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ABSTRACT

This report contains the proceedings of a seminar conducted by the Ad Hoc Subcommittee on Manpower of the National Science Board. The major topic of the seminar was the scientific and technical manpower projections of supply and demand, since such projections can serve as a major tool in effecting policy decisions. Six major papers were commissioned for the seminar, each with the following themes: (1) the accuracy of past predictions of scientific and technical manpower; (2) the methodology assumptions used, and limitations employed in projections of scientific and engineering manpower supply and demand; (3) the uses, limitations, and impacts of these projects; (4) methods for enabling students to make career decisions; and (5) possible steps to aid students and others over the long term to evaluate the realizability of their anticipated futures. This volume contains the commissioned papers, panel discussions and summaries, and a complete listing of all participants. (Author/MH)

Scientific and Technical Manpower Projections

Proceedings of the Seminar

National Science Board

October 1974

NSB-74-287

Proceedings of the Seminar on

SCIENTIFIC AND TECHNICAL MANPOWER PROJECTIONS

Including the Formal Papers

Under the auspices of the
Ad Hoc Subcommittee on Manpower of the
Planning and Policy Committee
National Science Board

April 16-18, 1974

NATIONAL SCIENCE FOUNDATION

FOREWORD

In June 1973, a task group of the National Science Board felt that the scientific and technical manpower trends which have developed in the recent past, were of such importance that they should be the subject of more detailed analyses and study. Accordingly, the Board appointed a subcommittee of its Planning and Policy Committee. This Ad Hoc Subcommittee on Manpower, under the chairmanship of Russell D. O'Neal, was charged with the responsibility of carrying out a critical comparative study of existing manpower analyses and the assumptions which underlie them.

To aid in identifying the issues and to assist in focusing its study, the Subcommittee decided to hold a seminar at which the major concern was to develop an understanding of scientific and technical manpower projections of supply and demand, since such projections could serve as a major tool in effecting policy decisions. All levels of scientific and technical manpower were addressed, but with concentration at the doctorate level. The seminar was structured to include participants with various points of view regarding the value of projections, and whether and how they might be improved. Among those present were experts in the preparation of supply and demand projections of scientific and technical manpower, as well as users in industry, government, and academia. Allan M. Cartter served as chairman and moderator of the Seminar, as well as assisting in its planning and organization.

Six major papers were commissioned and presented at the Seminar, held on April 16-18, 1974, in Hot Springs, Virginia. The major themes addressed were:

- The accuracy of past projections of scientific and technical manpower
- The methodology, assumptions used, and limitations employed in projections of scientific and engineering manpower supply and demand
- The uses, limitations, and impacts of these projections
- Methods for enabling students to make career decisions
- Possible steps to aid students and others over the long term to evaluate the realizability of their anticipated futures

After consideration of the many problems and possible solutions offered at the Seminar, their feasibility and timeliness, the Subcommittee formulated its recommendations. These are found in its report, *Scientific and Technical Manpower Projections* (NSB-74-286). Also to be found in that volume are an overview of the Seminar and highlights of the presentations.

This volume contains the proceedings of the Seminar, including the commissioned papers and a complete listing of all participants.

Norman Hackerman
Chairman
National Science Board

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1. Opening Comments

H. Guyford Stever:

Director,
National Science Foundation

I am very glad that the National Science Board has decided to establish an Ad Hoc Subcommittee on Scientific and Technical Manpower, and that the concerns of this committee are being discussed at this conference with a wide range of experts. The National Science Foundation has responsibilities with respect to scientific and technical manpower; broadly stated, our mission is to insure the health of American science, and one part of that is insuring an appropriate supply of manpower. Also, we are obliged to provide the various branches of government with information on which they can base policies and programs with respect to manpower.

At the broad national scale we are faced with a lack of knowledge about the elements of scientific and technical manpower issues. The effects of government support and the effects of technical opportunity are still not understood. Nearly everyone approaches the manpower problem from the standpoint of his own anecdotal evidence. We know, as individuals, why *we* started in science or engineering, and we think everyone else started for those same reasons, but we know little of the broad behavioral implications.

If we are the head of a university, a department, or a research laboratory, we know our job is made easier if there is fellowship money or traineeship money available. We know, if we are from an elite school, that fellowship students will flock to our kind of institution. But still, it is on our anecdotal experience that we seem to base our broad scale judgments.

With respect to its role, government has never thought out very carefully its role in supplying first-class talent in science and engineering. There are many policy issues; for one, Federal support for manpower training has been declining. For another, inadequate consideration has been given to unemployment and related issues as they are affected by change in government policies. All of us, in both institutional and industrial settings, have shared in the consequences. In these brief remarks, let me emphasize our need for a greater depth of understanding of manpower issues if there are to be more effective policies and programs, and if we are to present young people with useful information concerning career choice and career opportunity to enable them to make intelligent decisions, both for themselves and for the scientific enterprise.

Allan M. Cartter
Seminar Chairman, Professor in Residence,
Department of Education,
University of California at Los Angeles

I would like to express my appreciation to Dr. Stever and to the special committee of the National Science Board, which has taken such a lively interest in the topic of this seminar. It is a pleasant duty to call together those who have interest and expertise in manpower projections. Ten years ago a seminar such as this would have had a limited roster of participants, but now we easily could have doubled or tripled the forty who are here.

A review of the literature of the past ten years would accord places of honor to a number of persons. For a period of nearly twenty years, Dael Wolfle was almost "Mr. Manpower" in Washington, D.C. He kept a lively interest, had more insight than many, and encouraged others to work in the area of manpower. The predictions and projections of Barney Berelson have turned out to be surprisingly accurate, and he had a significant impact on a number of us. Dick Freeman probably has been the most prolific writer on the subject for the last five years, and he has very capably demonstrated that the market really works. The best monitoring and early warning system of any of the disciplines or professional societies was developed by Lee Grodzins and his colleagues of the American Institute of Physics. Hopefully, this conference will give rise to some device by which we can encourage other professional groups to do what AIP has done for physics.

One can almost assess the changing state of the art in manpower projections by reviewing the successive NSF reports on doctoral supply and utilization, performed under the direction of Charles Falk. Certainly the last report proceeded to a degree of sophistication that was not available six or eight or ten years ago.

For the last eight years Chuck Kidd has become the graduate education watchdog for the American Association of Universities and has been astutely analyzing trends in doctoral production. My own name would be on the citation lists. If I contributed anything it was what seemed obvious to an economist; namely that graduate education, insofar as it trains college teachers, is really the counterpart of an investment goods industry. The demand for its product depends upon the rate of change in total demand or total enrollment.

In retrospect, I regret that Barney Berelson and I were so critical in the early 1960's of the National Education Association's biennial surveys on teacher supply and demand from 1953 through 1963. The criticisms helped destroy the surveys, and that was unfortunate because NEA had collected more good data and spent more time focusing on teacher supply and demand than any other agency. So much for the past.

The market for doctoral scientists is intriguing, in part, because the demand for Ph.D.'s is divided almost equally (perhaps closer to 55/45) between academic and non-academic demand. Nearly two-thirds of the latter depend on government funding for research and development. Thus, one can almost isolate two markets for doctorates, one academic and the other government-related. The papers for this seminar try to look at both markets, and highlight some of the problems of assessing future manpower needs. Until very recently we tended to believe that academic demand was quite predictable, and that the factors influencing college enrollments were relatively stable, but events of the past two or three years are disabusing us of this assumption. While we all recognize that the Vietnam war and the draft were having a fairly significant impact on college attrition rates and entrance to graduate school, I think most of us were unprepared for the recent reversal in trends in high school graduation rates and college entrance rates.

It might be useful to begin this seminar with some selected key ratios of education progression for the last ten to fifteen years (Table 1.1.) This gives us a common beginning point. In addition, it might be interesting to consider why the assumptions made in earlier projections turned out to be false.

Table 1.1
Selected Key Ratios of Educational Progression;
Actual 1955/56 through 1973/74, and Projected to 1980/81

Year	High School Graduation Rate[1]	College Entrance Rate[2]	College Graduation Rate[3]	First-Year Graduate Enrollment[4]	Ph.D. Completion Rate[5]
1955/56	.631	.496	n.a.	.45	n.a.
1957/58 *..............	.653	.501	n.a.	.51	n.a.
1959/60	.726	.501	.522	.57	n.a.
1961/62	.689	.517	.517	.62	.075
1962/63	.696	.535	.521	.66	.075
1963/64	.824	.528	.535	.70	.076
1964/65	.712	.535	.516	.74	.080
1965/66	.757	.541	.508	.76	.081
1966/67	.760	.516	.537	.79	.083
1967/68	.771	.537	.556	.81	.082
1968/69	.785	.603	.546	.79	.083
1969/70	.782	.818	.581	.76	.084
1970/71	.765	.615	.596	.73	.082
1971/72	.768	.600	.571	.69	.079
1972/73	.764	.576	n.a.	.67	*.076
1973/74	n.a.	*.578	n.a.	*.66	n.a.
Projected					
1975/76	.776	.586	.579	.65	.072
1980/81	.801	.617	.588	.62	.070
1985/86	.821	.643	—	—	—
1990/91	.836	.659	—	—	—

* Preliminary data

[1] High school graduates/average of age 17 and 18 population

[2] First-time college degree credit enrollment/high school graduates of previous academic year

[3] Baccalaureate degree/average first-time enrollment of three and four years earlier

[4] First-year graduate enrollment/weighted average of B.A.'s one to four years earlier (Note that first-year graduate students are not the same as first-time graduate students, the latter constitute only about 40 percent of the former.)

[5] Ph.D.'s awarded/average first-year enrollment four to seven years earlier

The time series of high school graduation rates rose fairly consistently to a peak about the year 1968, and then turned down. Most analysts in the late 1960's, and even in 1970 or 1971, made the assumption that the high school graduation rate would continue to rise about one percentage point per year until approximately 1980, then level off at about 90 percent of average 17-18 age population. In reality, the high school graduation rate dropped to about 76.5 percent in the years 1972-73. Most analysts would attribute the reversal to the end of the draft.

Consider also the college entrance rate—that is, first-time college entrance in relation to high school graduates. This is a rising series that peaks in years 1969-70. Again, analysts in the late 1960's and early 1970's assumed that college entrance rates would continue to go up steadily over the next decade. The reversal has been fairly marked, and the rate has now dropped nearly 7 percent. Further, one does not know what the future trend will be.

The data on college graduation rates (baccalaureate degrees divided by average first time enrollment three and four years earlier) peaks in years 1970-71, and also appears to have turned down.

The data on first-year graduate students (enrollment in relation to a weighted average of baccalaureates granted from one to four years earlier) show a peak in years 1967-68, followed by a fairly sharp drop. This drop occurred at the time when the public became aware of the deteriorating job market and was coupled with the removal of the draft exemption in the summer of 1969.

