e.g., a given change in the market for doctoral mathematicians will change completion rates for graduate students in mathematics by the same number of percentage points in the projection period as it did in the past. The following diagram is a schematic representation of the model for projecting such awards.[7]

Doctoral degree projection model



Note: Variables are in parentheses. Signs, plus or minus, refer to direction of influence exerted by variables.

Whereas market conditions influence career choices of some students at both the undergraduate and graduate levels, the effects of such conditions appear to be stronger at the latter level where the market appears to affect student educational choices at two points. These are the stage at which the new baccalaureate elects whether to enter graduate school and the stage at which the enrollee decides whether to complete graduate training and earn a doctorate.

[6] The relationships described here were estimated using multivariate regression analysis. For details see appendix A-2, p. 26.

[7] Although all variables are measured separately in each S/E field, this diagram represents the model for all five S/E fields.

At the first stage, the proportion of baccalaureates enrolling in graduate school by sex and broad field[8] is statistically related to an index of the availability of jobs for doctorates. This index, derived from the Foundation-sponsored annual Survey of Earned Doctorates, reports, by field, the percentage in a given year of those who are about to receive doctorates who are seeking employment but have not found definite positions.[9] This index, SEEK, was used as an independent variable in equations explaining the annual percentages of baccalaureates in a field going on to graduate school.[10] Additional independent variables found to be related to graduate school enrollment rates were the number of baccalaureates awarded in a field, the number of men drafted for military service, and a simple linear trend variable.[11] Synchronous values were used for all variables, i.e., no variables were lagged or led. Starting salaries, another possible index of market conditions, were not used in these projections because starting salary data at the doctoral level were limited to a few fields (appendix A-2, p.29).

Unlike enrollment in graduate school, the decision to complete graduate training is not necessarily made at a discrete and fixed time. However, an assumption that such a choice is made two years after the start of graduate study permits relating completion rates (measured in percents of students beginning study at year t) to employment opportunities (indexed by SEEK at year t+2). Strong correlation between the market and completion rates were found for all fields and both sexes except for women in the social sciences. With this exception, SEEK alone explained at least three-fourths of the variation in completion rates.[8]

At the undergraduate level, the market exerts strong, clearly identified effects only on engineering students. Therefore, only engineering baccalaureates are projected with a market-related method similar to that used for doctoral degrees.[12] The limited role of the market in determining undergraduate science degrees can be illustrated by two examples. The number of baccalaureates in the life sciences has increased almost every year since 1961, irrespective of relative employment opportunities. For the social sciences the market seems to have an effect only after a lag. The number of baccalaureates in this broad field did not begin to fall until 1975, although many holders of such degrees had difficulty finding jobs as early as the late sixties. These examples suggest that noneconomic factors may play a major, and perhaps a dominant, role in the decisions of many undergraduates regarding study in the sciences.[13]

The projections for the four science fields assume that trends existing as of 1976 in the numbers of baccalaureate degrees awarded by field and sex will continue through 1987. The rate of change, however, is assumed to be one-half the current rate.[14] The assumption that existing trends will continue is based on the judgment that the factors that produced them will still be operational during the projection period. These include a continued shortage of jobs for social sciences baccalaureates and continued growth in female participation in science and engineering. The decision to reduce the rate of change was made because the projection of historical rates produced clearly unreasonable results. For example, if the rate of growth for life science baccalaureates does not moderate, almost 200,000 undergraduate degree awards would be made in 1987, or 2.6 times as many as were awarded in 1976.

[8] Female engineers were excluded from the analysis because there have been few graduates

[9] Forms for this survey are completed throughout the year Tabulations by the National Academy of Sciences, which administers the survey, show that the distribution of survey responses by month of completion has not varied much since the survey was begun in 1958

[10] Sixteen observations of SEEK were used for the period 1960-75

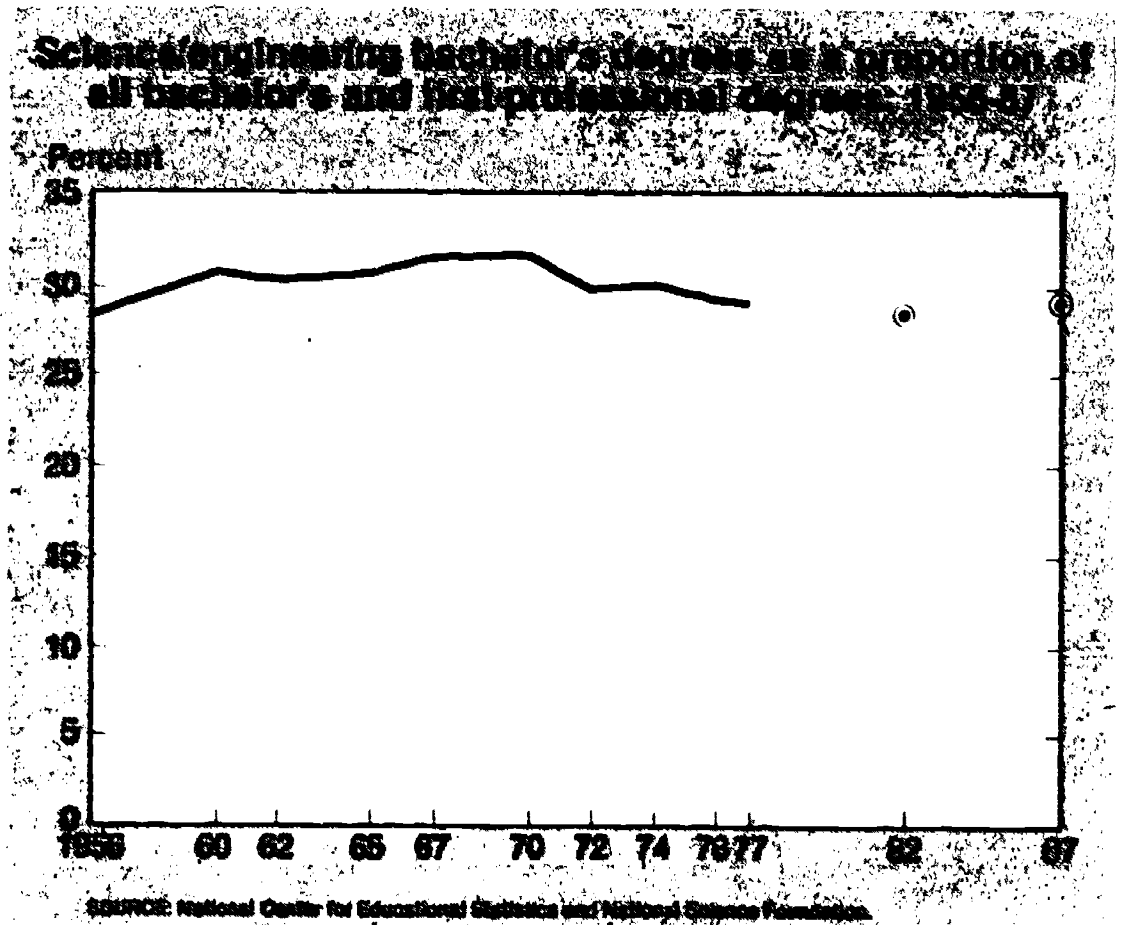
[11] This is included to account for factors which are not represented in the equations and which are related to time, i.e., they either increase or decrease with the passage of time The trend variable takes the value of one for the first observation, two for the second etc

[12] For this report engineering baccalaureate projections from the Center for Policy Alternatives, Massachusetts Institute of Technology, were adjusted and used as input to the engineering Ph.D projections (Unpublished report of SRS grant 76-22596 A01.)

[13] The fact that many undergraduates change fields when they enter graduate or professional school would make testing of this hypothesis difficult.

[14] Trends were assumed to begin either in 1960 or whenever the number of baccalaureate awards began a clear period of growth or decline The only exception is male social science baccalaureates where a 1972-76 period is used rather than 1974-76. Although degrees did not begin to drop until 1974, the fall was so precipitous that use of the 1974-76 period as a basis for extrapolation would lead to extremely low projections of 1987 male social science baccalaureates The following years mark the beginning of the trends used in projection of baccalaureate degrees Physical sciences, men - 1966 and women - 1969, mathematical scientists, men and women - 1970, life sciences, men and women - 1960, social sciences, men - 1972 and women - 1974

The decision to halve existing rates was based upon the historical relationship between S/E baccalaureates and the sum of all baccalaureates and first-professional degrees. The number of science baccalaureates projected for 1987 using the attenuated rates was added to the number of engineering baccalaureates projected for that year with the market-related approach. The result was then compared to the National Center for Education Statistics projection of the 1987 sum of bachelor's degrees in all fields plus first-professional degrees. The NSF projections of how many of these degrees would fall in S/E fields was within the narrow historical band—28.2 percent to 31.8 percent—formed by such proportions in the past 21 years.



International Mobility

Manpower flows between the United States and the rest of the world affect the size of domestic S/E Ph.D. labor force. The most important flow is the return abroad of foreign citizens who have earned American doctorates. The number of new S/E doctorates with temporary visas probably best indicates those degree recipients who expect to leave this country permanently. In the period 1974–77 about 2,600 doctorates a year, or about 15 percent of S/E doctorates, were earned by those on temporary visas. The distribution of these individuals by sex and field did not vary greatly during these years. The projections assume that the annual numbers of students on temporary visas who earn doctorates through 1987 will be equal to the 1974–77 averages[15] and that all such students will leave this country upon graduation.[16] For this reason, the estimated numbers of future doctorates earned by those with temporary visa status are subtracted from projected total doctoral awards by field and sex before the latter are included in the 1982 and 1987 labor forces.[17] It is also assumed that only insignificant numbers of doctorate recipients with American citizenship or permanent visas will emigrate.[18]

The annual inflow of scientists and engineers trained abroad offsets much of the loss of foreign citizens who receive their graduation training here. The most recent available data describing the level of education of immigrants are from a special study of those receiving permanent visas in 1964–69. This study reported the proportions of foreign-trained entrants with doctorates by field.[19] By assuming that these proportions have not changed since 1964–69, estimates were made of the numbers of immigrants with doctorates in 1974–76. It is assumed that the number of Ph.D. immigrants in each field entering this country yearly through 1987 will

[15] This assumption is based on the expectation that American S/E education will retain its current high standing relative to that in other countries. The largest absolute change during 1974–77 in the numbers of doctorates earned by those on temporary visas was in engineering where the total dropped from 810 in 1975 to 773 in 1977. National Research Council *Summary Report. Doctorate Recipients from United States Universities*, annual. (Washington, D.C.).

[16] If students on temporary visas remain in this country they must switch to a permanent visa in which case they are included in immigration totals. Such visa changes are reflected in the estimates of future immigration by field.

[17] Lack of data on citizenship and visa status of S/E students prevented exclusion of foreign students from the model before the doctoral award stage.

[18] Special tabulations from the National Research Council indicate that only 4 percent of U.S. citizens earning S/E doctorates in 1977 planned to locate outside the U.S. after graduation. This included those who would study abroad or join the Peace Corps, as well as others who were planning to return to this country after temporary residence abroad. About 11 percent of combined U.S. and foreign citizens with U.S. doctorates planned to locate abroad.

[19] National Science Foundation. *Immigrant Scientists and Engineers in the United States. A Study of Characteristics and Attitudes* (NSF 73-302) (Washington, D.C. 20402 Supt. of Documents, U.S. Government Printing Office)

equal these estimated average annual figures for 1974–76.[20] The latter assumption is of fairly minor importance in the overall projections. A 10-percent change in doctoral immigrants changes the projected 1987 doctoral labor force by 0.5 percent.

Field Mobility

Many scientists and engineers work in fields other than those in which they earned their doctoral degrees. These movements must be considered in any projection of supply by field. A National Academy of Sciences (NAS) study documents the extent of such mobility for Ph.D.'s active in 1973.[21] Since then, NAS studies of more recent data have found that these 1973 patterns of mobility have persisted.[22] The projected supply of new scientists and engineers has been adjusted to reflect the pattern of field-switching observed for the 1973 doctoral labor force.[23] This adjustment method assumes (1) all field-switching occurs immediately after receipt of the doctorate and (2) mobility after 1977 will remain stable at 1973 levels. These assumptions are necessary because the NAS studies deal with cumulative mobility and do not indicate when individuals change fields or how often they switch. The effects of these adjustments for mobility on projected 1987 supplies of doctorates are relatively small, ranging from a little more than 1 percent in the life sciences to 7 percent in the mathematical sciences.

Attrition

Those who were employed in 1977 and who continue working during the projection period constitute a principal component of the 1982 and 1987 supplies of doctoral scientists and engineers. Attrition from the labor force may result from death, retirement, or voluntary withdrawal.

[20] The doctoral averages were as follows Physical scientists, 500, engineers, 400, mathematical scientists, 300, life scientists, 300, and social scientists, 250. Scientists and engineers were classified as being in shortage occupations until 1973. Unless this classification is restored, S/E immigration is unlikely to return to the high 1967–72 levels

[21] National Research Council *Field Mobility of Doctoral Scientists and Engineers* (Washington, D.C., December 1975)

[22] National Research Council *Doctoral Scientists and Engineers in the United States, 1973 and 1975 Profiles* and *Science, Engineering, and Humanities Doctorates in the United States, 1977 Profile* (Washington, D.C.)