The data on the Ph. D. completion rate (the number of Ph.D.'s awarded in relation to first-year enrollments from four to seven years earlier) peaked in the years 1969-70, and it also has declined since then. However, it is interesting to note that for women the Ph.D. completion rate and the first-year graduate entrance rate are continuing to increase, so that the decreases for men are sharper than the average indicates.

Looking at the bottom of Table 1.1, no projections are estimated for 1985 and 1990 in the three right-hand columns because that is where the market forces will have a fairly significant influence. As for the two left-hand columns, it can be assumed that decisions to graduate from high school and to enter college are not very responsive to market forces as we think of them, short of another great depression.

The U.S. Office of Education has begun collecting data on first-time enrollments in graduate and professional schools (Table 1.2). Putting that information together with data on first-year students, one can estimate the entrance pattern for the last 18 years. Table 1.2 indicates that the proportion going to graduate school—that is, the ratio of column 3 to column 1—peaked in 1967 and has decreased sharply since then. In the case of the professional schools, the peak occurred about 1970-71. While the absolute numbers seem to be going up at a rate not quite keeping up with the increase in baccalaureates, by 1973 we appear to be back to the overall percentage of students going on to post-baccalaureate studies that we experienced in 1962.

Table 1.3 shows estimated enrollment figures for various levels of education. Total enrollments are shown by sector to the year 1985. The undergraduate enrollments after that time are based on Series F Census projections which at the moment look like the best of the census series. It appears that there will be a period of steady but somewhat modest contraction in enrollments until the mid-1990's, something that we would not have anticipated a few years ago.

Figure 1.1 shows what the various census projections tell us is likely to happen to the size of the college age group. Because the easiest age group to take out of the census series is the 20 to 24 group, that is the one shown. There is an amazing difference between today's Series F projection and Series B from 1967.

Until 1970, most of us used Series B as the most reasonable of the projections. It shows a growth to 26.5 million age 20 to 24 students by the end of the century. Now, Series F projects only 17.5 million for this age group at the end of the century. This is obviously a drastic change in expectations. Series F projections, out to the year 2020, indicate that for the next fifty years there is likely to be no growth in the size of the college age population, and that is a very different world than we anticipated five or ten years ago.

Table 1.2
Ratios of Estimated First-Time Students in Professional and Graduate Schools in Relation to Weighted Average of B.A.'s 1-5 Years Earlier

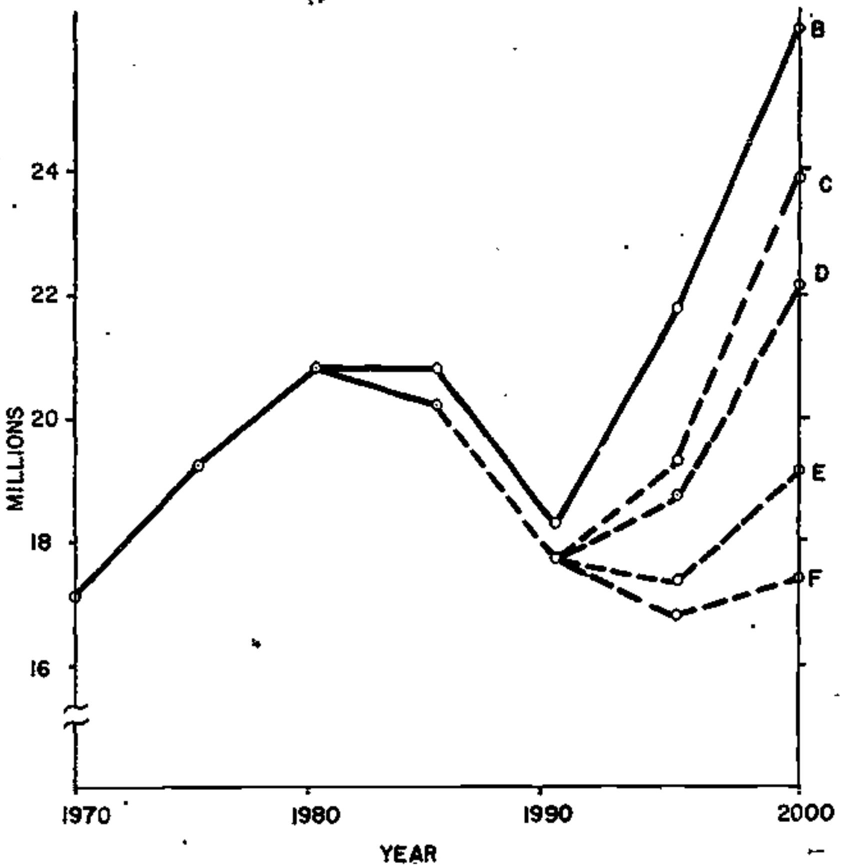
Year	Weighted Average of B.A.'s (000's)	First-time Professional Enrollment (000's)	First-time Graduate Enrollment (000's)	Ratio 2/1	Ratio 3/1	Ratio 2+3/1
	(1)	(2)	(3)			
1955	291	26	60	.09	.21	.30
1956	282	27	66	.10	.23	.33
1957	295	27	69	.09	.23	.32
1958	313	27	79	.09	.25	.34
1959	334	28	88	.08	.26	.35
1960	350	28	94	.08	.27	.35
1961	361	29	103	.08	.29	.37
1962	374	31	113	.08	.30	.38
1963	395	33	127	.08	.32	.40
1964	427	35	146	.08	.34	.42
1965	468	36	165	.08	.35	.43
1966	492	36	178	.07	.36	.43
1967	524	38	196	.07	.37	.45
1968	576	45	210	.08	.36	.44
1969	648	55	226	.08	.35	.43
1970	720	63	242	.09	.34	.42
1971	779	66	248	.09	.32	.40
1972	832	68	[2]257	.08	.31	.39
1973	[1]883	[1]70	[2]269	.08	.31	.38

[1] Preliminary data.
[2] Increases based on ETS/CGS Surveys

Table 1.3
Actual and Projected Degree-Credit Enrollment, Selected Years (000's)

Year	Undergraduate	First Professional	Graduate	Total	Ph.D.'s Awarded
1955	2258	160	242	2.660	8.9
1960	3058	169	356	3.583	10.6
1965	4689	218	619	5.526	18.2
1970	6677	343	900	7.920	32.1
1975	7690	443	1064	9.197	39.5
1980	8531	507	1136	10.174	43.7
1985	8186	560	1216	9.962	45.8
1990	7910				
1995	7333				
2000	8197				

Figure 1.1
Projected Size of 20-24 Age Group to Year 2000, According to Alternative Census Series



Many of us have been critical of the Office of Education projections, not only because the data were usually several years out of date, but because those projections have tended to swing to the extremes. It appears that OE's projections in the period of 1970 to 1972 were too optimistic, while their latest projections are, I believe, too conservative. The Office of Education's projections may turn out to be the perfect example of Freeman's cobweb theorem in which variables oscillate around an equilibrium.

This year's OE enrollment projections for 1980 are two million fewer than they had in their 1973 projections. If they are correct, the net addition to full-time faculty in the 1972 to 1982 decade will be only 34,000 faculty members. This is fewer than were hired in the single year 1965. During the period from 1962 to 1972 the number of full-time faculty expanded by 211,000. For the coming decade, the Office of Education suggests that the net increase in full-time faculty will be 34,000. Only a year ago OE was projecting an increase of 125,000 for the coming decade. The revisions in OE's projections have been rather extreme.

There is a commonly held view now that the period from 1970 to 1972 was a time of readjustment, and things are getting back into reasonable balance. We are once again talking about a shortage of engineers today while in physics it looks as if Ph.D. production may drop to only eight or nine hundred per ve- ' the late 1970's.

It is appropriate that we have continuing concern for the possibility of shortages in some fields, particularly in science and engineering fields where a large part of eventual employment is going to be in government and industrial R&D. However, the over-supply of doctorates in the general academic labor market looks grimmer for the period from 1980 to the early 1990's than it has at any time in the past.

I am pleased that NSF is beginning to realize that there may be a growing long-term manpower problem, especially at a time when the Department of Labor and the Department of Health, Education and Welfare seem not so concerned. Perhaps by the end of this meeting we will have a much better grasp of what we do and do not know, and how we can better monitor and improve manpower projections.

I would like to give special credit to Dr. Russell O'Neal of Bendix, chairman of the Ad Hoc Subcommittee of the Board, for being instrumental in organizing this meeting, and thank the NSF staff and other members of the Board committee who have been extremely helpful.

2. Experience in Projection of the Demand for Scientists and Engineers

This chapter is based on the oral presentation of Harold Goldstein and on his paper. The lead discussants were David W. Breneman, National Board on Graduate Education, and B.O. Evans, IBM Corporation.

Harold Goldstein
Consultant
National Manpower Institute, Washington, D.C.

The Need

Why do we need projections? Who uses them, and for what? Projections serve the purpose of providing information for decisions. The decisionmakers needing projections of demand of scientists and engineers are:

- *Young people.* They need them to make vocational choices, particularly if they are considering occupational areas which require long training periods. Before investing years of time, effort and possibly large sums of money, young people want to know their prospects for finding employment in a particular field as well as their potential earnings. If they could be helped to choose fields of study more in line with future manpower requirements, the great fluctuations in the supply/demand aspects of the labor market might be smoothed out.
- *Government.* Projections provide the government with data which may be used to develop educational support policies, or to determine the possible impact of new programs on the availability of trained manpower, or to limit the scope or extend the time frame of programs. New programs affect manpower supply and demand in that they can indicate the need to train more people, or to provide for dislocations which might result from shifts in demand.
- *Industry.* Industry needs projections to develop its own strategies and policies for manpower recruitment, training, and retraining.
- *Educational institutions.* Both as producers of trained manpower and as employers, educational institutions must anticipate manpower requirements. They must decide what programs may be needed and what faculty and facilities might be required.

It was for this first group—young people—that over thirty years ago the Bureau of Labor Statistics began making projections of manpower needs. It focused on the professions, the skilled crafts, and other career fields which require long periods of training. The information is published every two years in the *Occupational Outlook Handbook* which is widely used by high school and college students; 108,000 copies of the last edition were sold. Though economic factors are not the only ones which affect vocational choice, the projections of employment opportunities and salaries in the *Handbook* help young people make rational decisions, for themselves, by providing accurate and timely information.