[23] This is done by multiplying each vector of annual S/E doctoral awards by field by a matrix representing the 1973 distribution of all active doctorates by field of degree and field of employment

Table 2. Estimated combined death and retirement rates of doctoral scientists and engineers by field and sector of employment: 1977–87

[Percents]

Sector of employment	Physical scientists	Engineers	Mathematical scientists	Life scientists	Social scientists
Academia[1]	1.5	2.2	1.6	2.3	1.5
Business/industry	1.6	1.5	2.1	2.8	2.3
Federal Government	1.5	1.5	2.4	2.7	2.9
Nonprofit institutions	1.5	1.5	2.1	3.0	2.9

[1] Rates derived after applying age-specific mortality rates to estimated 1977 age distribution and assuming that faculty retire at age 66

Source: National Science Foundation

Losses from the 1977 doctoral labor force, summarized in table 2, were projected on the basis of information, most of which is unpublished, from the Teachers Insurance and Annuity Association (TIAA) and the Bureau of Labor Statistics (BLS). For college staff, estimates of future losses from death were made using age-specific mortality data from TIAA and estimates of the age distribution of faculty in 1973 from an American Council on Education survey. The projections assume that retirements for faculty will occur at age 66. This assumption was based on TIAA information on when faculty begin to receive annuities.[24] Recent Federal legislation raising the mandatory retirement age may result in a higher average academic retirement age after July 1, 1982. The possible effect of this legislation is unclear because some evidence[25] indicates that many faculty have recently tended to retire earlier than faculty did in the past. For doctorates in other sectors, BLS estimates of 1979 death and retirement rates for specific occupations, e.g., biologists, economists, chemical engineers, were used to estimate attrition between 1977 and 1987. The BLS rates were not specified by degree level (table 2).[26]

[24] Teachers Insurance and Annuity Association. *The Participant* (New York, January 1976) Annual deaths and retirements of 1977 faculty were calculated using the information above. The faculty attrition rates reported in table 2 were derived after those calculations. These derived rates are presented for purposes of comparability with rates for other sectors that were used directly in the calculation of attrition in those sectors

[25] "The Impact of Federal Retirement Legislation in Higher Education. A Report of the Special Committee on Age Discrimination and Retirement," *AAUP Bulletin*, September 1978, pp 181–192.

[26] The rates in table 2 are those actually used in calculating attrition of doctorates in nonacademic sectors. In some cases attrition rates for a broad field are not the same in different nonacademic sectors because broad field rates were derived by weighting rates for specific occupations (e.g., chemists and geologists) and sectors differ in the employment distribution of these occupations.

Table 3. Full-time labor force of doctoral scientists and engineers: 1982 and 1987

[In thousands]

Derivation of 1982 and 1987 labor force	Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences
				1982		
Employed full-time in 1977	277	69	44	20	70	73
Full-time entrants, 1977–82	110	19	19	7	29	35
Graduates[1]	114	20	20	7	30	37
Part-time or not seeking employment	4	1	—	—	1	2
Net migration	6	--	2	—	2	-2
Immigration	10	3	3	1	2	2
Emigration	16	3	5	-1	4	4
Attrition	29	5	3	2	9	9
1982 full-time labor force	352	83	68	25	88	97
				1987		
Full-time entrants, 1983–87	102	18	20	6	28	30
Graduates[1]	106	19	21	6	29	32
Part-time or not seeking employment	4	1	—	—	1	2
Net migration	5	--	2	—	2	2
Immigration	8	3	2	1	1	1
Emigration	13	3	4	1	3	3
Attrition	36	6	4	3	11	12
1987 full-time labor force	412	95	72	28	103	113

[1] Corrected for field-switching

Note Detail may not add to totals because of rounding

Source National Science Foundation

Projected Supply

In summary, the projected 1982 and 1987 full-time doctoral labor forces (table 3) equal the 1977 full-time labor force, less estimated future losses from death and retirement, plus all projected 1977–82 and 1983–87 recipients of S/E doctorates (adjusted for field-switching), less doctoral awards earned by those on temporary visas, plus projected numbers of immigrants with S/E doctorates. In addition, a deduction, not described previously, is made for the new graduates who are projected either not to enter the labor force or to work part time.[27] (This loss is estimated to be approximately 8,000 for the 1977–87 period.)

The projected 1987 full-time doctoral labor force of 412,000 scientists and engineers would be almost 50 percent higher than the comparable 1977 total, the equivalent of a compound growth rate of about 4 percent per year. In contrast, BLS projects that the total civilian labor force will grow from between 1.9 percent and 2.3 percent annually from 1977 to 1985.[28] The new projection for total supply in 1987 is close to that made for 1985 in the previous supply and utilization report if the latter estimate is adjusted upward to reflect two additional graduating classes.[29] Projected percentage rates of growth of the doctoral labor force of scientists and engineers by major field is similar to that reported in the previous study with two exceptions.[30] The physical sciences now show a higher growth rate, primarily because of larger projected graduate school completion rates that push up estimates of future doctoral degrees. On the other hand, the social sciences are now projected to grow more slowly than estimated before because much lower current expectations of future undergraduate degrees in this field would leave a smaller pool of potential graduate enrollees.

[27] It is assumed that in 1982 and 1987 the proportions of new graduates by field who will either work part time or will be unemployed and not seeking employment will be equal to the corresponding proportions of new graduates in 1977. These proportions changed little between 1973 and 1977 except in the physical sciences where they fell from 3.1 percent to 2.4 percent. National Science Foundation. *Characteristics of Doctoral Scientists and Engineers in the United States, 1973* (NSF 75-312) (Washington, D.C. 20402. Supt. of Documents, U.S. Government Printing Office) and 1977 (NSF 79-306) (Washington, DC 20550).

[28] "New Labor Force Projections to 1990. Three Possible Paths," *Mor- ly Labor Review*, December 1978

[29] National Science Foundation. *Projections of Science and Engineering Doctorate Supply and Utilizat.n, 1980 and 1985* (NSF ˙5-301), *op. cit.*, p. 2 (probable model)

[30] The fairly close agr– ent in engineering results in large part because new higher expectations of emigration cancel out the effects of n r projections of doctoral awards

Chapter II. UTILIZATION OF DOCTORAL SCIENTISTS AND ENGINEERS

The first section of this chapter briefly describes the utilization of doctoral scientists and engineers in 1977. With that as background, the next section explains how 1982 and 1987 utilization estimates were derived by summing eight categories of S/E-related employment. The two largest of these, academia and industrial research and development, are projected with linear equations (presented in appendix A-2), based on historical data, that relate staffing to demand factors, primarily baccalaureate degrees and R&D spending.

Extrapolation of past staffing trends in the five smaller nonacademic categories furnish employment estimates for the remaining sectors, excluding postdoctorates.

Projections of the numbers of new doctorates who are hired for S/E-related positions by S/E field and category during the projection period are also discussed in this chapter. The following summarizes the components of the model used to project doctoral hires:

1987 doctoral utilization
less
1977 doctoral utilization
plus
1977-87 deaths and retirements
equals
1977-87 doctorates hired

Hiring for 1977-82 is projected using comparable components.

1977 Utilization

There were about 300,000 doctoral scientists and engineers in the United States in 1977 (table 4). Of these, about 13,000 were retired or unemployed and not seeking employment. About 3,000 S/E doctorates, less than 1 percent of the doctoral labor force, were unemployed and seeking work. These deletions left about 285,000 employed S/E doctorates, of whom about 10,000 held postdoctoral positions. Of the 275,000 with permanent jobs about 93 percent were in full-time positions. The five broad S/E fields varied somewhat in the prevalence of part-time employment, with the social sciences having the largest percentage, between 4 percent and 5 percent,[31] and engineering the smallest, about 1.5 percent employed part-time. Whereas there was little interfield variation in rates of unemployment, the proportions engaged in postdoctoral study in the physical and life sciences were much higher than in other fields.

In 1977 universities and colleges accounted for 57 percent of employed doctoral scientists and engineers, including those who worked part time or had non-S/E jobs[32] (table 5). About one in four of all employed doctoral scientists and engineers worked in industry, either in research and development or other activities. The Federal Government had the third largest employment share with between 4 percent and 9 percent of those employed in each broad field. The remaining large category of employers was nonprofit institutions which accounted for between 4 percent and 11 percent. Such employment was concentrated in the social sciences, mainly because of the over 5,000 Ph.D. psychologists who worked in hospitals and clinics.

Job opportunities and changing career interests lead some S/E doctorates to take employment outside their field of training (table 6). The fraction switching fields at some point after receiving their doctorates ranged in 1977 from one-fourth in the physical sciences to one-seventh in the life sciences. These fractions include those who moved within S/E fields as well as those taking non-S/E employment. The latter totaled about 23,000, including part-time workers. Of the five categories of S/E doctorates, physical and social scientists showed the highest proportions in non-S/E activities. Unpublished NSF data from the Survey of Science and Engineering Doctorates indicate that only a small fraction of those who leave science and engineering were unable to find S/E positions. Much of the loss from S/E doctorates not working in science and engineering in 1977 was compensated for by non-S/E doctorates taking S/E positions. This is particularly true in the social sciences where three-fourths of all individuals with non-S/E doctorates who hold S/E jobs were employed.[33]

[31] The greater rate of part-time employment [illegible] reflects in part the heavy representation of women [illegible] 18 percent).

[32] Only [illegible] engineering and the physical sciences [illegible] academia employ less than one-half of S/E doctorates with jobs. These proportions include postdoctorates and [illegible] federally funded research and development centers.

[33] A study of the 1973 labor force indicated that [illegible] percent of those with non-S/E doctorates entering the social sciences labor force had degrees in the field of education. National Research Council, Field Mobility of Doctoral Scientists and Engineers [illegible]

Table 4. Labor force and employment status of science/engineering doctorates by field of degree: 1977

Employment status	Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences
			In thousands			
Total in population	303	76	47	21	78	82
Not in labor force[1]	13	4	1	1	5	3
Total in labor force	288	71	45	21	73	78
Employed	275	68	45	20	67	75
Full time	267	66	44	20	65	72
In science or engr	245	60	42	19	61	63
Other	22	6	3	1	4	8
Part time	8	1	1	—	2	4
In science or engineering	6	1	1	—	2	3
Other	1	—	—	—	—	1
Postdoctorates	10	3	—	—	5	1
Unemployed	3	1	—	—	1	1
			Percent distribution			
Total in labor force	100	100	100	100	100	100
Employed	95	95	98	99	91	97
Full time	93	93	97	97	89	93
In science or engineering	85	84	92	92	84	82
Other	8	9	6	5	5	11
Part time	3	2	1	2	2	5
In science or engineering	2	1	1	2	2	4
Other		—	—	—	—	1
Postdoctorates	3	4	1	—	7	1
Unemployed	1	2	1	1	1	1

[1] Retired or not seeking employment

Note: Details may not add to totals because of rounding and omission of category No Report

Source: National Science Foundation

Table 5. Science/engineering doctorates by sector of employment and field of degree: 1977[1]

Sector of employment	Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences
			In thousands			
Total	285	71	45	20	72	76
Academic	163	34	16	14	47	52
Regular staff[2]	153	31	16	14	42	51
Postdoctorates	10	3	—	—	5	1
Business/industry	72	26	23	4	10	8
Nonprofit institutions	19	3	2	—	5	9
Federal Government	21	6	4	1	7	4
Other government	10	1	1	—	3	3
			Percent distribution			
Total	100	100	100	100	100	100
Academic	57	47	35	71	66	68
Regular staff	54	43	34	70	59	66
Postdoctorates	3	4	1	—	7	1
Business industry	25	37	51	21	14	11
Nonprofit institutions	7	4	4	2	7	11
Federal Government	7	9	8	4	9	5
Other government	3	2	2	1	4	4

[1] Includes part-time workers

[2] Includes staff of federally funded research and development centers and 2,000 elementary and secondary school staff

Note: Detail may not add to totals because of rounding

Source: National Science Foundation

Table 6. Field mobility of employed doctoral scientists and engineers: 1977[1]

Field of degree	Total number	Field of employment — Percent distribution: Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences	Nonscience	No report
Physical sciences	62,947	100.0	74.4	8.5	1.8	5.6	.5	6.3	2.4
Engineering	33,303	100.0	6.0	80.7	5.5	1.2	.4	4.2	1.9
Mathematical sciences	12,589	100.0	.7	4.7	83.7	3.3	1.1	4.7	1.7
Life sciences	55,295	100.0	5.7	.8	.2	86.4	.8	3.3	2.2
Social sciences	51,223	100.0	.5	.4	.8	3.6	83.3	10.2	2.2
Nonsciences	7,734	100.0	4.1	2.5	10.7	4.7	76.0	.0	1.9

[1] Includes part-time workers

Note: Percents may not add to 100 because of rounding

Sources: National Research Council and National Science Foundation. Spread of doctorates with nonscience degrees based on 1975 NRC report, *Field Mobility of Experienced Scientists and Engineers*

The Projection Model

The projections of S/E-related full-time doctoral utilization treat academic federally funded research and development centers (FFRDC's) personnel separately from the main body of academic staff as are postdoctorates. Similarly, doctorates employed in industry who are engaged in research and development are estimated apart from those who are engaged in other S/E activities. These disaggregations result in the following eight categories of S/E employment:

- Regular academic staff
- Academic FFRDC staff
- Postdoctoral staff
- Industrial R&D staff
- Other industrial staff
- Federal civilian staff
- Other governmental staff[34]
- Nonprofit institutions staff

Estimates of those doctorates who are likely to have non-S/E jobs in 1982 and 1987 were derived by taking the differences between the sums of these eight categories and the projected full-time labor forces in each broad field.