The Statement

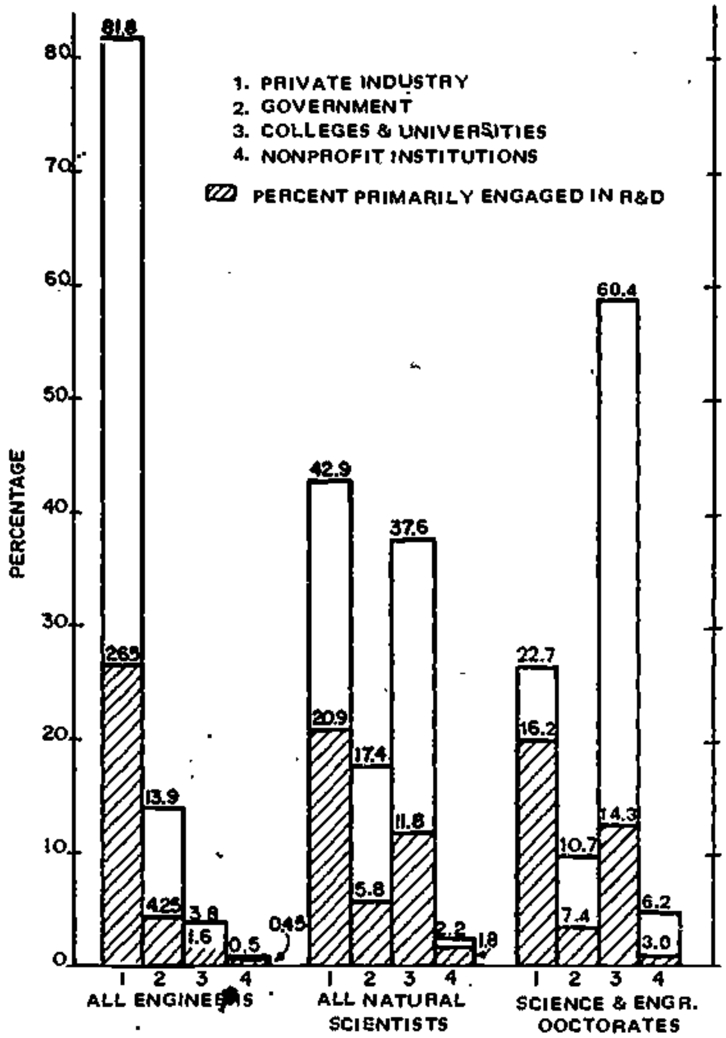
In making predictions to aid decisionmaking, we can either try to forecast what *will* happen, how demand and supply will be forced into equilibrium by the wage mechanism, or we can state the problem and leave the decisionmaking to the participants. I favor the latter approach. Specifically, this means that predictions of requirements for workers are made assuming continuation of present economic patterns, the growth of different sectors of the economy, and the utilization of different occupations independent of the supply of manpower. Secondly, projections of the manpower supply, of the number of young people entering each occupation, are made based on the continuance of present patterns of occupational choice. With these approaches, two projections result which can be examined for areas of match and mismatch in anticipated supply and demand for particular types of manpower. These data indicate the direction and magnitude of imbalances which may occur and provide information of use to decisionmakers.

The first task is to project requirements. This is done assuming unchanged relative wages and prices. Traditionally, the methods for projecting requirements which are used in this country and elsewhere are directed toward analyzing the factors that affect demand. An analytical method is used to project demand rather than surveying individual employers as to their own future needs because the latter method has not worked well in the past. Figure 2 gives data about the current utilization of scientists and engineers. (See also Table 2.1 in the accompanying paper.) Note that something like 80 percent of the engineers and 40 percent of the scientists in the U.S. work in industry. Of the engineers in industry, about one-third work in R&D; of the scientists, about one-half work in R&D. Thus, R&D expenditures in industry in particular have an important effect on industry's need for engineers and scientists.

In order to make meaningful projections, analysis must be disaggregated. Instead of considering scientists in general, one must consider chemists, or to be even more meaningful, chemists working in the paper industry. The paper industry, for example, employs four or five thousand chemists and their employment is framed by the activities and interests of the paper industry. Understanding this environment allows projections which are based in and can be tested against reality. It would not be possible to run a similar test on a projection of all 130,000 chemists, with all their diversities, in all the different industries that employ them.

The government is a major creator of requirements for scientists and engineers. As Figure 2.1 shows, a large number of scientists work in government. But governmental needs are not strictly market-oriented. The decisions of government to engage in particular programs and hence to create demands for this or that kind of personnel are ultimately based on the decisions of legislatures. To project effectively, one must look at the programs being mounted in government at all levels and examine the program plan and design in terms of manpower requirements, the kind and numbers of workers required, and the mix of occupations needed. This requires, however, second guesses about what the Congress, State legislatures, and other government decisionmakers will choose to bring to implementation.

Figure 2.1
Distribution of Engineers and Natural Scientists by Type of Employer and Percent Engaged in R&D (a)



(a) Data for doctorates are for 1973; data for all engineers and natural scientists are for 1970.

SOURCE: H. Goldstein, based on data from the Bureau of Labor Statistics and the National Science Foundation.

Projections of requirements in industry and government require estimates of the demand for scientists and engineers in terms of specific factors which affect it: the level of economic activity in each sector of industry, the amount of R&D engaged in by each sector, and the ways in which scientists and engineers are utilized in each sector. These activities, however, do not function in isolation; they are interdependent with national activities such as the growth and changing composition of the population, national income and production, and the distribution of products.

The Method

The Bureau of Labor Statistics, as part of a federal interagency research project on economic growth, is engaged in the preparation of projections of long-term trends in industrial and occupational growth. The BLS seven-step projection model, described in the accompanying paper, requires a functional model of the total economy since it involves such things as projecting the growth of the economy, the growth of various industrial sectors, and changes in the composition of each sector.

In making the projections, assumptions are made about the rate of economic growth which in turn is based on the projected growth of the labor force, assuming full employment and expected productivity growth. An underlying assumption of BLS projections is that we would be close to full employment (4.0 percent unemployed). If that assumption is not satisfied, it will affect the employment of scientists and engineers. The projections include the use of input/output analysis which allocates final demand for consumed products to the various producing industries. For example, the demand for automobiles relates to the auto industry, but it also relates to the steel industry, glass and rubber industries, and other contributing suppliers of the auto industry. The results of the analysis are checked against independent multiple regression analyses of the relation of production or employment in each industry to the major variables affecting it.

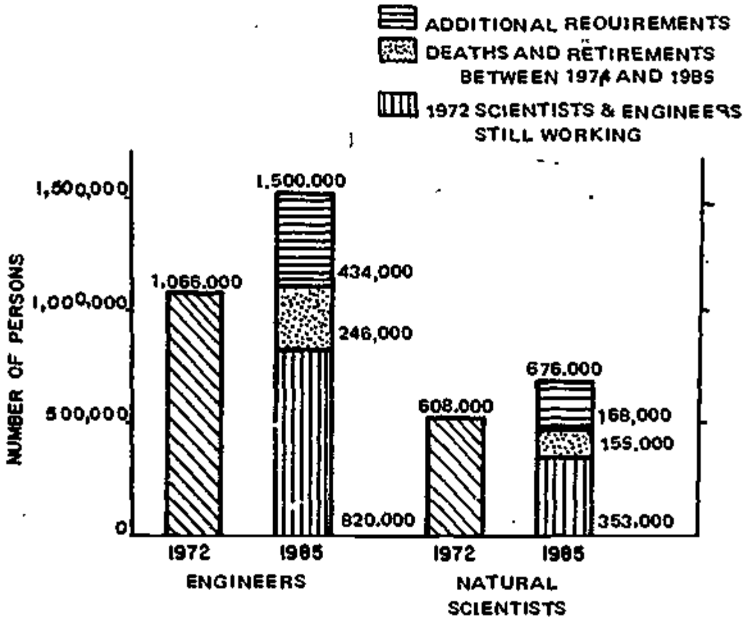
One difficult factor to assess is the occupational mix of industries; this mix is used to determine future employment by occupation. While some substitution of one profession for another occurs among scientists, engineers and technicians, the amount of substitution appears limited. Also, the mix is affected by technological change. This poses problems in making projections since scientists and engineers are at the forefront of technological change and thus are the originators as well as the recipients of the effects.

For information about the current occupational mix of scientists and engineers in industries, the decennial census has been the only data source, but it has been rather inaccurate; moreover, it has given us aggregated occupational composition for each industry, not data on individual plants. The Department of Labor is just beginning to make systematic surveys of employment by occupation in individual plants; the resulting data are expected to aid in the analysis of differential occupational composition.

The results of the latest BLS projections of requirements for workers in all occupations were issued in December 1973. The projections for scientists and engineers are shown in Figure 2.2, based on data in Table 2.2 in the paper. The projected requirements of 1985 indicated much slower growth from 1980 to 1985 than is expected for the period up to 1980. The tentative conclusion is that when occupational requirements are projected against projected supply, there will be, in the early 1980's, more persons qualified to work in the scientific and engineering professions than there are jobs. This means more of today's students will be employed in nonprofessional, nonmanagerial occupations in the future than in the past; that is to say, they will be underemployed.

Again, however, all this could be—and, we hope as a result of publication of the projections, will be—affected by changes in choice and preparation of students.

Figure 2.2
Employment and Demand for Engineers and Natural Scientists, 1972-1985



SOURCE: H. Goldstein, based on data from the Bureau of Labor Statistics.

The Outcome

A reasonable question to ask is, "How well have past projections been made?" The response comes with caveats. Projections cannot be tested accurately against the actual; first, because assumptions underlying the projections—such as full employment and no war—are not borne out, and second because demand was explicitly plotted without consideration of supply, and supply without consideration of demand. It was expected that adjustments would be made in both supply and demand as decisionmakers reacted to the projections and to unfolding events.

The projected requirements for scientists were fairly close to actual; the requirements for engineers in the past decade were overestimated. A principal reason for the overestimation was the assumption, quite generally held in the early 1960's, that R&D expenditures would increase to 3.7 percent of the gross national product. It never achieved more than 3 percent of GNP and in the 1970's tapered off to 2.7 percent. This led to overprojection.

A review of projections made since the beginning of the 1960's indicates that the projections are getting better. This is due to improved techniques and more sophisticated methodologies. It is not to say, however, that further improvement is not needed.

In conclusion, several points should be emphasized:

- The need to replace manpower, because of death or retirement, will account for a large part of future employment opportunity. A lot of time is spent on analysis of demand, but not enough on replacement. More attention must be given to it.

- Research should be expanded on the question of utilization of occupations in industry and the responses of industrial organizations to technological change, relative wages, and general supply and demand factors.
- Occupational data must be analyzed and disaggregated by plants in order to be of maximum usefulness.
- Short-term projections are needed. Typically projections have been for ten to fifteen years forward. Four or five-year projections would be useful for many purposes.
- Methodologies must be examined and systematically checked to determine the sensitivity of the projections to their various internal assumptions.
- Continuing and unremitting research on manpower projections is needed and must be carried on in the broad context of the whole economy and for all the relevant occupations. We need to know how occupations are interrelated. Responsible analysis requires a continuing across-the-board research program in the field of manpower projections.

David W. Breneman, Discussant
Staff Director, National Board on Graduate Education

Three themes seem to be common to the papers prepared for the conference. The first is the attempt to understand the labor market by means of economic analysis of supply behavior. Freeman's work is perhaps the best example of this type of analysis. A basic question is the extent to which students respond to the economic aspects of the market. Goldstein in his written paper and in his remarks commented on this problem when he noted that ". . .economic information plays only a modest role in career decisions," and that ". . .psychological and social factors as well as personal commitments to a field of interest" play a role in the choice. The question is what quantitative role do the various factors play?

It is evident that projections ignoring market demand are simple nonsense, yet the arguments which occur on this subject are usually anecdotal. Everyone knows students who are going into physics no matter what. When this type of argument arises there is a tendency for the arguers to say either that the economic models of student response to demand are accurate (i.e., all students are choosing fields with regard to wages), or that the models are totally wrong.

What is lacking is an understanding of how important the various factors, economic as well as social, are in the process of career choice. Neither position, all economic or all social, is correct. There is a distribution of reasons. Some students are probably influenced almost totally by price; some hardly at all.

There is no reason, though, why a supply-demand curve for manpower cannot be drawn incorporating all classes of students, with this analysis used in manpower projections. Empirical estimates of how responsive the supply curve is to economic effects are important pieces of information. With that sort of information, forecasts can be made about the likely affects of simple economic factors. This research is in its very early stages, however.

A second point concerns the inability of projections to be integrated with policy variables. A case in point involves the report of the Newman Task Force on Graduate Education. One finding was that during the 1960's when large amounts of federal money were spent supporting science and engineering in the universities, the proportion of Ph.D.'s in science and engineering did not increase with respect to total Ph.D. production. The conclusion reached by the Task Force was that universities had been substituting federal funds for their own in the sciences and shifting their own funds to humanities and the social sciences. This is a fundamental policy issue and one that those who have been making projections should be in a position to comment upon. In spite of all the work on factors affecting supply and demand, an evaluation of the conclusion cannot be made, in part due to the failure of projection techniques to consider behavioral components of the total system. A more explicit analysis of the behavioral side, an example of which is student supply behavior, is necessary before conclusions can be reached about what policy variables do or don't do.

At least one potential data base exists for examining this question, the NSF Graduate Student Support surveys. Over the past few years, federal support for fellowships has been drastically reduced. What effect has this had on the number of students, their distribution by university, and what (if anything) is happening to the quality of the students? We need to analyze existing data for insight into these questions.

Finally, one great enigma concerns the response of the universities. In the manpower market the universities are the producing firms. Yet there are almost no studies of the "theory of university behavior." Adjustments of many types are occurring and yet the modes and mechanisms of response are not being analyzed. Universities will not expand or contract simply as a means for pumping out trained manpower. To make adequate projections, present techniques must be augmented and an analysis of the producing sector of the market included if implications of various policy options are to be understood.

B. O. Evans, Discussant
Office of the President, IBM Corporation

Mr. Goldstein's approach, forecasting demand by analytic methods based on econometric models of GNP and R&D expenditures, yields projections which may be accurate in the large, but may not be accurate in the small. It is the technique of mailing questionnaires to individual industries which is probably unreliable. IBM's experience is an example of what might occur.

In 1950, IBM employed less than 3,000 scientists and engineers; in 1964 the number had risen to 10,000; in 1973 it had risen to 20,000. This sort of increase in demand for scientists and engineers could be forecast. What would offer more difficulty is predicting the mix of specialties within that demand. The mix changes as a result of technological changes within the business, the technological changes in turn being stimulated by the scientists and engineers.

The speciality changes were dramatic within IBM. For example, in 1950, 50 percent of the scientists and engineers were mechanical engineers. There were no programmers nor were there any significant number of physicists. In 1973, mechanical engineers comprised less than 8 percent of the work force, with programmers now comprising 36 percent. Physicists accounted for 5 percent. The question is raised as to whether the macro approach ("top-down") would be sufficiently sensitive, even in its disaggregated form, to offer useful manpower data in a situation such as this. Better techniques of building internal data of this type into the models should be explored. Perhaps questionnaires to industry offer a means to develop some of this data. Some way must be found to get industry to pay attention to the questionnaires and to introduce more accuracy to their responses.

The computer industry might be an excellent candidate for case study. The applications of computers now touch more industries, businesses and institutions that will generate professional requirements in the future. Analysis of specific requirements of the computer industry might in this sense give a valuable indication of future needs for scientists and engineers in the society.

General Discussion

Following the remarks of Mr. Goldstein, Dr. Breneman, and Dr. Evans, general discussion raised several new points and expanded on some already discussed. The areas of concern are listed below.

- The question of how inclusive econometric models actually are was raised. It was agreed that conceptually they could be made to be all inclusive, but in fact they are not. It was suggested that a promising area of research would be to see how far the models could be pushed even in their present states.

- The question of the real meaning of percentage changes in manpower demand was examined. Lee Grodzins presented data on migration of faculties in physics departments from 1972-73 to 1973-74. While the actual change in positions was only 23 (a drop), this small change was accomplished by 291 faculty leaving and 256 entering (the two sets are independent) for a flux of 547. Thus, while the actual number of faculty employed changed from 4,481 to 4,458, this was accomplished by 547 individuals actually switching jobs. This same situation is probably true in industry. Grodzins stressed that upgrading in employment—the hiring of Ph.D.'s into positions held by non-Ph.D.'s—is proportional to the flux of employment (the 547 figure above) and not on the net change (the 23 figure, above).

- The possibility of substitution was discussed; it was noted that while engineers are lumped together in projections, there is probably less of a chance of one engineering specialty substituting for another than that of one scientist substituting for another. For example, there is a greater difference between an agricultural engineer and an electrical engineer than between a physicist and a chemist. Further, 110 engineers (referring again to Grodzin's data) who received their Ph.D.'s in 1972 joined physics departments and twelve chemists became physicists. In short, models must include consideration of these substitution possibilities if they are to accurately represent the potential supply of manpower to fill demands. (With total substitution, the problem would vanish.)

- It was agreed that questionnaires aimed at determining demand have not been very useful, partly because of lack of any response, but partly because response has not been well informed.

- A need does exist for intermediate projections (i.e., projections of five years or less). It is possible that these will be affected more by short-term economic cycles than are the long-term projections which tend to balance out, but they may be useful.

The formal paper prepared by Harold Goldstein for this session appears below.

Experience in Projection of The Demand For Scientists and Engineers

This paper will concentrate on the projection of demand—only half of the total subject—but since demand and supply are not independent, I will consider that I have a license to poach on the supply side as well.

It will begin by looking at the purposes for which projections are made, and what they must do to best serve these purposes. We will then review the methods that have been used and some of their problems, look at the accuracy of some of the projections, and conclude with some suggestions for their improvement.

The major purpose projections serve is to provide information for decisions, on the theory that a free market functions best when all the participants are well informed. The participants in the scientific and engineering market include individuals (students and adult workers), employers, government, and educational institutions.

1. Individuals choosing a field of training, particularly one requiring an investment of several years, want to know their chances of getting a job in the future, and their potential earnings.
2. Government needs to make decisions on the support of education, and also needs to know the implications of major contemplated program changes (such as launching or curtailing defense, medical research, medical service, housing construction, highways, space, or energy research and development) for the availability of trained manpower, which may affect the speed with which the programs are launched, or policies for the support of additional training.
3. Employers need information on which to base decisions on recruitment, training, utilization, salaries, or even capital investment to replace scarce labor.
4. Educational institutions need information both as employers and as producers of trained workers—in this case scientists and engineers; they have to make long-term decisions on construction and staffing.

Individuals are listed first because their decisions have a major role in labor market adjustments. While they are in school the young people who will enter the labor market annually are potentially the most flexible participants, since they have as yet no investment in specialized education or in years of personal commitment to an occupation. If they make their decisions on a course of education on the basis of the longer-term outlook rather than the immediate situation, we might avoid the crazy see-sawing in demand-supply balances resulting from the necessarily lagged response to the current labor market picture that Richard Freeman describes so well in his account of the "cobweb" adjustment pattern for occupations with a long training period. A case in point is the drop in first-year enrollments in engineering in response to reports of unemployment of engineers in the past few years without regard to the outlook. It was with this need in mind that a President's Advisory Committee on Education recommended in 1938 that an occupational outlook service be set up in the Bureau of Labor Statistics. The interest in this information is illustrated by the sales of the Bureau's biennial publication, *Occupational Outlook Handbook* (14); 108,000 of the last edition were sold at the hefty price of about six dollars a copy—the equivalent of more than three copies for every high school and college in the United States.

Having said this, we have to realize that economic information—on employment opportunity, wages, working conditions—plays only a modest role in career decisions. Anyone in contact with youth knows this, and the literature on vocational choice bears this out—emphasizing psychological and social factors, as well as personal commitment to a field of interest. This is true even of the studies in which not only psychologists and vocational guidance specialists but also economists worked (21, 28). At most, one can say that among all the students interested in a field there is, as a result of the value system of each student, a continuum of degrees of commitment, at one end of which are those who would most readily change their goal if employment opportunity or economic reward seemed less promising than elsewhere, and this provides some margin of adjustment (32). One of the questions is whether the information available to them—for example, on relative wages—is adequate.

On the employers' side there are also rigidities and inelasticities in adjustment to supply-demand conditions. Theory leads us to expect that they will use more workers in an occupation when the wages are low relative to those of workers who can be substituted, or relative to the cost of machinery or equipment that could do the same work; and that the reverse would be true with high relative wages. But substitution is limited by the technology of the industry, the way work is organized, and institutional factors such as unions, professional societies, licensure laws, and notions as to what is proper. (Can you see a university hiring only mathematics professors because they are cheap this year?) The production process, whether in a cookie bakery or a college, requires some particular mix of occupations. Some substitution is possible, such as using more technicians when engineers are hard to get. Substitution also takes place within occupations by using less competent or qualified workers. It is plausible that the elasticity of demand in response to relative wages varies among industries and, within an industry, among occupations.

The decisions government has to make in considering new programs require not only information on the kinds and approximate numbers of highly skilled workers needed for a given type and amount of expenditure, but also the outlook for the demand/supply picture for these workers in the economy, excluding the contemplated program. Changing the pace of introduction of the new program, or stimulating additional training are some of the decision responses that might follow.

From these comments on the nature of decision-making we may draw several implications for the kind of outlook information that would be useful.

The time horizon for projections for use in occupational choice and government program development has to be at least as far into the future as the length of the period of education or training—a minimum of four or five years for professional occupations, and longer for many of them. Employers and educational institutions may be able to make their decisions with less lead time.