Two considerations determined the method used to project each category of doctoral employment, (1) the number of years for which employment data are available and (2) whether past employment levels could be explained by reference to a demand factor such as R&D expenditures. For the two largest employment categories—"(regular) academia" and "industrial R&D"—there were sufficient numbers of years of data[35] to allow regression analyses which found strong statistical links between employment and demand factors. (See appendix A-2, pp.30 and 31 for employment equations.) The results of those regressions provided a basis for estimating future total S/E employment (including nondoctoral). From these totals, estimates were made, using the methods described below, of the number of 1977–87 S/E doctorates who are likely to find regular academic and industrial R&D positions.

For the remaining five categories (excluding postdoctorates), data limitations or the apparent absence of meaningful demand factor-employment links dictated the use of some other projection method. The chosen procedure was to extrapolate past trends in doctoral employment by broad field in each category. The extrapolations assume that conditions which may have accounted for the recent growth in these categories of utilization, e.g., an ample supply of new doctorates, will continue in the future. Estimates of the numbers of new doctorates finding these five types of S/E employment during the projection period were derived using actual 1977 doctoral staff totals, estimated attrition rates, and the projected 1982 and 1987 levels of staffing produced by the extrapolations. (See p. 21 for a description of the projection of postdoctoral positions.)

A few assumptions are implicit in these projections of utilization. A steadily expanding economy would be necessary to support the high annual growth rates in real R&D spending which are used in the projections of R&D employment in industry. It is also assumed that doctorates currently holding permanent S/E-related positions will not switch to non-S/E employment. This assumption is important in projecting the number of new doctorates finding S/E positions between 1977 and 1987 (table 7).

Table 7. Projected new doctorates hired for full-time science or engineering positions[1]

[In thousands]

Category of employment	Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences
				1977–82		
Total	67	15	12	3	18	19
Universities and colleges	20	4	3	1	8	4
FFRDC's[2]	1	1	—	—	—	...
Industry R&D	14	6	5	1	2	1
Industry, other	9	2	2	1	2	2
Federal Government	7	1	1		2	2
Other government	3	1	1	1	1	2
Nonprofit institutions	13	1	1	-	3	8
				1983–87		
Total	61	15	9	3	16	17
Universities and colleges	18	5	1	1	7	4
FFRDC's[2]	2	1	1	—	—	--
Industry R&D	13	5	4	1	2	1
Industry, other	9	2	2	1	2	2
Federal Government	7	1	1	—	2	2
Other government	3		-	—	1	2
Nonprofit institutions	9	1		—	2	6

[1] Excludes postdoctorates

[2] Federally funded research and development centers administered by universities

Note: Detail may not add to totals because of rounding

Source: National Science Foundation

[34] This category includes a small residual (less than 600 in 1977) of S/E doctorates not elsewhere classified

[35] Eight years (from 1965 to 1976) in "academia" and 19 years (1957 to 1975) for "industrial R&D"

Overall Projections

The projections indicate continued steady growth in the total number of S/E positions held by doctorates.

Within these totals, a shift away from the traditional dominance of colleges and universities is expected.[36] Academic employment—the sum of regular positions, postdoctorates, and FFRDC staff—may account for only 40 percent of all full-time S/E doctorates in 1987 (table 8). About 23 percent of S/E doctorates would, according to the projections, work in industry in S/E-related positions—the sum of industry, research and development and industry, other—with the highest percentages so employed being in engineering, 44 percent, and the physical sciences, 36 percent. No other category of S/E employment is projected to account for more than 9 percent of S/E doctorates either in total or in any of the broad fields with the exception of social scientists in nonprofit institutions.

A comparison of the distribution by type of employment of the 1977 labor force of S/E doctorates with the distribution projected for new doctorates holding S/E jobs in 1987 provides a rough indication of employment shifts. It is estimated that about 130,000, or 70 percent of the 1977–87 new doctorates who enter the full-time labor force, will have regular S/E positions in 1987 (table 7).[37] (Of the remaining additions to the full-time labor force about 10,000 would be postdoctorates in 1987 and about 45,000, or 25 percent, would have non-S/E jobs.) Only about one-third of the S/E-employed are projected to be faculty or academic FFRDC staff as compared to 57 percent of S/E doctorates in the labor force in 1977.[38] The estimated share of the next largest employer, industrial research and development, is one-fifth as compared to about one-sixth in 1977. The most marked expansion is in nonprofit institutions which are projected to account for about one in six of new S/E-employed doctorates, in contrast to only about one in fifteen in 1977. This growth would continue 1973–77 trends in nonprofit employment.[39] The projection techniques used in this study indicate that industry may expand its non-R&D employment of doctorates to account for 14 percent of new Ph.D.'s engaged in S/E activities in 1987, about double the 1977 share.

[36] The following percentages compare only 1987 S/E employment to the 1987 full-time labor force. These figures are not comparable to those in table 5 which compare total 1977 doctoral employment, including non-S/E, to the 1977 full-time work force

[37] For purposes of computation, this assumes that no doctorate employed in an S/E position in 1977 will have a non-S/E job in 1987 and that only U.S. graduates will enter S/E positions during the projection period. The latter implies that foreign-trained immigrants will find only non-S/E employment. This method of estimation also assumes perfect substitutability of scientists and engineers across age groups and does not consider whether certain levels of experience are necessary for some positions.

[38] The two distributions are not strictly comparable. The 1977 figures are percents of all S/E doctorates in the full-time labor force, including those with non-S/E jobs. The 1987 figures refer to percents of 1977–87 graduates, excluding postdoctorates, who are projected to hold full-time S/E jobs.

[39] National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1973*, (NSF 75-312), *1975*, (NSF 77-309) (Washington, D.C. 20402: Supt. of Documents, U.S. Government Printing Office) *and 1977* (NSF 78-306) (Washington, D.C.: 20550).

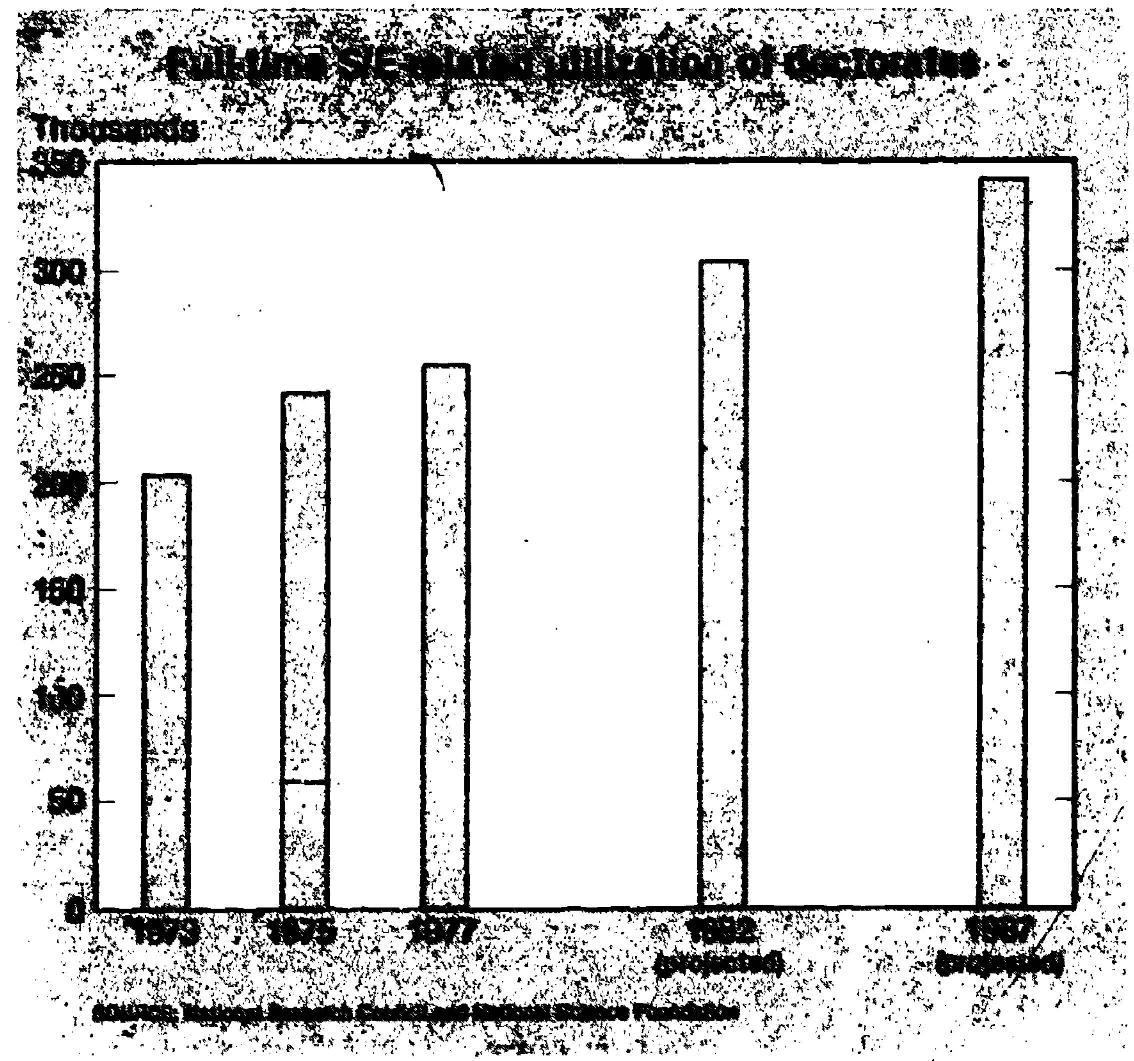


Table 8. Projected full-time utilization of science/engineering doctorates by category of employment: 1982–87

[Numbers in thousands]

Category of employment	Total		Physical sciences		Engineering		Mathematical sciences		Life sciences		Social sciences	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
						1982						
Total	352	100	83	100	58	100	25	100	88	100	97	100
Universities and colleges	148	42	30	36	14	26	13	52	40	52	46	47
Regular	138	39	27	33	14	25	13	52	40	45	45	46
Postdoctorates	10	3	3	3	—	1	—	—	6	7	1	1
FFRDC's[1]	7	2	4	5	2	3	—	1		—	—	—
Industry R&D	60	17	25	30	21	36	4	16	7	8	3	3
Industry, other	24	7	6	7	6	10	2	8	5	6	7	7
Federal Government	26	7	7	8	5	9	1	4	8	9	6	6
Other government	10	3	1	1	1	2	—	1	3	3	4	4
Nonprofit institutions	27	8	4	5	2	3	1	4	7	8	13	13
Nonscience[2]	50	14	6	7	7	12	4	16	12	14	18	19
						1987						
Total	412	100	95	100	72	100	28	100	103	100	113	100
Universities and colleges	157	38	33	35	14	19	13	46	50	49	47	42
Regular	146	35	30	32	14	18	13	46	44	43	46	41
Postdoctorates	11	3	3	3	1	—	—		6	6	1	1
FFRDC's[1]	8	2	5	5	2	3	—	1	1	1	—	—
Industry R&D	68	16	28	29	24	33	5	18	9	9	3	3
Industry, other	31	7	7	7	8	11	2	7	6	6	9	8
Federal Government	31	7	7	7	6	8	1	4	9	9	8	7
Other government	12	3	1	1	2	3	—	1	3	3	6	5
Nonprofit institutions	34	8	5	5	2	3	1	4	9	9	18	16
Nonscience[2]	70	17	9	9	14	19	6	21	16	16	22	19

[1] Federally funded research and development centers administered by universities.
[2] Includes involuntary unemployment.
Note: Detail may not add to totals because of rounding.
Source: National Science Foundation.

Academic Staff

The initial step in projecting this category of utilization was to couple historical relationships, by major field, between full-time academic staff (excluding those in FFRDC's)[40] and numbers of baccalaureates awarded[41] (an index of teaching loads) with NSF projections of degrees to obtain projected full-time staff by broad field in 1982 and 1987. This step assumes that past associations between degrees and staff will not change over the projection period. (As explained below, this procedure was not followed for the social sciences. See appendix A-2 for a discussion of how use of various independent variables—such as baccalaureates in a single broad field or total S/E baccalaureates—in the projection equations affected the projected staff levels.) These estimates were then adjusted to exclude postdoctoral staff.

The next step was to estimate how many 1977 faculty members would be active in 1982 and 1987 in order to be able to determine how many new faculty would be required to attain projected levels of full-time staff by field. In estimating faculty attrition, it was assumed that all 1977 staff would retire at age 66. Mortality was estimated from unpublished data on death rates provided by TIAA and on age distribution by broad field from ACE. Subtraction of the 1977 faculty by field, reduced by projected deaths and retirements, from estimated 1982 and 1987 staff levels produced estimates of faculty hires during the projection period. It was assumed that all new faculty in doctorate-granting institutions would have Ph.D.'s.[42] For 2- and 4-year schools, ACE conducted a special survey for this study to obtain estimates by field of the proportions of 1976–77 appointees who had or would soon receive doctorates.[43] These proportions were increased by 10 percent to reflect the limited upgrading of staff credentials anticipated by the respondents to the ACE survey and multiplied by estimated total hires by broad field and type of institution to project 1977–82 and 1983–87 appointments of doctorates to 2- and 4-year college faculties.

[40] These historical relationships were derived using time series data which aggregate postdoctorates with regular academic staff

[41] The historical associations were derived from regression analysis In only one field was it also possible to enter the number of doctorates awarded into the regressions, primarily because of the collinearity between numbers of bachelor's and Ph D degrees

The insufficiency of data on nationwide undergraduate S/E course enrollment by field precluded using enrollments as an independent variable in the regressions This lack of information also ruled out the use of student-faculty ratios, a common method of estimating faculty requirements

Because of the limited number of observations (8) on academic staff, it was also not possible to include academic R&D spending as an independent variable

[42] A 1974 NSF study found that nondoctorates held only 4 percent of all full time faculty positions in 15 selected S E fields See National Science Foundation, *Young and Senior Science and Engineering Faculty, 1974 Support, Research Participation and Tenure* (NSF 75-302) (Washington, D C 20402 Supt of Documents, U S Government Printing Office)

[43] Frank J Atelsek and Irene L Gomberg *New Full-Time Faculty 1976 77 Hiring Patterns by Field and Educational Attainment* (Washington D C American Council on Education, March 1978)

The projected total 1987 doctoral S/E full-time faculty of 146,000 is 11 percent higher than the figure for 1977 (table 9). This increase would have been smaller if social sciences faculty were expected to drop along with social sciences baccalaureates. Recent NSF surveys,[44] however, found that staff in this field grew from 1975 to 1977 in spite of a sharp decline in bachelor's degrees in social sciences. Consequently, it was assumed that total social sciences staff will remain constant during the projection period. Because of anticipated upgrading, however, doctoral staff is projected to grow by 5 percent in this field by 1987. The number employed full-time as mathematical sciences faculty was negatively related to the number of baccalaureates awarded in this field but was positively related to total S/E bachelor's degrees, probably reflecting the role of such faculty in teaching students majoring in engineering and other fields of science. Because of this finding, mathematical sciences staff, both total and doctoral, is projected to remain roughly unchanged in spite of anticipated declines in bachelor's degrees in the mathematical sciences. Doctoral faculty in engineering is projected to grow slightly, whereas projections for the physical and life sciences indicate about 20 percent expansion of doctoral faculty by 1987.

[44] National Science Foundation *Detailed Statistical Tables Manpower Resources for Scientific Activities at Universities and Colleges, January 1977* (NSF 77-321) (Washington D C 20550)

Table 9. Number and percent change in full-time doctoral scientists/engineers employed in universities and 2- and 4-year colleges[1] by field

Field	1977	1982	Percent change 1977–82	1987	Percent change 1982–87
Total	131,000	138,000	5	146,000	6
Physical scientists	24,500	27,000	11	30,000	11
Engineers	12,700	14,000	10	14,000	0
Mathematical scientists	12,600	13,000	3	13,000	0
Life scientists	37,400	4[illegible],000	7	44,000	10
Social scientists	43,800	45,000	3	46,000	2

[1] Excludes postdoctorates and staff of federally funded research and development centers
Note Detail may not add to totals because of rounding
Source National Science Foundation.

Industrial R&D Staff

In 1977 industrial R&D positions accounted for 16 percent of full-time employment of S/E doctorates. This share is projected to be the same in 1987.

Lack of reliable data on the proportion of new industrial R&D employees who have doctorates dictated a change from the order of steps followed in projecting doctoral utilization in academia. For research and development in industry, estimates of doctoral hires were derived from projections of total employment of S/E doctorates in 1982 and 1987.

As the first step, the historical relationships between full-time-equivalent (FTE) R&D scientists and engineers and constant-dollar R&D expenditures in major industries, e.g., chemical and allied products,[45] were statistically estimated using regression analysis (appendix A-2).

Estimates of full-time employment by major industry in 1982 and 1987 were produced by combining the regression results with the Foundation's estimates of future industrial R&D expenditures by major industry.[46] These estimates were summed to yield projected total employment (over all industries and fields) in 1982 and 1987. The proportion of these totals who would have doctorates was estimated from the comparable 1977 fraction (.129). This proportion was adjusted by multiplying it by 1.1 to reflect the limited amount of future staff upgrading anticipated by R&D directors responding to a recent NSF poll.[47] Multiplying the adjusted fraction (.142) by the estimated 1982 and 1987 totals derived above produced projections of 1982 and 1987 doctoral scientists and engineers for all fields combined. These projections were then disaggregated according to the 1977 distribution of S/E doctorates by broad field in this category of utilization. (This assumes that doctoral employment in all fields will rise by the same percentage (30) in the 10 years 1977–87). This procedure produced projections of 1982 and 1987 employment of S/E doctorates by broad field in industrial research and development. In the next step, use of BLS occupation-specific attrition rates allowed estimation of future losses from the 1977 S/E doctoral work force. Those who were projected to be still employed in 1982 and 1987 were subtracted from doctoral staffs by field in those two years to yield estimates of the numbers of S/E doctorates hired in 1977–82 and 1983–87.

[45] Industries were specified at the 2-digit SIC code level

[46] National Science Foundation *1985 R&D Funding Projections* (NSF 76 314) (Washington D C 20402 Supt of Documents U S Government Printing Office) Because relatively few have part-time jobs in industrial research and development the projections drop the distinction between FTE and full time employment

[47] National Science Foundation *Science Resources Studies Highlights*. Utilization of Science and Engineering Doctorates in Industrial Research and Development (NSF 78 301) (Washington D C 20550 April 11 1978)

Other Categories

The remaining five categories (excluding postdoctorates) of S/E employment—the civilian component of the Federal Government, nonprofit institutions, that part of industry not included in industrial research and development, "other government,"[48] and FFRDC's administered by universities—accounted for about 20 percent of the utilization of S/E doctorates in 1977. This share is projected to rise to almost 30 percent of the 1987 full-time labor force of S/E doctorates.

A brief summary of current trends demonstrates why these categories are projected to increase their share of doctoral employment.[49] The Federal Government, the largest of the 1977 employers considered here, accounted for about 7 percent of the 1977 labor force of S/E doctorates. Federal civilian doctoral employment increased from 17,600 to 21,400 between 1973 and 1977 while Federal staffing of total scientists and engineers remained stable, resulting in an increase in the proportion of the civilian Federal S/E workforce with doctorates from 11 percent to about 13 percent.

Industry expanded utilization of S/E doctorates in activities other than research and development by almost 70 percent between 1973 and 1977—from 12,500 to 21,000. Unlike the Federal Government, FFRDC's, and nonprofit institutions, industry employed many of its S/E doctorates in non-S/E activities—an estimated 5,000 in 1977, or one-fourth of those not in research and development.

In 1977 nonprofit institutions, including hospitals and clinics, had almost 19,000 S/E doctorates on their staffs, about one-half more than four years earlier. This increased this category's share of the S/E work force from 5 percent to 7 percent. The most dramatic growth in this sector was among psychologists who went from 4,900 in 1973 to 8,700 in 1977, primarily as a result of hiring by hospitals and clinics.

During 1973–77 employment of S/E doctorates in "other government" employment—State, local, military, and Federal Commissioned Corps—rose by almost 30 percent to comprise about 3 percent of total 1977 utilization of S/E doctorates, about the same share as in 1973. This category accounted for about one-fourth of all 1977 public employment of S/E doctorates. Approximately 10 percent of S/E doctorates in "other government" were engaged in non-S/E-related activities in 1977.

[48] State, local, military and Federal Commissioned Corps (e g , officers in Public Health Service)

[49] Time series data on employment of doctorates are very limited in all five sectors with the exception of academic FFRDC s The chief sources of information are the 1973 1975 and 1977 Surveys of Doctorate Recipients as reported in National Academy of Sciences *Doctoral Scientists and Engineers in the United States* (Washington D C 20418) FFRDC data are from the National Science Foundation s series of surveys of scientific and engineering personnel at universities and colleges for selected years 1969 through 1977

Academic FFRDC's employed 3,600 S/E doctorates in 1969, the first year that NSF surveyed these centers, and 5,400 in 1977. During these eight years, total S/E employment in FFRDC's rose by about one-fourth to 13,700.

Two considerations suggest that factors of demand may not be as closely linked to utilization in these categories as was found in industrial research and development and academia. First, it is not feasible to relate future S/E utilization to projections of R&D spending in these categories as was done for industrial research and development. No direct link was found between R&D spending and total S/E staffing (including nondoctorates) in the Federal Government and academic FFRDC's in spite of the concentration of staff in both cases in R&D activities. Regressions did indicate a strong relation between S/E manpower and R&D expenditures in nonprofit institutions, but only about one-half the S/E doctorates in nonprofit institutions are engaged in research and development. A slightly smaller fraction of S/E doctorates in "other government" are so employed. With the proportions involved in research and development so low, it was decided not to project doctoral staffing in nonprofit institutions and "other government" on the basis of R&D spending. The second consideration is that no quantifiable demand factor was found which would explain hiring by industry of S/E doctorates for non-R&D positions.

The seemingly limited importance of demand factors suggests that the rapid growth of employment of S/E doctorates in these categories between 1973 and 1977 may have been largely a result of the large supply of doctorates available during this period. This allowed employers to substitute doctoral for nondoctoral staff at little increase in cost. This hypothesis seems most reasonable for those types of positions for which doctorates are generally not considered essential. To the extent that this hypothesis is valid, past growth in doctoral staffs may continue through 1987 because similar opportunities for employers to upgrade staff should continue throughout the projection period. On the basis of this reasoning, extrapolation of 1973–77 rates of growth in utilization[50] of doctorates by field and category are used to project 1982 and 1987 doctoral employment for four categories, whereas for the fifth, academic FFRDC's, 1969–77 growth rates are used.[51] Because of the short periods which provide bases for extrapolation of utilization and the difficulties in explaining demand for doctorates, less confidence is attached to projections of utilization in these five categories than is given to projection of industrial R&D and academic employment.

[50] As stated above, industry and "other government" employ many S/E doctorates in positions not related to science and engineering. The 1973 and 1977 bases used in extrapolations for these two categories were reduced to account for those engaged in non-S/E activities so that the two bases would represent only S/E employment.

[51] The longer time period was used for extrapolating FFRDC doctoral staff but not for the other categories because, first, 1969 data were not available for the other four categories and, second, the longer trend produced a lower projected 1987 staff in FFRDC'S (8,000 vs. about 9,000 using the 1973–77 trend). The smaller figure appeared more likely in view of projected moderate growth in FFRDC expenditures and the already high proportion of FFRDC staff with doctorates (40 percent in 1977).

Chapter III. PROJECTED BALANCE BETWEEN DOCTORAL SUPPLY AND SCIENCE/ENGINEERING-RELATED UTILIZATION

The 1982 and 1987 balances between full-time supply and utilization in the market for doctoral scientists and engineers are projected by comparing the estimates of the Ph.D. workforce in those two years with estimates of the future numbers of S/E jobs held by doctorates (table 8). Non-S/E utilization, which is not projected directly, is derived as the difference between the estimates of doctoral supply and S/E utilization. Non-S/E utilization thus consists of those in non-S/E positions and those who may be unemployed. Table 10 summarizes this report's supply and utilization projections for 1982 and 1987 and compares the estimated future percentages of doctorates with non-S/E employment with 1977 figures.[52] The projections indicate almost a doubling in the proportion of the work force in non-S/E positions from 9 percent in 1977 to 17 percent in 1987. All broad fields, with the exception of the physical sciences, are projected to share in the rapid expansion of non-S/E utilization. The projections do not describe where doctorates with non-S/E jobs may work or the types of activities in which they may be engaged.

Explicit incorporation of market feedback in the doctoral-degree projection model did not prevent this projected growth in non-S/E utilization. Factors such as downward inflexibility of salaries and the nonresponsiveness of employers to changes in relative salaries partly explain why the market does not balance supply with requirements. An example in higher education of the second factor may be found in the practice of many community colleges of hiring staff on the basis of an applicant's practical experience rather than advanced academic credentials.[53] Because of this practice decreased differentials between the salary expectations of master's and doctoral applicants might not strongly affect the number of Ph.D.'s hired by some 2-year schools.

[52] The estimated actual and projected future percentages reflect a difference in the treatment of academic staff. The National Academy of Sciences classified about 10,000 academic scientists and engineers as being engaged in non-S/E activities in 1977, whereas for the projections it is assumed that all academic staff are in S/E positions. National Research Council. *Science, Engineering, and Humanities Doctorates in the United States. 1977 Profile*, op. cit.