Since the uncertainty of projections probably increases with time, projections for a series of years into the future—say, every five years—would be more informative than the single-point projections that are commonly made for ten-year periods or more.

The kind of statement that is made is critical. One approach is to make a "best estimate" of what is likely to happen. Since the purpose is to help people to make decisions that will affect the outcome, a forecast of this kind—even assuming it is technically possible—appears inappropriate because it prejudges the decisions, and thus obfuscates the important policy issues.

Another approach is to state what would happen if present trends and patterns of relationships were to continue without any attempts to modify them to achieve a better outcome; the conclusions would suggest whether any action is needed and, if so, how much. More concretely in application to projecting demand and supply of scientists and engineers, this approach would first estimate the numbers of each type of scientist that would be employed to meet production and other needs if the growth of the economy and the patterns of utilization of scientists were to continue as in the recent past. (This is, more precisely, a projection of "requirements" under the assumption of unchanged relative wages and prices, rather than of "demand" which is properly related to wage levels.) Second, it would estimate the number of scientists available if current trends in the number of students entering the field, and in other patterns of behavior affecting the supply (retirements, etc.) were to continue. Comparing these estimates, we learn whether present trends are leading to a balance of supply and demand or an imbalance. The direction and magnitude of the imbalance would suggest the extent of the adjustments needed. This would leave the options of students, employers, government and schools open for a variety of combinations of adjustment measures, such as were described in one of the projection reports by the Bureau of Labor Statistics:

> The purpose of these projections of scientific, engineering and technician demand and supply is to provide information on the Nation's future scientific and technical manpower situation—both as a basis for consideration of possible actions and as a framework of data against which the results of these actions may be evaluated. Since the demand projections were developed without taking into account limitations in future supply, they represent needs in 1970, rather than actual employment. . . It is unlikely that deficits of the magnitude projected for engineering manpower, for example, will be clearly observable in 1970. Accommodations to the existing manpower situation will occur each year, and adjustments will be made by employers of these personnel. Some adjustments might result in projects and programs being postponed or even canceled. Other adjustments could result in all programs still being carried out, but only with difficulty, less efficiently, or over a longer period than anticipated. Others could result in steps being taken to improve utilization of available scientific and technical manpower. Efforts to avert potential shortages might also take the forms of inducing more students to major in engineering or science fields or in technician programs and of inducing more graduates to remain in their fields after graduation.

* * *

Illustrative projections of the supply of scientists, engineers and technicians likely to be available in 1970 were also developed to illustrate the relationship of demand and supply if no actions were taken to affect the supply. The supply was projected on the basis of population growth and assumptions as to the proportions of college-age population going to college and the proportions of college students taking science and engineering. No attempt was made to allow for events which might radically alter currently foreseeable trends, such as special efforts to increase the supply through legislation by Congress or specific actions by Government agencies, professional societies, or industrial concerns. The prediction of such events, the results of which could greatly affect requirements for or supply of scientific and technical manpower, was specifically avoided in this study. Nor was allowance made for more marked increases in salaries which might attract additional persons into these fields.

* * *

Some combination of these and other adjustments in all probability will occur. Thus, actual 1970 employment levels will be at whatever point a balance develops as the accommodations are made to the supply-demand situation. The key question, then, is how the necessary adjustments can be made—whether they can be accomplished with a minimum of dislocation to the economy and without disturbing the free market mechanisms through which manpower allocations and utilization have traditionally been determined in this country (3, pp. 1, 4).

I would add that research on the elasticities of response to labor market imbalance, or relative wage changes, would help participants to judge the extent and kinds of adjustments needed. The decisions should be left to them rather than being taken over by whoever does the forecasting.

Methods for projecting requirements for scientists and engineers

Before discussing methods, let us look at where scientists and engineers work. Private industry employs 82 percent of the engineers, 43 percent of the natural scientists, and even 23 percent of the Ph.D.'s in these fields. Educational institutions employ most Ph.D.'s and a substantial portion of the scientists (Table 2.1). It is also apparent from the table that we have to assess the requirements both for those engaged in research and development and for those engaged in other work.

Two general methods have been used to project requirements: one is to ask employers what their future requirements will be; the other is to analyze the factors affecting demand and then estimate how these factors will operate in the future. We may call these the "questionnaire" method and the "analytical" method.

The questionnaire method has been used in the United States and in other countries, both for short-term projections (a few months ahead) and for long-term projections, but its use is diminishing as experience has often shown poor results (22, p. 146; 20, p. 19 and 240-260).

Table 2.1
Distribution of Engineers and Scientists, by Type of Employer, and Percent Engaged in Research and Development,[a] 1970

Type of Employer	All Engineers		All Natural Scientists		Science and Engineering Doctorates	
	Percent of Total Employed	Percent of These Engaged in R&D	Percent of Total Employed	Percent of These Engaged in R&D	Percent of Total Employed	Percent of These Engaged in R&D
Total	100.0	—	100.0	—	100.0	—
Private industry	81.8	32.4	42.9	47.3	22.7	71.2
Government	13.9	30.6	17.4	33.2	10.7	55.5
Colleges and universities	3.8	43.4	37.6	31.5	60.4	23.7
Nonprofit institutions	.5	91.4	2.2	80.2	6.2	48.6

Sources: Engineers and natural scientists: *Employment of Scientists and Engineers, 1950-1970*. Bureau of Labor Statistics Bulletin No. 1781. 1973. p. 33, 39, 43 and 49.

Science and engineering doctorates: Based on *Doctoral Scientists and Engineers in the United States, 1973 Profile*. National Academy of Sciences. March 1974 and unpublished data. Data represent 1973 status of all those receiving doctorates through mid-1972.

[a] Major activity reported by respondents; additional persons, particularly in colleges and universities, are also engaged in R&D.

If a firm has given careful thought to its long-term economic prospects and investment plans, it should be able to make good judgments of its own manpower needs (36). Unfortunately, few firms do this, and when approached for an estimate give answers based on hunches, and unstated—and possibly inconsistent—assumptions about general economic growth. There are better ways of tapping the insights into technological change, policy decisions, and institutional factors affecting utilization of occupations that undoubtedly exists in industrial management; these will be referred to again.

Applying analytical methods to projecting the requirements for scientists and engineers involves looking at each type of employer separately. Occasionally attempts have been made to project requirements for an occupation on the basis of an overall relationship with major explanatory variables, but this is subject to substantial error; the major employing sectors of the economy are growing at widely different rates, some are declining, and their utilization of various occupations is changing in different ways. Moreover, a sector-by-sector analysis makes it possible to take explicitly into account such new developments as a massive energy research program and to spell them out in terms of the specific industries or occupations affected. Finally, highly generalized relationships do not lend themselves to concrete tests of plausibility: employment of chemists by the paper industry can be usefully examined, trends can be reasonably analyzed, and, (most important) errors later identified and corrected, while a projection in one swoop of the employment of 130,000 chemists in the United States is a pig in a poke, analytically and metaphorically speaking.

The future utilization of scientists and engineers in each sector depends on both the future levels of economic activity in each and the way in which the sector is changing its patterns of utilization of occupations, including R&D programs. It becomes quickly apparent that the growth of each sector depends on the general growth of its potential markets, and therefore the growth and changing composition of the population, national income and product, and the distribution of the product among consumption, investment, and government expenditures.

The Federal government is engaged in a continuing Interagency research project on economic growth, out of which the Bureau of Labor Statistics has published a series of projections of the growth of the economy, of each industrial sector, and of the growth in requirements in each of several hundred occupations. (8. This publication lists earlier reports.) The most recent report was issued several months ago, with projections to 1980 and 1985 (13).

The attempt is to project the long-term trends in industrial and occupational growth, rather than to pinpoint demand or employment in any one year, which might be affected by temporary aberrations such as a recession, a war, or a fuel shortage. The projections explicitly assume a low level of unemployment (4 percent), and Armed Forces of two million, slightly below the present level, and defense expenditures declining as a proportion of the gross national product. The use of a "full-employment" assumption tends to overstate employment opportunities somewhat; projections have been made on alternative assumptions, and the sensitivity of specific occupations to business cycles is usually pointed out in the occupational outlook reports.

The method involves several major steps:

1. The potential gross national product is projected at close-to-capacity levels (assuming that 96 percent of the projected civilian labor force will be employed, that output per man-hour will grow at its long-term rate, and that average hours of work will decline somewhat.) In the latest projections, GNP is projected to grow at the rate of 4.6 percent a year from 1972 to 1980, and 3.2 percent a year from 1980 to 1985, the slow-down resulting from a declining rate of growth of the labor force. Employment would increase by 2.2 percent a year up to 1980, and 1.2 percent from 1980 to 1985.

2. The projected GNP is distributed among personal consumption, investment, and government purchases of goods and services by a macroeconomic model, and the amounts of each kind of goods and services that would be finally consumed is estimated on the basis of patterns of consumer and government expenditure and capital investment.

3. The production level in each industry—including those providing raw materials, transportation, components, and services—required to produce these final products is estimated by input-output relationships among industries, the method initially developed by Wassily Leontief (whose Nobel prize was largely in recognition of this accomplishment). The input-output coefficients from a base year are adjusted to reflect subsequent and expected future technological changes—for example, the use of a different mix of raw materials in the manufacture of a product. Results of this method are checked against estimates of production in each industry developed by regression analysis of the relationships between output in the industry and the major factors that have been found to affect it, such as GNP, gross private domestic investment, consumer expenditures, net family formation, or defense expenditures. For major industries a more thorough analysis is made of markets, technological changes, and the foreign trade balance if relevant.

4. Projected industry production is converted into industry employment requirements by projecting productivity change and hours of work.

5. Projected requirements for workers in each occupation in the industry are estimated on the basis of the occupational composition of the industry, adjusted to reflect expected changes in technology and patterns of work organization. The numbers of scientists and engineers engaged in research and development in each industry are checked independently against projections of R&D expenditures in relation to the level of business activity, allowing for rising average costs. The projections for the major industries are discussed with management to get insight into market, technological and other factors that have impinged on past trends and may affect the future, as technological innovations are introduced. This is a quite different and more productive way of drawing on the knowledge and judgment of industry than sending them a questionnaire asking for their projections of manpower requirements.

6. For two major sectors of the economy employing scientists and engineers, higher education and government, the projections use different methods. Office of Education projections of graduations by field are used to project the employment of faculty members teaching in each field, assuming a constant relationship of teaching load to students majoring in the field (a dubious assumption in the case of tool subjects like mathematics). R&D scientists in higher education are projected on the basis of a projection of total R&D performance by higher education institutions, which is itself derived from a projection of total R&D as a constant proportion of GNP, prorated among performing institutions in line with past patterns.

   The programs composing Federal, State and local government employment—schools, health, highways, defense, police, etc.—are projected separately, since their use of occupations is quite different. Projections here are essentially guesses as to what legislatures will appropriate, and are not based on market behavior, as are the projections of activity and manpower in industry.

7. The requirements for each occupation in all industries are then summarized. To the net growth in requirements in each occupation is added an estimate of the replacement needs resulting from deaths and retirements. This is estimated from the age composition of the members of the occupation, using death and retirement rates for men and women at each age developed from tables of working life.

The projections for scientists and engineers derived in the most recent study are shown in Tables 2.2 and 2.3.

Comparing the manpower requirements projected for these and other occupations requiring higher education with projections of college graduates made by the Office of Education, the BLS concludes that if these trends were to continue there would be an excess of graduates, even after allowance for recent patterns of absorption of graduates into jobs once performed by less educated workers. The excess would be greater in 1980-85 than in 1972-80, because of the expected slow-down in the economy's growth. Many additional graduates would have to take lower-level jobs. If past trends in the courses students select were to continue, shortages of graduates would occur in medicine, chemistry, and engineering, and oversupply in teaching and the biological sciences (13).

Table 2.2
Employment of Scientists and Engineers, 1972 and Projected Requirements, 1985

	(in thousands) Estimated Employment 1972	Projected Requirements 1985
Scientists end engineers, total	1,573.9	2,185
Engineers	1,066.3	1,509
Scientists, total	507.6	676
Mathematicians	76.1	107
Physical scientists, total	249.8	334
Chemists	133.5	184
Physicists	48.9	61
Geologists and geophysicists	31.3	43
Other physical scientists	36.1	46
Life scientists, total	181.7	235

Source: Bureau of Labor Statistics

Table 2.3
Job Openings for Scientists and Engineers Resulting from Projected Increases in Requirements and Deaths and Retirements, 1972-1985

	(in thousands) Increases in Requirements	Deaths and Retirements	Total Openings	Average Annual Openings
Scientists and engineers, total	611	401	1,012	78
Engineers	443	246	689	53
Scientists, total	168	155	323	25
Mathematicians	31	24	55	4
Physical scientists, total[1]	84	64	149	11
Chemists	51	38	88	7
Physicists	12	8	20	2
Geologists and geophysicists	12	6	20	2
Life scientists	53	66	120	9

Source: Bureau of Labor Statistics.

[1] Includes other physical scientists, for whom no separate projections were made.

Problem areas in methodology

Following the above brief summary of the methods followed, some comments on the problem areas are in order.

As a general comment, one must recognize the difficulty of anticipating some factors making for economic change. In addition to those, like wars and depressions, which have to be assumed away like Cinderella's coach, the most pervasive is technological innovation. It is not easy to predict scientific breakthroughs or their effect on technology, markets, and the kinds of occupations and industries affected. Although the BLS has a staff constantly studying the subject and watching innovations as they are introduced into industry (some years back a member of the staff went all over the country looking for the first computer-controlled machine tool), this is to some extent a guessing game. Only the fact that after an innovation has actually been introduced into production it usually takes some years before it is widespread makes projections for five to ten years not too hazardous (34).

Similarly, events like the petroleum exporting countries getting together and suddenly facing the whole world with a very substantial increase in the price of energy cannot easily be anticipated. This requires a re-evaluation of the latest projections as soon as the new situation takes shape. The outlook for scientists and engineers may be markedly affected by large research and development programs on alternative energy sources or on fuel-saving throughout the economy.

Going back over the steps in the method outlined above, it is apparent that some are likely to result in larger errors in a projection than others.

Projections of the labor force for up to 15 years ahead, the foundation of the general economic growth rate and GNP projection, have usually been accurate within one or two percent, since they are based on population already born, and therefore are only minimally affected by difficult-to-predict birth rates (which do affect the labor force participation of women). The assumption of 4 percent unemployment may be overly optimistic; the average since World War II—a period that includes two wars and five recessions—has been 4.7 percent. But this introduces an error of about one percent in the estimate of total employment, and somewhat more in industries and occupations more sensitive to business cycles—manufacturing, construction, transportation and public utilities and trade; a one percent difference in total employment was estimated to result in a 3.5 percent difference in manufacturing (4, p. I-132). These errors are well within the band of error we expect in long-term projections for decision-making. Somewhat larger errors in the projection of demand for scientists and engineers can be introduced in the projections of industry employment and of the occupational composition of industries.

Industry employment or activity growth rates can be crucial because scientists and engineers are heavily concentrated in certain sectors. Two-thirds of them are in the metal products, chemicals and construction industries, engineering consulting and business services, and colleges and universities. Projections of industrial activity are heavily affected by how final demand is estimated, and the translation of activity levels into employment by a projection of productivity (which reflects technological change).

Errors in projecting the occupational mix of industries can also be critical. Here our sources of data for the past are poorest, and the analysis most tentative. Moreover the occupational mix is more likely to have been affected by supply-demand balances in individual occupations than is total employment in an industry. The main sources of data are the decennial censuses and special industry surveys. Past changes in ratios are examined and an attempt is made to relate them to the technological and organizational changes that have occurred, including collective bargaining agreements, and to determine the effects on them of labor market factors. The ratios are projected into the future by judgment, attempting to take into account technological changes but to discount the effects of supply-demand factors in the past. (6, 2)

For scientists and engineers there are special difficulties in this type of projection. Utilization of these occupations in industry is only partly associated with the current level of production. For those engaged in testing, supervision, design and similar functions the relationship to output is not linear. For those engaged in R&D—one-third of the total in industry—employment is related to decisions on R&D expenditures, which are more independent of current production, more discretionary, more like capital investment. Moreover, while change in the employment patterns of production workers *follows* introduction of new technology, and therefore can be more readily anticipated for some years ahead when the technology is being introduced, the employment of R&D scientists and engineers may *lead* the new technology.

One method that may be promising in projecting the occupational mix is to examine that of the technologically most advanced plants in an industry, on the hypothesis that the industry's total mix in the future may come to resemble that of the advanced plants (4, p. I-367). This is not possible from population census data, which shows only the total occupational mix of each industry. A new collection of data on employment by occupation which BLS began in cooperation with State agencies, going to industries rather than to households, will make plant-by-plant analysis possible (30).

One way of getting additional insight into the special factors affecting requirements for scientists and engineers is to compare their employment with research and development expenditures, and use projected growth in the latter as a factor in the projections. For example, the projections for scientific and engineering manpower requirements in a 1960-1970 study were reviewed in the light of projections of research and development expenditures, which were expected to rise by 123 percent from 1960 to 1970, or to 3.7 percent of the gross national product. (This projection was consistent with others being made at that time by the Department of HEW, Arthur D. Little Company, and *Business Week* magazine. The atmosphere was heady in those halcyon days!) Allowing for rising costs per research scientist and engineer, their numbers were projected to double from 1960 to 1970. This appeared consistent with the projection of total requirements for scientists and engineers in the study (3, pp. 10-14). (Actually, R&D expenditures amounted to only about 2.7 percent of GNP in 1970, and R&D scientists' and engineers' employment increased by only 38.7 percent from 1960 to 1970 (12, p. 1, 3). The difference between projected and actual R&D scientists' and engineers' employment in 1970 was 237,000 after adjustment is made for revision of the base period employment estimate.)

While an attempt is made to discount market effects on the occupational mix at this stage in the projections, this information is needed later in examining the possibilities of adjustment to imbalances. Research is needed on these effects and the way in which employers react to changes in relative wage rates. It is a plausible hypothesis that effects differ among occupations and industries: that, for example, utilization of pilots by airlines is less affected by relative wages than that of reservation clerks, or, to take an example closer to home, a construction firm employing one or two engineers is less likely to react to their relative wage rates than is a large electrical manufacturing firm that employs hundreds of them. The degree to which less qualified persons can be used is also likely to be a factor.

The tables of working life that are used in estimating deaths and retirements in occupations are developed for all males and females. While differences in mortality rates by occupation have probably narrowed in recent years as health and nutrition standards improved, there are probably still some differences, and the same may be true of retirement rates. Research in this area could be fruitful, since a very large part of the annual requirements for new workers in most occupations is associated with this component of the estimate (Table 2.3).

In decision-making on the basis of projections it would be useful to know the effect on the outcome of the uncertainties entering at the various stages. This would be clarified if alternative projections were made showing the effect on the outcome of a range of estimates reflecting reasonable possible limits above and below the estimate used for such critical factors as unemployment, productivity growth, production or employment in each industry, occupational ratios, or death and retirement rates. This would show the sensitivity of the projections to errors, and aid the user in interpreting their implications for his decisions. It would also guide the producer of the estimates in allocation of investment in research or data collection to get the greatest payoff in reducing the uncertainty of the estimates. The Bureau of Labor Statistics has made a few such alternative estimates; it is costly, and becomes unwieldy because the numbers proliferate with combinations of alternatives, but it is worth doing.

Evaluation of the accuracy of projections

Accuracy has to be judged in the light of the contribution projections make to the decisions. One criterion has been stated as follows: "A forecast which reduces the uncertainty of a future outcome to a level that dictates a unique decision is clearly useful for policy purposes. On the other hand, if the range of uncertainty in the forecast is so large that contradictory policy decisions are compatible with it, then the forecast may be of little use for planning purposes." (20, p. 24) This criterion implies the availability of a measure of the forecast's uncertainty, which, as we just noted, is lacking for the projections that BLS has published. While we may be able to shed some light on this by hindsight, this valuable commodity was not available at the time the projections were published.

In evaluating the accuracy of projections of the type we have described, it is not relevant to make a simple comparison of the "requirements" projected for a target year with the actual employment in the occupation when that year rolls around. It was expected at the outset that they would not necessarily coincide, for two reasons:

1. The "normative" assumptions of a full-employment and peacetime economy may not have been borne out by events.
2. If a demand-supply imbalance had been projected we would expect the actual employment to be different from the requirements—most likely lower if a shortage had been projected, higher if a surplus—unless all of the adjustment was made in the supply.

While we cannot judge the projections solely on this criterion, it is useful to take it apart and see what elements in the projections differed from the actual event. Some of the elements, such as the industry activity or employment requirements projections, should be less subject to the effect of demand-supply imbalances in occupations, and therefore capable of being judged against actual employment changes.

Only a few projections for scientists and engineers had been made long enough ago so that the target year has arrived. One was published in 1961, with 1959 as a base year and projections to 1970; this was a methodological study (2). A second was published in 1963, used 1960 as a base year, and also projected to 1970 (3). Employment projections for industries were made to 1970 as well as 1975 in a third study, this one focusing on technicians who work with scientists and engineers (5), and we can thus evaluate the industry employment projections and an interpolated value for scientist and engineer requirements in 1970 against 1970 experience. All these studies were conducted with the support of the National Science Foundation.