[53] *This conclusion is based on an NSF-sponsored survey reported in Atelsek and Gomberg, op. cit.*

Table 10. Utilization of full-time science/engineering doctoral labor force by field: 1977, 1982, and 1987

[In thousands]

Type of utilization	Total	Physical sciences	Engineering	Mathematical sciences	Life sciences	Social sciences
			1977 Estimate			
Labor force	280	70	45	20	71	73
S/E utilization	255	63	42	19	67	64
Non-S/E utilization[1]	25	7	3	1	4	9
Non-S/E utilization as percent of labor force	*9*	*10*	*6*	*6*	*6*	*13*
			1982 Projection			
Labor force	352	83	58	25	88	97
S/E utilization	302	77	51	21	76	79
Non-S/E utilization[1]	50	6	7	4	12	25
Non-S/E utilization as percent of labor force	*14*	*7*	*12*	*16*	*14*	*19*
			1987 Projection			
Labor force	412	95	72	28	103	113
S/E utilization	342	86	58	22	87	91
Non-S/E utilization[1]	70	9	14	6	16	22
Non-S/E utilization as percent of labor force	*17*	*9*	*19*	*21*	*16*	*19*

[1] Includes unemployed.
Note: Detail may not add to totals because of rounding.
Source: National Science Foundation

In addition, student responses to market conditions may not be adequate to equate supply and requirements because students receive only incomplete information on market conditions. Another consideration contributing to market imbalance is that noneconomic factors predominate in the career choices of many individuals. Many students begin and complete graduate training in spite of poor salary prospects or even the possibility that they will not be able to find jobs in their fields. Students in different fields seem to vary in their responsiveness to market conditions. For example, the results of regression equations indicate that women in the social sciences are not very responsive to market conditions in deciding whether to complete graduate school (appendix A-2, p.28).

Demand can also change unexpectedly so that temporary shortages or surpluses occur until supply can adjust. Such an imbalance might result, for example, from suddenly expanded requirements for young researchers because of a new Federal R&D initiative. Any of the causes above may produce short-run market imbalance. Whether the doctoral market attains balance in the long run and how that balance is reached depends on market forces beyond the scope of this study.[54]

[54] For further discussion see entries in bibliography under Richard Freeman.

Chapter IV. SUMMARY OF PROJECTION METHODS AND ASSUMPTIONS

Methods

The methods employed to project the number of S/E doctorates supplied to and utilized in the S/E labor market consist of a substantial number of steps. To assist the reader through these complexities, the specific steps used in generating the projections are summarized below. An overview of projection assumptions and sensitivity of findings to variations in these assumptions can be found in the second part of this chapter.

Projecting the S/E Doctoral Supply

The supply projections are generated by first establishing a base estimate for the year 1977. This base-year supply is projected to the target year (1982 or 1987) by adding the number of S/E doctorates projected to flow into this market (new doctorates, immigrants) and by subtracting the number of S/E doctorates projected to flow out of this market (retirements, deaths, emigrants). The specific steps used to estimate the target-year supply are outlined below:

1. Base-year data for 1977 S/E doctorates are tabulated from data collected in the 1977 Survey of Doctoral Scientists and Engineers.
2. New entrants for a broad field are estimated using the following factors: (a) the number of S/E baccalaureates; (b) the proportion of those baccalaureates who enter graduate school; and (c) the proportion of those who enter who ultimately complete the requirements for the doctorate.
   - (A) The number of baccalaureates are extrapolated on the basis of trends observed for the period beginning as early as 1960 or as late as 1974, depending on field and sex, and ending with 1976 (p. 2).[55]
   - (B) Projections of (b) and (c) are assumed to depend on an index of market conditions—SEEK, the fraction of those about to receive their doctorates who are seeking employment and have not yet found jobs at the time they respond to the annual Surveys of Earned Doctorates. Projections of SEEK for a broad field are generated from an equation in which SEEK is linked to selected supply and demand factors.[56] Future values of SEEK are generated year by year by first projecting the number of new doctorates in a year and then determining the value of SEEK for that year (p. 28).
   - (C) Projections of the proportion of baccalaureates who enter graduate school are generated from an equation in which this variable is linked to SEEK and other variables that have been found to be associated with entrance rates (p. 27).[57]
   - (D) Projections of the proportion of those entering in year t who ultimately complete the requirements for the doctorate are generated from an equation in which completion rates are related to values of SEEK in year t + 2 (p. 28).[58]
3. Net international mobility is estimated as follows: (a) The projected number of new doctorates awarded, generated by the steps described in 2 above, are adjusted downward to account for doctorates received by foreign students who are assumed to return to their native countries. Estimates of the number of new doctorates who will emigrate by field are based on statistics describing S/E doctorates earned by those with temporary visas in the years 1974–77. The projected total number for all fields, 2,600 annually, is the average of the 1974–77 numbers. (b) The projected number of new immigrants with S/E doctorates is added to the base-year

[55] For the four broad science fields, the number of baccalaureates were extrapolated at one-half the annual rates of change reflected by observed trends to generate projections that would be consistent with historical experience. projections of engineering baccalaureates, derived from an econometric model incorporating responses to market conditions, were obtained from an unpublished report furnished NSF by the Center for Policy Alternatives, Massachusetts Institute of Technology

[56] The supply variable used in this equation is the number of new doctorates awarded. The demand variable used varied by field, junior faculty openings are used for mathematical, life, and social sciences, whereas industrial R&D expenditures are used for physical sciences and engineering. The relationship between SEEK and these variables is estimated from historical data by means of linear regression analysis.

[57] The relationship between the proportion who enter graduate school and independent variables, including SEEK and other variables, is estimated from historical data by means of linear regression analysis. The other variables included in the relationship varied by field and sex. The complete set of other variables used in this analysis is time (a trend variable), the number of baccalaureates, and the number conscripted for military service.

[58] The relationship is estimated from historical data by means of linear regression analysis.

estimate of S/E doctoral supply. The annual number of immigrants with S/E doctorates is projected at estimated 1974–76 average annual levels. No adjustments were made to the base-year stock to account for annual emigration of American S/E doctorates (p. 3).

4. Net flows into and out of S/E fields are projected by assuming (a) all field-switching occurs immediately after receipt of the doctorate and (b) post-1977 switching will remain stable at 1973 levels (p. 4).[59]

5. Adjustments for projected attrition caused by death and retirement are made by subtracting the amount of attrition expected from these causes from the base-year S/E doctoral supply. Projected attrition is estimated separately for S/E doctorates in the academic and the nonacademic sectors of the economy (p. 4).

Projecting the Number of S/E Doctorates Utilized

Two sets of utilization projections are generated by this study for each major field: (a) the projected number of S/E doctorates employed in S/E fields and (b) the projected number of new openings for S/E doctorates in S/E fields. Projected employment in academia and industrial R&D is based on historical relationships between employment and key demand factors—student enrollments proxied by S/E baccalaureates and industrial R&D expenditures.[60] Projected employment in other areas is generated by linear extrapolation of past trends. The estimated numbers of new doctoral openings were generated from projected growth in employment and projected attrition of S/E doctorates currently employed in S/E fields. Specific methods used to produce these projections are outlined below.

Separate employment projections were generated for individual areas of the economy using three distinct methods—one for academia, one for industrial R&D, and one for all remaining areas.

1. Academia: The projections of S/E doctorates employed in academia were made in three steps.
   (A) The employment of full-time academic staff is linked to the number of S/E baccalaureates and trend variables (p. 29).
   (B) Total new openings are defined as the sum of (1) projected attrition and (2) projected growth in employment. Attrition projections were discussed earlier in this chapter. Growth in employment is estimated from the projection equations describing the linkage between academic employment and baccalaureates for a broad field.
   (C) Future doctoral hires are estimated by field by multiplying total academic openings by projected proportions of these openings expected to be filled by S/E doctorates (p. 12).[61]
   (D) These projected hires are added to numbers of 1977 doctoral staff who are expected to be employed in academia in 1982 and 1987.
   (E) The projected utilization of S/E doctorates in academia derived from steps (A) and (B) above are augmented by projections of the number of postdoctoral positions. These are derived by assuming that, except for life sciences, the number of U.S. citizens and permanent residents holding such positions will remain at 1977 levels. For life sciences, it is assumed that the number of such positions will increase by a constant amount each year (p. 21).[62]
2. Industrial R&D: The projections of the number of S/E doctorates employed in industrial R&D activity were made with the following steps.
   (A) Full-time R&D employment is linked to industrial R&D expenditures in seven separate industries—representing about 85 percent of all R&D employment.[63] Future R&D employment in each industry is estimated on the basis of projected R&D expenditures. R&D employment is summed over the seven industries and multiplied by 1.16 to account for the excluded industries. Doctoral employment by field is then generated on the basis of the assumptions that (1) the proportion of all R&D employees with S/E doctorates will increase by 10 percent from the 1977 level and (2) the percentage distribution of S/E doctorates by field will be the same as in 1977 (pp. 13 and 31).
3. All remaining sectors: The projections of the number of S/E doctorates employed in S/E jobs in the remaining sectors of the economy were extrapolated from historical trends (pp. 13 and 14).[64]

[59] The interfield mobility patterns were estimated from a comparison of field of degree and field of employment for all S/E doctorates in 1973. Adjustments for interfield mobility are made only to the supply of new S/E doctorates.

[60] These relationships are estimated from historical data by means of linear regression analysis.

[61] The proportions of new openings filled by S/E doctorates is projected by assuming doctorate-granting institutions would hire only S/E doctorates and that all other institutions would hire proportions that would be 10 percent above the proportions of 1976–77 new openings in these institutions that were filled by S/E doctorates.

[62] These assumptions are based on recent trends and the assumption that funding constraints will inhibit growth in postdoctoral positions.

[63] These industries include the following: Chemical and allied, professional and scientific instruments, aircraft and missiles, machinery, electrical equipment and communication, motor vehicles, and nonmanufacturing. The relationship between employment and R&D expenditures is estimated from historical data by means of linear regression techniques.

[64] Except for employment in FFRDC's, 1973-77 trends were used in the projection model. For FFRDC's, 1969–77 trends were used.

Rationale for and Sensitivity of Assumptions

Factor	Assumptions	Sensitivity	Rationale
SUPPLY			
Projections of doctoral awards			
Projected numbers of bachelor's degrees and their relation to numbers of doctoral degrees awarded	For broad S/E fields other than engineering, the number of bachelor's degrees will continue through 1987 the trend established as of 1976. The rate of change, however, will be one-half the established rate. (Engineering baccalaureates are projected with an econometric approach that links degree awards to market conditions.)	Analysis of available data and literature indicates that market conditions exert limited influence on the choice of undergraduate majors by most science students. Extrapolation of existing trends, attenuated by one-half, produces projected science baccalaureates that, with the addition of projected engineering baccalaureates, represent 29% of NCES projection of total baccalaureates and first-professional degrees in 1987. This proportion ranged narrowly from 28% to 32% in the years 19'4 to 1976.	Sensitivity varies by field in relation to strength of market effect. In mathematical sciences, for example, a 10% variation in annual number of baccalaureates for 1977–87 changes projected doctoral degrees by about 5% in 1987. The number of mathematical scientists in the full-time labor force would change by about 2%. The comparable changes in engineering would be 3% and 1%, respectively.
Doctoral awards in physical sciences and engineering	Graduate school enrollment and completion rates in these two broad fields can be related to the amount spent in industry on R&D. Growth in such expenditures varies by major industry group. The average projected annual rate of R&D growth is 3.2%	Regression analysis indicates that enrollment and completion rates in these two broad fields are responsive to market conditions which can be explained by the level of industrial R&D spending and the numbers of doctoral degrees.[1] See appendix A-2 for regression equations used in projections.	A drop in the average projected growth in R&D expenditures from 3.2% to 1.5% a year decreases 1977–87 doctoral awards by about 10% in each field. The projected 1987 full-time doctoral labor force would drop as a result by about 3% in the physical sciences and in engineering by about 5%.
Doctoral awards in life and social sciences and mathematical sciences	Graduate school enrollment and completion rates in these three broad fields can be related to the numbers of junior faculty openings	Regression analysis indicates that enrollment and completion rates in these three broad fields are responsive to market conditions. The latter can be explained by the numbers of junior faculty openings and doctoral degrees in each of these broad fields. Estimates of past openings are for all fields combined whereas estimates of future openings were made for each broad field.[2] See appendix A-2 for regression equations used in projections	In mathematical and life sciences, a 10% variation in projected junior faculty openings would result in about 2% changes in projected doctoral awards and about 1% changes in full-time doctoral labor forces in 1987. Comparable changes in social sciences would be less than 1%

[1] [illegible] R&D expenditures and faculty openings [illegible] equations explaining [illegible] between [illegible] independent [illegible]

[2] A [illegible] and NSF projections produced for this report. The [illegible]

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Factor	Assumptions	Rationale	Sensitivity
International mobility			
Emigration	Annual numbers of doctoral emigrants by sex and field in period 1977–87 will be equal to average numbers of doctorates earned by foreign students on temporary visas in 1974–77.	Students on temporary visas must leave the United States on completion of studies or receive a permanent visa, in which case they are included in immigration totals. Presumably few American citizens with doctorates leave this country permanently. Information in the 1977 Survey of Doctorate Recipients indicates that only about 4% of U.S. citizens planned to locate abroad after receiving doctorates. This included those planning study abroad as well as those employed by the Federal Government.	10% variation in the numbers of emigrants changes the projected 1987 full-time labor force by about 0.7%.
Immigration	Annual number of immigrants in each broad field in 1977–87 will equal the estimated average annual numbers of S/E doctorates who immigrated in 1974–76.	Projected oversupply of doctoral scientists and engineers in this country will deter enough potential immigrants to prevent future totals from climbing above 1974–76 averages.	10% change in doctoral immigrants changes doctoral labor force by 0.5% over projection period.
Field mobility			
Field-switching of doctorates	All field-switching occurs immediately after receipt of the doctorate. Future mobility of new doctorates will be the same as the 1973 distribution of all active doctorates by field of degree and field of employment	Recent data indicate that 1973 patterns of mobility have persisted.	Not applicable
Attrition			
Attrition of regular academic staff	Mortality of academic staff in 1978–87 will equal 1978 mortality rates for the male population insured by Teachers Insurance and Annuity Association (TIAA). All staff will retire upon reaching 66 years of age. (Voluntary separation from labor force prior to age 66 will be insignificant.)	Mortality data show that university and college staff live longer than the general population. TIAA information on annuities indicate that 66 is close to the median age of retirement	Use of BLS death rates lowers the 1987 total full-time doctoral labor force by about 1.4% below the level projected with TIAA rates. Assuming academic staff retire at 71 increases the projected 1987 total full-time doctoral labor force by about 1.5%.
Attrition of doctorates not employed in academia	Death and retirement rates in 1978–87 for doctorates not employed in academia will equal unpublished BLS occupation-specific death and retirement rates for 1980	No other attrition rates are available in these sectors	A 10% variation in BLS rates changes projected 1987 total full-time labor force by about 2%.

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Factor	Assumptions	Rationale	Sensitivity
UTILIZATION			
Academia			
Projected numbers of bachelor's degrees and their relation to the number of full-time regular staff.	The number of academic staff employed in a broad field is related to the number of bachelor's degrees awarded either in that field or in a group of S/E fields. (See appendix A-2 for equations relating staff to bachelor's degrees and other variables.) Future baccalaureates can be projected as outlined in first assumption for supply model	Teaching is the primary function of three-fourths of the permanent staff. Bachelor's awards are the best among existing measures of the demand for teachers in a field. Unavailable measures such as enrollments by field should be highly correlated with baccalaureate awards.	10% variation in baccalaureate variables changes 1987 staff requirements (including non-Ph.D.'s) by the following percents: Life sciences, 9; mathematical sciences, 10; engineering, 2; and physical sciences, 3. Social sciences faculty would be unaffected because a 10% change in social sciences baccalaureates would not affect the assumption that staff in this broad field will not drop below 1977 total in spite of falling degree totals. The changes above would total about 2% of total 1987 doctoral S/E utilization.
Proportion of new faculty hires in 2- and 4-year colleges who have doctorates	For each broad S/E field at the 2- and 4-year college levels, the proportion of new faculty with doctorates will increase 10% above the levels found for the period 1976–77 in an ACE survey.[3]	This amount of faculty upgrading would be consistent with the expectations of those responding to the ACE survey.	A 10% change in the proportion of new faculty with doctorates at 2- and 4-year colleges changes the number of S/E doctoral hires by all academic institutions, including universities, by 4% during the projection period. This would alter total S/E doctoral utilization in 1987 for all sectors combined by less than 0.5%.
Numbers of U.S. citizens and permanent residents holding postdoctoral fellowships	For broad S/E fields other than life sciences, the numbers of U.S. citizens and permanent residents holding postdoctoral fellowships will remain at 1977 levels through 1987. The number of postdoctoral fellows in life sciences will increase from 5,200 in 1977 to 5,600 in 1982 and 6,000 in 1987. (There were less than 3,000 such positions filled in 1972.)	Only in the physical and life sciences do large numbers of S/E doctorates hold postdoctoral fellowships. The number of such positions in the physical sciences was stable between 1972 and 1977. Postdoctorals in the life sciences grew significantly over this period, but funding constraints may reduce such growth in the future.	A 10% variation in the number of postdoctoral fellows changes the size of the S/E doctorate labor force by 0.25%.

[3] Frank Atelsek and Irene L. Gomberg, op. cit.

Factor	Assumptions	Rationale	Sensitivity
Industrial R&D			
Projected amount of R&D expenditures in industry and its relation to the number of scientists and engineers employed.	The number of industrial R&D staff employed in a broad field is related to the amount of R&D spending in each industry group. Future R&D spending will grow an average 3.2% annually in industry.	Expenditures and staffing are closely linked in this activity. Future growth rates are from *1985 R&D Funding Projections*, (NSF 76-314).	A drop in average projected growth in R&D expenditures to 1.5% a year decreases 1977–87 doctoral hires in industrial R&D by 40%. This would cause a 3% drop in total S/E doctoral utilization in 1987 for all sectors combined.
Other categories			
Level of S/E utilization of doctorates in 1982 and 1987 in the Federal Government, industry (other than R&D), nonprofit institutions, "other government," and FFRDC's.	Observed trends in doctora' employment from 1973 to 1977 (1969 to 1977 for FFRDC's) by broad field and category of employment will continue through 1987.	Observed trends reflect the effects of a period of ample supply of new doctorates. This allowed employers in these categories of employment to upgrade academic credentials of staff. Employers will continue to have these opportunities for upgrading throughout the projection period.	A 10% variation in existing employment trends in these categories of employment would change 1987 S/E utilization of doctorates by about 1.5%.

APPENDIXES

A. Technical Notes

1. Comparison of Current and Previous NSF Projections
2. Market Analysis
3. Comparison of NSF and BLS Projections
4. Components of Fields of Science

B. Bibliography

APPENDIX A
Technical Notes

1. Comparison of Current and Previous NSF Projections

The estimates presented in this report reinforce the chief results of the Foundation's earlier study, *Projections of Science and Engineering Doctorate Supply and Utilization: 1980 and 1985* (NSF 75-301). Both reports conclude that the labor force of doctoral scientists and engineers in the United States will expand rapidly through the eighties and that increasing percentages of these highly trained personnel will be employed in non-S/E-related positions. The new projections, however, put the estimated 1987 level of non-S/E utilization below that estimated for 1985 in *Supply and Utilization* (table A-1). Also, the new projections of future doctoral awards differ significantly for the physical sciences and engineering from those in *Projections of Degrees and Enrollment in Science and Engineering Fields to 1985* (NSF 76-301) (table A-2).

Table A-1. Projections of labor forces and S/E-related utilization by field

[In thousands]

Field	Projections in previous report[1]: 1985 doctoral labor force	1985 S/E-related utilization of doctorates	1985 non-S/E related utilization as a percent of labor force	New projections: 1987 doctoral labor force	1987 S/E-related utilization of doctorates	1987 non-S/E related utilization as a percent of labor force
Total	375	293	22	412	342	17
Physical sciences	85	76	11	95	86	9
Engineering	64	45	29	72	58	19
Mathematical sciences	22	16	27	28	22	21
Life sciences	92	85	8	103	87	16
Social sciences	113	71	37	113	91	19

[1] *Projections of Science and Engineering Doctorate Supply and Utilization 1980 and 1985* (NSF 75-301) probable model

Source National Science Foundation

Three factors—improvements in projection modeling, recent educational and economic developments, and better information on doctoral utilization—account for changes between the outlook of the previous reports and the current projections. On the supply side an important modeling advance has been to link graduate school enrollment and completion rates to market conditions in each of the five S/E fields. For estimating future utilization, equations based on regression analysis now link S/E employment in academia and industrial R&D to demand variables.

Recent developments affecting the projections include higher expectations of industrial R&D spending and greater participation of women in engineering and the life and physical sciences. In the projection model, higher industrial R&D spending results in more S/E jobs in the business sector and larger doctoral classes of engineers and physical scientists.

Table A-2. Comparison of new and previous doctoral S/E projections by field

Field of degree	1985 previous report[1]	1985 new	1977 actual	Historical highs
Physical sciences				
Men	1,500	3,200	3,100	4,145 (1971)
Women	200	600	310	310 (1977)
Total	1,700	3,800	3,410	4,391 (1971)
Engineering				
Men	2,500	3,800	2,567	3,679 (1972)
Women	200	500	74	74 (1977)
Total	2,700	4,300	2,641	3,704 (1972)
Mathematical sciences				
Men	600	800	831	1,245 (1970)
Women	100	100	128	128 (1977)
Total	700	900	959	1,343 (1970)
Life sciences				
Men	3,600	4,200	3,421	3,910 (1971)
Women	1,000	1,400	845	845 (1977)
Total	4,600	5,600	4,266	4,534 (1971)
Social sciences				
Men	4,800	4,100	4,524	4,524 (1977)
Women	2,300	2,500	1,573	1,573 (1977)
Total	7,100	6,600	6,097	6,097 (1977)

[1] Probable model *Projections of Degrees and Enrollments in Science and Engineering Fields to 1985* (NSF 76-301)

Source National Science Foundation and National Research Council

Improved information on utilization has also affected the projections. Since the last NSF report on supply and utilization, a special survey has been conducted on the proportion of new hires for 2- and 4-year college faculty who have doctorates.[1] Other recent surveys provide a basis for extrapolating utilization of S/E doctorates in government, nonprofit institutions, FFRDC's, and industry (other than research and development).[2] The discussion below compares the new and previous projections in more detail.

Balance Between Supply and S/E-Related Utilization of Doctorates

For four broad fields as well as for all fields combined, the new projections place non-S/E utilization in 1987 below the percentage levels estimated earlier for 1985 (table A-1). The most marked change in outlook is in the social sciences where the projected imbalance has dropped from 37 percent to 19 percent. The smaller gap between supply and S/E utilization can be attributed to higher expectations of nonacademic S/E employment in this field. Similarly, the new projections have reduced the imbalance in engineering from 29 percent to 19 percent, again primarily because of estimated higher future employment outside of universities and colleges. In the mathematical sciences, projected 1987 supply and S/E utilization are both 6,000 above the earlier estimates for 1985. This change has the effect of lowering the projected non-S/E utilization from 27 percent to 21 percent. The outlook for the physical sciences has not changed appreciably between the two reports, whereas a faster projected rate of growth in supply in the life sciences has raised the estimated level of imbalance from 8 percent for 1985 to 16 percent for 1987.

Doctoral Awards

Much higher projected rates of graduate school completion are the chief factor causing the current projection of 1985 male physical sciences doctoral awards to be more than double the projected value in the previous report (table A-2).[3] The earlier report assumed that the downward trend in completion rates observed when the report was prepared would continue, whereas this report links completion to conditions in the market for doctoral physical scientists. Because this market is now expected to become more favorable for future graduates because of projected increases in industrial R&D expenditures, completion rates are projected to rise well above those in the preceding projections. The estimated future values, however, are within the range of historical rates of completion. The projected 1985 totals for female physical sciences doctorates have risen from 200 to 600 because new data show that more women are earning baccalaureates in this field and because, as was the case for men, completion rates are projected to be well above those in the earlier report. (As explained in the next section of this appendix, the degree projection model for this field uses R&D spending as the only demand variable affecting SEEK. If it had been possible to include junior faculty openings as an additional demand variable, it is probable that the market projections would have indicated poorer job opportunities. As a result, projections of doctoral degrees in the physical sciences would have been moderately lower.)

Factors analogous to those cited above for the physical sciences also help to explain why projections of engineering doctoral awards in 1985 are now 60 percent higher than in the previous report. In addition, the projected proportions of male engineering baccalaureates entering graduate school have risen over the values used in the previous report because of the link between entrance rates and SEEK, which for engineers is affected by industrial R&D expenditures.[4]

For both men and women in the life sciences, where SEEK depends on junior faculty openings, projections of graduate school enrollment and completion rates have changed little compared to the previous report. Since the latter was prepared, however, the numbers of baccalaureates earned by each sex have accelerated above their long-term growth rates, leading to higher projections of future baccalaureates in this field and, consequently, to projections of doctorates in 1985 that are 22 percent higher than in *Degrees and Enrollment*.

[1] Frank J. Atelsek and Irene L. Gomberg. *New Full-Time Faculty 1976-77: Hiring Patterns by Field and Educational Attainment* (Washington, D.C.: American Council on Education, 1978).

[2] National Academy of Sciences. *Doctoral Scientists and Engineers in the United States, 1975 and 1977 Profiles* (Washington, D.C. 20418).

[3] The earlier report projected only up to 1985 so this is the last year to which the current projections can be compared.

[4] The projected 1985 total of male engineering doctorates is about 100 more than the number in the 1972 class, whereas women received only 74 doctoral awards in 1977.

2. Market Analysis

This part describes the econometric analysis used in these projections in more detail than was given in the text.

A Market Index

The model used to project S/E doctoral awards reflects the evidence that students considering earning Ph.D.'s are responsive to market conditions.[5] This meant that some index of doctoral employment opportunities, available on a regular basis, was required. This index should link, via equations with acceptable statistical properties, supply and demand variables with graduate school enrollment and completion rates. Such equations would help explain historical variations in entrance and completion rates and could be used to project their future values. The model used to project doctoral awards is comprised of a set of three equations for each S/E field and for each sex.[6] These equations have the following general form

Market index $= a_1 + b_1$ Supply variable $+ b_2$ Demand variable
Enrollment rates $= a_2 + b_3$ Market index
Completion rates $= a_3 + b_4$ Market index
where the a's are constant terms and the b's are coefficients.

A market index for this model was found in the annual NSF-sponsored Survey of Earned Doctorates which reports the percentage, by field, of individuals who are about to receive doctorates and who are seeking, but have not found a definite position at the time they respond to the survey. This index is called SEEK.[7]

Table A-3 presents the results of regression analyses in which SEEK is the dependent variable. In the equations for the mathematical, life, and social sciences, SEEK is related to the number of doctorates awarded in each field, GRAD (a supply variable), and to junior faculty openings, OPEN (a demand variable). Choice of OPEN to represent demand reflects the large majorities of the work force in these three broad fields who are employed in academia.[8] Allan Cartter's estimates of junior faculty openings for all fields combined provide values for OPEN for each year from 1960 to 1975.[9] (NSF projections of openings by broad field were used in projecting values of SEEK after adjusting for the difference in scale between the Cartter and NSF series.)