The methods for industry projections used in the earlier studies were rather crude as compared to those used in the more recent studies: While careful studies of markets, technology, and net foreign trade balance were made for a limited number of important industries, the majority were projected by their relationship to total employment, which was taken as a proxy for the general level of economic activity. Employment for each industry was correlated with total employment, so that what was achieved was a distribution of the previously estimated total among the various industries in line with their average past relationship.

The industry projections in the study of technicians were done by a more sophisticated method, described in a study prepared for the National Commission on Technology, Automation and Economic Progress, which used essentially the same projections (5, p. 45; 4, p. 112-15). In addition to intensive studies of some of the major industries, a general framework analysis of national economic growth similar to the first six steps of the seven-step method described above was used, but since input-output coefficients were not available to distribute final production among industries, a multiple regression method was used, relating production or employment in each industry to major economic variables. Occupational projections were made separately for engineers and a number of other important occupations and reviewed against projections made using the occupational mix of each industry. The approach was eclectic; alternative methods were used at each stage, and estimates that appeared most reasonable were selected.

The projections are shown in the Appendix Tables and in the chart (Figure 2.3). Since the base year data on employment has been subsequently revised (usually by small amounts), all comparisons of projections with actual changes shown by the best presently available statistics are expressed in terms of percent changes. The projections shown in the charts in the appendix are adjusted for differences in level in the base year.

The evaluation in detail is described in the appendix to this paper, and may be summarized as follows.

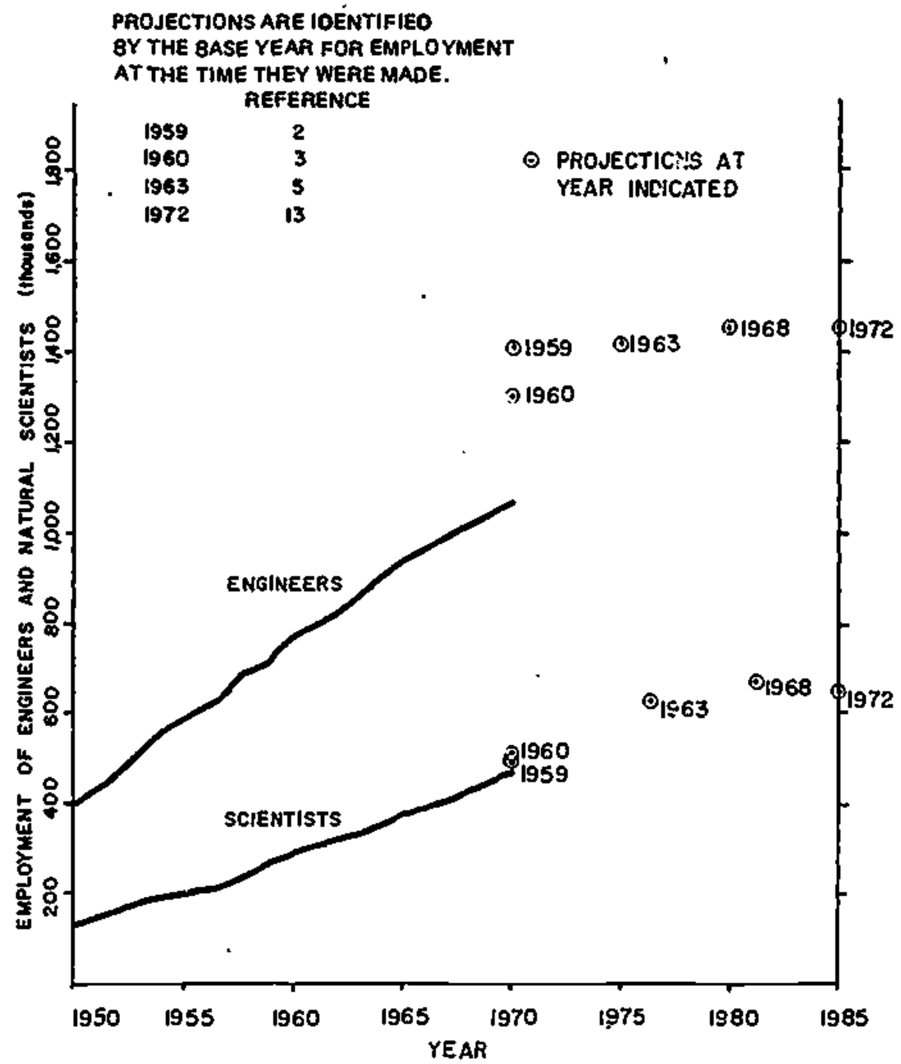
1. A modest expectation that one may have of a statement about future growth in occupations is whether it correctly identifies fast-growing or slow-growing fields. The two projections of scientific occupations for 1970 made a decade earlier correctly identified the scientific fields growing faster or slower than the average in six out of seven instances in one case, and in all instances in the second case.

2. The projections, however, overstated the growth in requirements for engineers substantially. The overstatement was larger in the 1959-1970 projection. A 90 percent expansion in requirements was projected, when an accurate figure might have been closer to half that amount. The increase in the second projection was projected at 67 percent; an accurate figure might have been between 50 and 60 percent of that amount.

   Projections of requirements for scientists were much more realistic in both cases; one showed just about the right increase, the other projected an increase that was about 14 percent too high.

   A major cause of the overprojection was the prevailing view in the early 1960's that total research and development expenditures would grow much more than they actually did. In this sense the projections were not so far off, given this assumption that underlay them and was specifically stated in one of them.

Figure 2.3
Employment of Engineers and Natural Scientists (1950-1970), and Various Projections of Requirements



In the projection from 1963 to 1975, implicit projections interpolated for 1970 showed a 39 percent increase in requirements for scientists and engineers, while actual employment rose by 25 percent. It is likely that this difference, too, represented an overstatement of requirements, since there was an adequate supply of engineers and scientists in 1970.

There was a distinct improvement in accuracy in the requirements projections for the individual scientific fields from the earliest to the most recent; after allowing for the varying periods of the projections (11 years, 10 years, and 7 years, respectively), the reduction in error seems to be of the order of 25 percent. The average error in projecting for a scientific field was down to 2 percentage points per year. This means that in a five-year projection the rate of growth projected would be 10 percentage points off, on the average. The most recent projections, using better methods, may improve on this.

3. The industry employment projections, which have so significant an effect on requirements for the major concentrations of scientists and engineers, have a somewhat greater degree of accuracy. A review of the three projections shows distinct improvement from the earliest to the latest; the average error in projecting the rate of growth for individual industries dropped from 19 to 6 percentage points, or, after correcting for the varying periods, the reduction in error was of the order of 40 percent. Techniques are improving in this area. The average error in projecting employment change in an industry was down to one percentage point a year.

4. On the other hand, the projection of the occupational composition of industries is too little understood and subject to somewhat greater errors in projection. The projected rates of increase in the ratios of scientific and engineering employment to total employment in each industry showed average deviations of 22 and 26 percentage points from the actual rates of increase that occurred, equivalent to an error of 2 to 2.6 percentage points per year in these earlier projections. (It was not possible to make this calculation for the 1963-1970 projection, as has been done above for the projections of requirements for scientists and engineers and the projections of industry employment.)

In summary, these early projections tended to overproject requirements for engineers and were better for scientists; the overprojection reflected an overestimate of the prospective growth of R&D activity that was common at that time; the later projections, embodying improved techniques, are more accurate; industry employment projections are more reliable than projections of the ratios of scientists and engineers employed; and the farther away the target, the harder it is to hit it.

Recommendations for improvement of projections

From this review of projections, it is apparent that progress has been made in improving methods and gaining accuracy. Much of it comes from continuing research and data collection on employment, R&D activity, the behavior of labor markets, the flow of students through the educational system, and other areas. I will emphasize several suggestions for data collection and research to bolster the weakest elements in projection method.

1. Better understanding of the factors affecting the utilization of the various occupations employed in each industry would require, first, collection of data from employing establishments on their employment by occupation (a program that has gotten off to a start, but needs to be extended), and then analysis of the differentials in occupational composition among plants in each industry. How are they affected by technological change, by R&D activity of the company, by changes in relative occupational wage rates? Does the industry's average occupational composition ultimately follow that of the most advanced plants?

2. Tables of working life should be developed showing differential mortality and retirement patterns for individual occupations or groups of occupations. The wider prevalence of pension plans and company-sponsored life insurance coverage forms the institutional foundation for the records that would be needed. Such tables are of value for many purposes besides manpower projections, including calculation of lifetime earnings and of income lost by disabling accidents. The importance of an accurate estimate of deaths and retirements is clear from the projections that show that after 1980 they will account for most of the openings in the scientific fields.

Several recommendations come out of this review for the kinds of projections that are made:

1. Medium-term projections of three to five years should be made as well as those ten or more years ahead. They suffice for many purposes; they are likely to contain smaller errors; often they reveal significant information about the character of the intervening period; and they can be checked against unfolding events and this knowledge can aid in reviewing the longer-term projections. I fail to see the magic of years ending in 5 and 0. Users of projections may well wonder whether the people who make them, and who know them best, are afraid to touch them with anything shorter than a ten-year pole.

2. Projections should be systematically made on alternative assumptions, so that their sensitivity to various contingencies can be examined and better measures of their possible errors provided to the user in advance. Sensitivity analysis also tells the maker of projections where he gets the most payoff in accuracy for additional investment in research. The cost of alternative projections might be offset by this saving alone.

3. While I believe that the procedure of separately projecting requirements and supply is most useful for presenting the issues for decision, more information is needed by decisionmakers on the ways, and combinations of adjustments, by which equilibrium is reached. The research suggested above on response of occupational utilization in industry to wage changes contributes to this. Other aspects of the adjustment process need study, and hopefully models of the whole adjustment process may be developed. I think a sector-by-sector approach may be needed because each industry's demand schedule for each occupation may be unique.

4. It is obvious, but I'll say it anyway, that a continuing research effort is needed, constantly improving data and method, frequently revising projections. This is not a subject that can be tackled ad hoc and then dropped. Nor can one group of occupations be analyzed or understood out of the context of all related occupations—the technicians as well as the scientists, the management and sales people as well as the engineers, the other professions that offer alternative employment opportunities and attractions to young people interested in a scientific field. Has science lost students to medicine or law in the last few years? Those broadly interested in science have a deep and abiding interest in the total picture.

Appendix

Evaluation of Projections Made in 1959, 1960 and 1964

In this evaluation of the projections we will make some comparisons of the projected changes in requirements with the actual changes in employment, even though the comparison is not technically valid, as pointed out in the text of this paper. The comparison may shed some light on the nature and causes of errors in the projections, and the areas in which method can be improved.