[5] See Richard B. Freeman, *The Overeducated American*, New York: Academic Press, 1976.

[6] Enrollment and completion rates are measured by field and sex whereas the same market index, SEEK, is used for both sexes for a given field.

[7] The values of SEEK used in the regressions come from special tabulations which cover 1960 through 1975. NSF is indebted to Richard Freeman for supplying this information.

[8] In 1977, 67 percent in the mathematical sciences, 61 percent in the life sciences, and 64 percent in the social sciences. National Science Foundation, *Detailed Statistical Tables: Characteristics of Doctoral Scientists and Engineers in the United States, 1977* (NSF 79-306) (Washington, D.C. 20550).

[9] Allan Cartter, *Ph.D.'s and the Academic Labor Market*, 1976, p. 143.

Table A-3. SEEK by field

Field	Regression equation	R^2	Durbin-Watson statistic	Regression technique
Physical sciences ...	SEEK = 77.2 + .003·GRAD − .09·R&D (3.3) (2.0) (−3.4)	.95	1.5	Cochrane-Orcutt
Engineering ...	SEEK = 4.28 + .007·GRAD − .09·R&D (7.2) (16.9) (8.6)	.96	2.1	Ordinary least squares
Mathematical sciences' ...	SEEK = 3.7 + .012·GRAD − .21·OPEN (1.1) (5.1) (−2.3)	.76	.4	Ordinary least squares
Life sciences ...	SEEK = 4.1 + .002·GRAD − .12·OPEN (2.6) (6.9) (−3.3)	.88	1.4	Ordinary least squares
Social sciences ...	SEEK = 4.3 + .001·GRAD − .10·OPEN (3.3) (6.2) (−2.9)	.86	.8	Ordinary least squares

Note: SEEK, a percentage, is measured separately for each broad field. The period of analysis is from 1960 to 1975.
Numbers in parentheses refer to values of t-statistics.

For the remaining two broad fields, engineering and the physical sciences, the demand variable used is industrial R&D expenditures by field. The use of R&D expenditures is in accordance with the important role of industry as an employer of graduates in these fields.[10] Historical values for this variable "R&D" for 1960 to 1975 were approximated by a transformation of R&D expenditures by major industry group.[11] Ideally, both OPEN and R&D would be used in each equation to describe demand forces influencing each of the five markets. Unfortunately, it was not possible to use both demand variables in the same equation because they are collinear, i.e., their past values vary together.

In time series regressions, the error terms (the differences between values predicted by the estimating equations and actual past values) for adjacent observations are often related. Such an undesirable statistical property—serial correlation of error terms—renders the regression results less reliable than they would

[10] Industry is the largest employer of doctoral engineers, with about 49 percent of the 1977 work force. Industry employed 35 percent of doctoral physical scientists in that year as compared to 44 percent employed by academia (including postdoctorates). Research and development was used in both cases as the demand variable, however, because it explained more past variation in SEEK and had more coefficients of statistical significance in equations for engineering and the physical sciences than did OPEN. This may have been because of the poor data available on junior faculty openings.

[11] This was done by multiplying the vectors of annual R&D expenditures by major industry group by the 1973 percentag[illegible]istribution matrix of doctoral R&D scientists and engineers by field and major industry.

otherwise be. The presence of serial correlation, indicated by critical values of the Durbin-Watson statistic, was a problem in the physical, mathematical, and social sciences. For the first of these fields a Cochrane-Orcutt transformation of the variables eliminated the serial correlation. Such a transformation was unsuccessful in the other two cases so the serial correlation remains for the mathematical and social sciences.

The numbers in parentheses in table A-3 refer to the t-statistics which indicate that all the constants and variable coefficients are significant at .05 or better except the constant term for mathematical sciences. The results are very good in the physical and life sciences and engineering. Even in the mathematical sciences, where the statistical results are the poorest, the equation should be an acceptable indicator of the influence of supply and demand variables on SEEK.

Graduate School Entry

The first stage in the projection model which is affected by the market involves decisions to enter graduate school. The equations below relate ENROLL, the proportion of baccalaureates by sex and broad field who enter graduate school, to SEEK in that field and varying combinations of other variables.[12] The latter consist of TIME—the trend variable, BACC—the number of baccalaureates for a field and a single sex, TOTBAC—the total numbers of baccalaureates in a field for both sexes, and DRAFT—the number of men conscripted for military duty. Variables relating to bachelor's degrees were included on the basis of the assumption that the proportion of baccalaureates entering graduate school falls as the total number of baccalaureate degrees rises. The variable DRAFT was included because of the possibility that many men entered graduate school in the sixties to avoid conscription. The analysis covered periods 14 to 18 years in length ending in the school year 1974–75, the number depending upon which sex and field the equation describes. The values of the dependent variable ENROLL were estimated by dividing NSF estimates of the number of first-*time* graduate students[13] by numbers of baccalaureates in a given year. In deriving the historical values of ENROLL, adjustments were made reflecting the past patterns by which baccalaureates have delayed enrollment in graduate school.[14]

The regression results of the historical data are summarized in table A-4. All but 3 of 26 regression coefficients are significant at .05 or better. The coefficient for SEEK for female physical scientists is just below statistical significance of .10, and coefficients for two other variables, DRAFT in the equation for male mathematical sciences baccalaureates and BACC for female life sciences baccalaureates, are significant at .10. Serial correlation of error terms is indicated for the male physical and mathematical sciences equations. Despite the presence of serial correlation, the results of ordinary least squares regressions are used in cases where Cochrane-Orcutt transformations remove meaningful relations among the variables, i.e., their coefficients either became insignificant or took on the wrong sign. Because of the very small numbers of female engineers graduating in the past, analysis of market effects on their enrollment behavior is excluded from this study. The projections assume female engineers react to the market in the same way as their male counterparts.

[12] Different specifications of the equations for each sex-field were tested. Those specifications in table A-3 were chosen because they had the best statistical properties for purposes of projections. These properties were as follows (1) Percent of past variation in the dependent variable explained (R^2). (2) statistical significance of the coefficients and, (3) when possible, absence of correlation of error terms

[13] The National Center for Education Statistics reports first-*year* graduate students which is a broader category than first-time students

[14] For example, NSF estimates that 50 percent of engineers who ever go into graduate school do so in the same year in which they earned their baccalaureates, 20 percent do so in the following year, and so forth. These same adjustments for delays in enrollment are incorporated in the projection of awards

Table A-4. Percent of science/engineering baccalaureates who ever enter graduate school by field and sex

Field	Regression equation	R^2	Durbin-Watson statistic	Regression technique
Physical scientists:				
Men	ENROLL 91.0 − .63 SEEK − 1.87 TIME (8.5) (− 1.8) (− 2.2)	.92	1.2	Cochrane-Orcutt
Women ..	ENROLL − 98.3 − .51 SEEK · .01 BACC (17.3) (1.3) (2.2)	.88	2.3	Cochrane-Orcutt
Engineers:				
Men	ENROLL 79.9 · .95 SEEK · .00056 TOTBAC (8.1) (3.3) (2.0)	.95	1.3	Cochrane-Orcutt
Mathematical scientists:				
Men	ENROLL − 46.5 − .51 SEEK + .000007 DRAFT (32.0) (− 5.9) (1.4)	.87	1.1	Ordinary least squares
Women ..	ENROLL 19.5 .58 SEEK + .87 TIME (17.2) (4.2) (4.2)	.63	1.4	Ordinary least squares
Life scientists:				
Men ...	ENROLL 42.7 · 1.01 SEEK (11.2) (2.7)	.79	1.4	Cochrane-Orcutt
Women .	ENROLL 31.3 .97 SEEK .0005 BACC (40.4) (6.8) (1.6) + 1.31 TIME (4.9)	87	1 9	Ordinary least squares
Social scientists.				
Men	ENROLL 47.7 · .62 SEEK .0003 BACC (49 9) (2 5) (9 5)	97	7	Ordinary least squares
Women .	ENROLL 24.6 .70 SEEK (11 6) (3 1)	90	1 7	Cochrane-Orcutt

Note Numbers in parentheses refer to values of t-statistics
Source National Science Foundation

Graduate School Completion

The second point of market influence in the projection model comes when the graduate student decides whether to earn a doctorate. For the projections it is assumed that this occurs two years after entry into graduate school. This length of time would allow most students to finish master's-degree programs and, hence, would provide a logical point for deciding whether to continue graduate study. In table A-5 are the results of regressions relating FINISH, the NSF estimates of the proportion of first-time graduate students in a given year who earn a doctorate, to the value of SEEK2, the market index two years after those students begin graduate study. For each equation there were 14 or 15 observations covering the period ending in the 1969–70 school year.[15] As in the case of the analysis of ENROLL there have been too few female engineering graduate students to allow analysis of the effect of the market on their behavior so it is assumed for projection purposes that they have the same market responses as men have. Regression analysis found that for women who are engaged in graduate study in the social sciences FINISH is not related to SEEK2. For the projections it is therefore assumed that the same proportion of women will complete graduate school in this field as have done so in the last 10 years of estimates.

In the completion equations all coefficients are significant at .025 or better. After Cochrane-Orcutt transformations of the variables in all the equations, the Durbin-Watson statistic indicates possible serial correlation of error terms for the equations concerning male graduate students in engineering and the social sciences.

Steps in the Projection of S/E Doctoral Degrees

The relationship between the supply of new doctorates in a given year and demand factors[16] determines the value of the market index SEEK for that year. As explained below, SEEK in turn affects the proportion of recent baccalaureates who go to graduate school. This relation is negative: as SEEK rises, smaller percentages of baccalaureates in a field enter graduate school. SEEK also negatively influences the proportion of graduate school entrants who earn doctorates.

The degree projections are produced two years at a time by estimating values of SEEK, ENROLL, and FINISH for years after the end of the historical time series of these variables. In more detail, values for SEEK are calculated for two initial years (t and t + 1) by relating demand and supply variables for a broad field with the appropriate equation from table A-3. These values of SEEK are used in the equations in tables A-4 and A-5 to derive the estimated percents of baccalaureate recipients in those two years who ever enter graduate school (i.e., the values of ENROLL for baccalaureates in years t and t + 1) and the estimated percents of graduate enrollees one and two years earlier who ever earn doctorates (i.e., the values of FINISH for graduate students entering in years t−1 and t−2). In the model Ph.D. graduates from a given entering class earn degrees over a 10-year period beginning four years after entry.[17] Therefore, the first doctorates from the entering class of year t−2 graduate in year t+2 and from t−1 in t+3. With estimates of graduates in t+2 and t+3, values of SEEK in those two years are computed. The projections continue in this recursive manner, two years at a time, until degrees for 1987 are produced. Although this approach admittedly represents a simplification of actual market processes, data constraints prevented development of a more complex approach that would more fully reflect the market.

[15] This is the last cohort of beginning graduate students from which a sufficiently large fraction had obtained doctorates by 1976 to allow calculation of completion rates.

[16] The two demand variables are exogenous to this model, i.e., their values are not affected by the number of doctorates that are projected.

[17] The pattern of delays between enrollment and completion used for each field and sex reflects historical data on the length of doctoral study. The simplifying assumption that all doctorates are earned between 4 and 14 years after students enter school approximates observed data. In 1976–77, for example, only 3.8 percent of all S/E doctorates were awarded to those enrolled three years or less and only 0.7 percent to those enrolled more than 14 years. (Unpublished data from the Survey of Earned Doctorates).

Table A-5. Percent of science/engineering graduate students who ever attain doctorates

Field	Regression equation	R^2	Durbin-Watson statistic	Regression technique
Physical scientists				
Men	FINISH 45.7 .83 SEEK2 (17.1) (4.0)	.90	1.4	Cochrane-Orcutt
Women	FINISH 38.5 .56 SEEK2 (31.0) (4.9)	.86	1.4	Cochrane-Orcutt
Engineers				
Men	FINISH 27.4 .74 SEEK2 (22.7) (6.5)	.91	1.1	Cochrane-Orcutt
Mathematical scientists				
Men	FINISH 29.4 .93 SEEK2 (22.9) (7.4)	.93	1.8	Cochrane-Orcutt
Women	FINISH 10.0 .29 SEEK2 (9.9) (3.4)	.91	2.1	Cochrane-Orcutt
Life scientists				
Men	FINISH 52.4 1.66 SEEK2 (18.4) (5.1)	.84	1.6	Cochrane-Orcutt
Women	FINISH 38.3 .91 SEEK2 (12.7) (2.9)	.79	1.6	Cochrane-Orcutt
Social scientists				
Men	FINISH 40.2 1.07 SEEK2 (13.7) (2.6)	.78	1.2	Cochrane-Orcutt
Women	No evidence of market responsiveness			

Note: Numbers in parentheses refer to t-statistics.
Source: National Science Foundation

A Test of the Degree Projection Model

As a test of the usefulness of the projection approach described in this appendix, "ex post facto" projections of doctoral degrees were made for men for 1967–76. This was done by using in the equations presented earlier the actual values of SEEK to "predict" what graduate school entrance and completion rates would have been in those years for each of the five S/E fields according to the behavioral relationships described in those equations. Estimates were then made of how many degrees would have been awarded with those predicted values of entrance and completion rates. The results differed from actual awards over the 10-year period by standard errors of 7 percent or less.

Analysis of Starting Salaries for Doctoral Scientists and Engineers

Starting salaries for S/E doctorates were evaluated as possible market indicators for the projections before SEEK was chosen as the market index. Regressions showed that starting salaries could serve as market indices only for engineering and chemistry (which represents only one component of the physical sciences). To maintain a consistent approach and for statistical convenience SEEK was used as an index of market conditions for supply projections in all fields.

Starting salaries for inexperienced workers are a commonly used measure of the relation between supply and demand in a labor market. Salary data are available from the College Placement Council and professional associations for new doctorates in engineering, mathematics, chemistry, and physics. One equation below (table A-6) relates starting salaries, SALARY, for doctoral engineers to GRAD and R&D (described in the analysis of SEEK) and SALBA, starting salaries for baccalaureate engineers. SALBA appears on the basis of the hypothesis that movements in baccalaureate and doctoral salaries may be highly correlated. The other equation relates starting salaries to research and development as well as values of the dependent variable, SAL2, and the supply variable, GRAD2, each lagged one period. Another variable used in this equation is TIME, which takes a value equal to the number of the observation. This variable is included to account for any trend-related factors not included in the equations. The final forms of the two equations were chosen after testing several different specifications to determine which had the most favorable statistical properties. (See footnote 10 in this appendix for a discussion of these properties.)

Each equation explains nearly all the variation in doctoral salaries, as is reflected in the high R^2's, and all of the regression coefficients are highly significant, as shown by the t-statistics in parentheses. The Durbin-Watson statistic indicates that serial correlation of error terms may remain in the equation relating to starting salaries for doctoral chemists after a Cochrane-Orcutt transformation of variables. There are 16 observations for chemists' salaries (1960–75) and 22 for engineers' salaries (1954–75). Similar analysis for physicists and mathematicians produced very low R^2's or coefficients which lacked significance or were of the wrong sign.

Table A-6. Beginning salaries for doctoral chemists and engineers

Doctorals	Regression equation	R^2	Durbin-Watson statistic	Regression technique
Chemists	SALARY = −298.6 + 2.41·R&D (−5.2) (9.3) −.12·GRAD2 + .53·SAL2 (−6.1) (8.6) −16.21·TIME (−4.7)	.99	2.9	Cochrane-Orcutt
Engineers	SALARY = −7325.0 + 1.57·SALBA (−4.3) (9.8) +20.?6·R&D − 1.12·GRAD (5 9) (−10.1)	.96	2.6	Cochrane-Orcutt

Source: American Chemical Society, College Placement Council, and National Science Foundation
Note: Numbers in parentheses refer to t-statistics.

Utilization of S/E Doctorates

Academia

This section expands the text discussion of the projection methods used for the largest category of utilization of S/E doctorates, academia. The next section discusses industrial R&D employment.

For each broad field, regression analysis related the number of full-time academic staff, including nondoctorates, in January of a given year to the independent variables listed below.

BACC—the total number of baccalaureates awarded in a single broad field
BACC (1)—the total number of baccalaureates awarded in all S/E fields except the social sciences
BACC (2)—the total number of baccalaureates awarded in all S/E fields
PHD—the total number of Ph.D.'s awarded in a single broad field
TIME—a trend variable equal to the number of the observation (e.g., one for the first observation)
BACC/TIME—the variable BACC divided by the trend variable
BACC(1)/TIME—the variable BACC(1) divided by the trend variable
BACC(2)/TIME—the variable BACC(2) divided by the trend variable.

There were eight observations for the period 1965 to 1976. Different equation specifications were tested to determine which variables best explained past variation in academic employment. Those specifications which seem most consistent with what is known about the types of courses taken by students in different fields and those which had the best statistical properties appear in table A-7.[18] For each

[18] See footnote 10 in this appendix. Ordinary least squares were used in all cases because Cochrane-Orcutt transformations correct for correlation between error terms in adjacent observations. If observations are separated by gaps of unequal length, as in this case, these transformations are not possible.

Table A-7. Employment of science/engineering faculty

Field	Constant	BACC	BACC(1)	BACC(2)	PHD	TIME	BACC/TIME	BACC(1)/TIME	BACC(2)/TIME	R^2	Durbin-Watson statistic
Physical sciences:											
(1)	22,941 (7.7)		0.052 (2.1)			312 (2.6)		-0.056 (-7.5)		.99	2.8
(2)	4,249 (1.3)		.186 (8.4)							.92	2.7
(3)	12,772 (6.1)			0.070 (8.8)						.93	2.1
(4)	25,415 (14.0)			.020 (2.4)		315 (3.0)			-0.038 (-6.9)	.99	2.4
(5)	22,593 (9.0)	0.316 (2.6)				470 (8.3)	-0.330 (-8.2)			.99	2.5
Engineering:											
(1)	17,799 (8.7)	.130 (2.8)					.124 (-7.5)			.96	2.0
(2)	10,963 (4.6)		.077 (4.6)							.78	2.3
(3)	14,260 (9.9)			.030 (5.4)						.83	2.3
(4)	19,715 (6.8)		.024 (1.3)					.039 (-3.5)		.94	1.9
(5)	20,223 (9.6)		.012 (1.7)					.024 (3.2)		.94	1.9
Mathematical sciences:											
(1)	1,099 (.6)			.080 (11.8)						.96	1.3
(2)	10,867 (4.9)		.210 (13.7)							.97	2.5
(3)	5,079 (.9)		.154 (2.9)			295 (1.1)				.98	2.0
(4)	3,282 (1.1)			.050 (2.8)		409 (1.7)				.97	1.5
Life sciences:											
(1)	6,838 (1.6)		.246 (8.3)							.92	2.5
(2)	18,346 (5.8)			.090 (7.6)						.91	1.6
(3)	8,029 (1.5)		.211 (2.4)		0.981 (.4)					.92	2.1
(4)	18,174 (5.1)			.085 (2.0)	.490 (.2)					.91	1.5
(5)	18,788 (10.6)	193 (5.7)			3.160 (4.6)					.98	2.6
Social sciences:											
(1)	12,279 (2.0)			137 (5.9)						.85	1.4
(2)	22,786 (4.9)	216 (5.5)								.84	.8

Note: Numbers in parentheses are t-statistics field the equation listed first was used to project total staff, except in the social sciences.[19] In the physical and life sciences, specifications using BACCS(1) (all S/E baccalaureates less the social sciences) were chosen for the projection equations to reflect the service function performed by faculty in these two fields for students majoring in other S/E fields. (It is assumed that social sciences undergraduates do not take natural sciences courses as frequently as do other S/E students.) BACC(2) (all S/E baccalaureates) appears in the projection equations for the mathematical sciences on the basis of the assumption that faculty in this field instruct all S/E undergraduates. On the other hand, few nonengineering students enroll in engineering courses so BACC (in this case baccalaureates in engineering only) was the independent variable in the projection equation. In this field as well as in the physical sciences, trend variables were also used. The text describes how projections of regular staff with doctorates were derived from these projections of total staff (p. 12).

Industrial Research and Development

Projections of doctoral employment were based upon historical relationships between total S/E staff, EMPLOY, and expenditures by major industrial groups,[20] R&D, as estimated by linear regression analyses of the annual data for the period 1958–76. Results are summarized in table A-8. The trend variable, TIME, appears in the three equations where its coefficient was statistically significant. All coefficients are statistically significant at .05, except the constant term for electrical equipment.

Future staffing was estimated with these equations and projected growth rates for R&D expenditures by industry presented in *1985 R&D Funding Projections.*[21] The projected employment for the seven industry groups were summed and multiplied by 1.16 to impute the smaller industries not included in the regressions.[22] The text describes how projections of doctoral staff by field were derived from these estimates of total future staff (p. 13).

[19] As explained in the text (p 12) the projections assume that full-time social sciences faculty, including nondoctorates, will be constant throughout the projection period

[20] National Science Foundation. *Research and Development in Industry*. annual series (Washington, D C 20402 Supt. of Documents. U.S. Government Printing Office)

[21] National Science Foundation *1985 R&D Funding Projections* (NSF 76-314) (Washington. D C 20402 Supt of Documents, U S Government Printing Office)

[22] The excluded industries employed 16 percent as many scientists and engineers in R&D activities as did the industries included in the regressions in 1976 The excluded industries were food, textiles, lumber, paper, petroleum, rubber, stone, primary metals, fabricated metals and nonmanufacturing

Table A-8. Employment of scientists and engineers in industrial research and development

Industry	Regression equation	R^2	Durbin-Watson statistic	Regression technique
Chemicals and allied products	EMPLOY = 23.9 + .006·R&D (6.4) (2.1) +.347·TIME (2.35)	.88	1.5	Ordinary least squares
Professional and scientific instruments	EMPLOY = 5.0 + .013·R&D (8.4) (13.8)	.92	1.6	Ordinary least squares
Aircraft and missiles	EMPLOY = 5.7 + .013·R&D (1.6) (21.9) +.297·TIME (2.5)	.97	1.5	Ordinary least squares
Machinery	EMPLOY = 12.0 + .014·RD (1.8) (3.8)	.91	1.6	Cochrane-Orcutt
Electrical equipment & communication ..	EMPLOY = −12.5 + .023·R&D (−1.2) (9.3)	.84	.8	Cochrane-Orcutt
Motor vehicles & motor vehicle equipment	EMPLOY = 22.4 + .003·R&D (6.0) (1.7)	.96	2.0	Cochrane-Orcutt
Nonmanufacturing	EMPLOY = 1.1 + .014 R&D (1.6) (7.9) +.239 TIME (3.6)	.96	1.5	Ordinary least squares

Note Numbers in parentheses refer to t-statistics
Source National Science Foundation

3. Comparison of NSF and BLS Projections

Projections by the Bureau of Labor Statistics (BLS) of the supply and utilization of doctoral scientists and engineers[23] largely agree with estimates presented by the National Science Foundation (NSF) in this report. The respective projections are close in spite of differences in the concepts and techniques used by the two agencies.

NSF and BLS agree on the overall balance between supply and utilization as well as on the possibility of growing imbalances in the four broad fields of science. More specifically, the two differ by only a few thousand on both the future supply and utilization of doctoral physical scientists and mathematicians. Also NSF and BLS agree closely on future utilization in the life and social sciences, but BLS projects about 15,000 more doctoral life scientists and about 5,000 more social science doctorate-holders. Only for engineering do the two sets of projections differ on the future nature of the labor market. BLS foresees a small shortage of doctoral engineers, whereas NSF estimates that about 15,000 of this group will hold non-S/E positions in 1987.

Most of the divergence between the two agencies on the outlook for engineering and almost all of the differences on the extent of the future imbalances in the life and social sciences can be traced to how NSF and BLS account for future additions to supply. The National Center for Education Statistics (NCES) provides the degree projections used by BLS.[24] NCES derives its estimates of future degrees from extrapolation of trends in (1) the ratios of total doctoral awards to the college-age population and (2) the ratios of degrees in a field to total doctorates. Examination of NCES projections reveals that future degree totals generally differ not only in magnitude but also in direction of change from those generated by the NSF model. These divergences highlight the roles in the recursive NSF model of (1) feedback from the market to the number of doctorate graduates and (2) expectations concerning demand factors.

The fairly close agreement in regard to future utilization in the four science fields occurs in spite of differences in how the two agencies approach this question. In contrast to NSF, which estimates the number of S/E positions available in 1982 and 1987, BLS projects to 1985 "traditional" employment for doctorates. Such utilization is defined in terms of the proportions of the labor force in a field that were comprised of Ph.D.'s in a past period when doctoral supply and utilization were assumed to have been in balance. An estimate of "traditional" doctoral employment in 1985 is derived by first extrapolating 1966–70 trends in the proportional representation of doctorates in a field. The extrapolated fraction for 1985 is multiplied by the BLS projection of total 1985 labor requirements in that field to obtain the number of traditional jobs for Ph.D.'s.

[23] Douglas Braddock, "The Oversupply of Ph.D.'s to Continue Through 1985," *Monthly Labor Review*, October 1978, p. 48-50.

[24] National Center for Education Statistics, *NCES Projections of Education Statistics to 1985-86*, NCES 77-402 (Washington, D.C.)

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4. Components of Fields of Science

Physical sciences: Includes chemistry, earth science, physics, geology, meteorology, astronomy, metallurgy, geophysics, pharmaceutical chemistry.

Engineering: Includes aeronautical, architectural, biomedical, ceramic, chemical, civil, electrical, engineering sciences, environmental health engineering, geological, industrial, mechanical, mining, nuclear, petroleum, and all other forms of engineering.

Mathematical sciences: Includes mathematics, statistics, computer sciences, data processing, systems analysis, and all related fields.

Life sciences: Includes agriculture (except agricultural economics), forestry, biology, botany, zoology, ecology, embryology, entomology, genetics, nutrition, plant pathology, plant physiology, anatomy, biochemistry, biophysics, microbiology, pathology, pharmacology, physiology, and related fields.

Social sciences: Includes agricultural economics, geography, econometrics, anthropology, archeology, economics, linguistics, sociology, government (political science), demography, and psychology. (Does not include history, education, social work, public administration, or other applied fields.)

Nonscience: All other fields.

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APPENDIX B
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