The analysis will deal with some of the earliest projections, one made with 1959 as a base year and 1970 as a target year (2), and one made with 1960 as a base and 1970 as the target (3). In addition a projection based on 1964 and projecting industry employment to 1970 and 1975, and requirements for scientists, engineers and technicians to 1975 will be compared with actual changes from 1964 to 1970 (5). In these comparisons rates of change for projected requirements and actual employment will be compared, since the base figures have been corrected somewhat in later revisions of the statistics, and comparisons would be confused if the numbers were used.

Relative growth rates of scientific occupations

One simple question that might be asked of a projection is whether it correctly identifies fast-growing and slow-growing fields. To what extent did the two projections of requirements for scientists properly identify those growing faster or more slowly than the average for all scientists?

This may be examined in Tables 2.A2 and 2.A3. In the first table, physicists, mathematicians and medical scientists were identified as growing faster than the average for all sciences, and chemists, geological scientists, agricultural scientists and biological scientists as growing more slowly than the average. When the actual growth in employment from 1959 to 1970 is examined, this turned out to be right in all cases. The same comparison made for the 1960-70 projection shows that the identification of faster and slower growing occupations was made correctly in six out of the seven cases (Table 2.A3).

Projected increase in requirements compared to employment growth, by occupation

1959-1970 study

In the 1959-1970 projections (Table 2.A2), the projected increase in requirements for all scientists and engineers was two-thirds greater than the actual employment increase. Requirements for engineers were projected to rise by 90 percent; employment actually increased by less than half that amount. Employment of scientists rose almost as much as projected requirements, but among the scientific fields there were substantial differences. The actual employment increase for chemists was only 55 percent as much as the requirements increase projected, while employment of medical scientists rose twice as fast as projected requirements. On the average (using the median) the projected changes differed from the actual employment changes by 29 percentage points (ignoring signs), and in only three of the eight cases was the projection within 10 percentage points of the actual employment change. A weakness in this projection was the inadequacy of data by which to distribute scientists by occupation among industries: the data available was for 1959, and there was little information for earlier years by which to examine trends.

1960-1970 study

The projection based on 1960 data used new industry employment projections; a special study was done of the aircraft, missiles and spacecraft industry (which was affected by the burgeoning Space program) including projections of NASA and Defense expenditures and civilian aircraft purchases. A special projection of R&D employment was made. A new projection was made for colleges and universities, using Census projections of enrollments instead of those by the Office of Education. Also, a more thorough projection of supply was undertaken.

The results of this study (Table 2.A3) were somewhat closer to actual employment changes for engineers and scientists as a whole—projected requirements rose by 69 percent and employment actually increased by 44 percent, or nearly two-thirds as much. Engineers were again projected high, but the difference was less: the actual growth in employment was more than half as great. The overall growth rate for scientists was within 14 percent of that projected, but again there were disparities in the comparison for individual scientific fields. Employment of chemists again increased less than projected rquirements. The median deviations in growth rates, ignoring signs, was 29 percentage points, no better than the earlier projection; in two out of the eight cases the deviation was below 10-percentage points.

A principal reason for the high projections of requirements in both the 1959-70 and the 1960-70 projections was the general expectation at that time of a much larger growth in research and development expenditures than in fact occurred. This expectation reflected the tenor of the times in the early 1960's when the national space effort was being launched at the same time that health research was accelerating. This assumption was implicit in the 1959-70 projections, and, as noted above, it was explicitly built into the 1960-70 projections; requirements for scientists and engineers for R&D were projected to double by 1970 (3, pp. 10-14) which would have brought requirements to 772,000 based on the 1960 R&D employment of 386,100 (12, p. 3); actual employment on R&D rose by only 38.7 percent to 535,400. This difference of 237,000 amounts to 88 percent of the difference between projected total scientific and engineering requirements in 1970 and actual employment. (Applying the 68.9 percent increase projected (Table 2.A3) to a revised employment estimate for 1960 of 1,104,000 (12, p. 3) gives a projection of 1,864,700; actual employment in 1970 was 1,594,700, or 270,000 less.)

1963-1975 study

A third comparison between projected requirements and actual employment growth may be made from a projection made in connnection with the study of requirements for technicians. The base year employment data for scientists and engineers was for 1963, and requirements of scientists and engineers were projected to 1975 (5). Since the projectiuns purport to describe long-term trends, it would not do inordinate violence to their concept to take seven-twelfths of the projected percentage change in requirements from 1963 to 1975 to represent the growth to be expected by 1970. This is compared with actual employment changes for each occupation over this period in Table 2.A4.

As noted in the text of this report, the methods used for the projections in the study of technicians were more sophisticated than the earlier ones. The results were closer to actual employment changes. As can be seen in the table, the projections for all scientists and engineers was an increase of 38.9 percent; employment actually rose by 24.5 percent, or nearly two-thirds as much. Projections of requirements for engineers and chemists were still higher than actual employment gains. The median deviation between projected and actual changes was 14 percentage points, only half that in the two previous projection studies.

Some of this improvement in accuracy (within the limits of this comparison of requirements to employment) may be attributed to the fact that the last projection was only seven years into the future, while the others looked ahead eleven and ten years respectively. To adjust for this factor the median deviations may be divided by the number of years, with the following results:

Projection	Number of Years	Median Deviation (Percentage Poin.s)	Average Deviation per Year
1957-70	11	29.3	2.7
1960-70	10	28.9	2.9
1963-70	7	14.2	2.0

There was, by this way of looking at it, a 25 percent reduction in "error" in the most recent projection, which may be attributed to improvements in method or just plain luck.

Analysis of differences between projected requirements growth and employment gains by reference to supply and wages

To what extent was limitation of supply a factor in the difference between projected requirements and actual employment change? If we had a clear answer to this question we could sort out the extent of error in the requirements projections. Our data on supply changes are less than adequate for a complete appraisal, since we have no data on the total supply in the base year other than what is shown by actual employment in the occupation (there may have been others unemployed or in other occupations), and the only information we have on supply changes in the forecast period is the actual graduations in the field. If there were errors in the estimates of deaths and retirements or net occupational mobility, we cannot measure them.

Engineers

Table 2.A5 shows the comparison of projections and actual developments for engineers, 1959-1970. Requirements had been projected to increase by 688,000, and supply by 473,000, implying a "shortage" of 215,000. Employment actually rose by 330,000, less than half the projected rise in requirements. Despite the concern about a shortage, 106,000 fewer graduates entered the profession than had been projected on the basis of past trends in the proportion of students taking engineering. When the projected supply increase is adjusted for the smaller number of graduates it is 37,000 more than the actual employment increase. (Some of this could be accounted for by an increase in unemployment of engineers.)

Since relative earnings of engineers were little changed over this period (Tables 2.A12, 2.A13) and no more workers were drawn into engineering from other occupations (net of engineers leaving for other occupations) it appears that the requirements projections were unrealistically high.

The same comparison is made for the 1960-1970 projection for engineers in Table 2.A6. The projected increase in requirements was 539,000, lower than in the earlier projection. The projections of supply changes were made more carefully, and allowance was made for engineers shifting to other occupations. The number of graduates was projected more conservatively than before, using a new projection by the Office of Education. A "shortage" of 253,000 was projected. Employment actually increased by 297,000, or somewhat more than half the projected increase in requirements. The actual number of graduates was slightly more than projected, and when the projected supply is adjusted for this, it is about equal to the actual employment.

Again, in view of the stable relative earnings of engineers over this period, the fact that no more workers were drawn into the profession than would have been expected on the basis of the previous trends in supply suggests that the requirements projections were unrealistically high.

Scientists

The projections for scientists, 1959-70, are shown in Table 2.A7. The projected increase in requirements of 217,000 was seen to be in rough balance with the projected increase in supply of 236,000. (The figures in the original report were even closer; revisions in the base employment figure for 1959 result in a larger reduction in the requirements projection than in the supply projection.) The actual employment increase was 207,000, close to the requirements. There were, however, 31,000 more graduates planning to enter scientific occupations than had been projected, bringing total additional supply available to 60,000 above the employment increase. Some were unemployed in 1970 and some graduates eventually found work elsewhere, but there is no evidence of a decline in earnings over this period; relative earnings of chemists held their own (Table 2.A13). Thus the requirements projections appear realistic, but the supply is difficult to evaluate. Estimates of shifts into and out of scientific occupations are crude and based on little hard data.

A somewhat similar picture emerges in the comparisons for the 1960-70 projection. A requirements increase of 244,000 was matched with a projected 263,000 increase in supply, suggesting a rough balance. (Revisions in the base figures affect the requirements more than the supply, lowering the former by 24,000.) The report pointed out that the largest increase in requirements in the decade would be in its first half, while the largest graduations would be toward the end of the decade. Employment actually increased by 14 percent less than projected requirements. Graduations exceeded what had been projected, as in the 1959-1970 projections. When the projected change in supply is corrected by the 40,000 additional graduations, it is raised to 302,000, or about 208,000 more than the 194,000 increase in employment. Since employment increased less than requirements despite the plentiful supply of scientists, this implies that the requirements projections were somewhat higher than would have been realistic. The supply picture here, too, is clouded.

In summary, this comparative analysis suggests that requirements for engineers were substantially overstated, while those for scientists were closer to being accurate. The effects of unduly high expectations for research and development expenditures distorted the projections, but the error was allocated to the requirements for engineers but not those for scientists.

To take apart the projections further in order to identify sources of error we will first examine the projections of activity in each industry, for which employment may be considered a proxy, and then look at the projection of ratios of scientific and engineering employment to the total. The industry projections are less likely than the occupational requirements or the occupational ratios projections to have been affected by supply-demand factors, since most jobs in industry can be filled readily by less-trained workers, and therefore can more fairly be compared with actual employment changes: the differences reflect error in the projections or in the assumptions underlying them rather than labor market factors.

Projections of industrial activity and employment

Table 2.A9 compares the changes in total manpower requirements projected for 1959-1970 for industries using significant numbers of scientists and engineers with the employment changes that actually took place. In 18 out of the 20 industries that can be compared, the projected increases were greater than what actually occurred. The total projected for these industries was a 29 percent increase, twice the increase that actually took place. The median deviation of projected from actual for each industry was 19 percentage points, or two-thirds of the overall projected employment growth of 30 percent; in six cases the deviation was less than 10 percentage points. On the average, then, changes in employment requirements of these industries were projected within 19 percentage points, but there was a strong upward bias in the projections.

A similar comparison is shown in Table 2.A10 for the 1960-1970 projections. The projections were closer to what actually occurred; for the 15 industries compared, the projected increase was 19.4 percent; the actual was 20.8 percent. Eight of the 15 projections were too high and seven were too low. The median deviation was 8.5 percentage points, and nine of the projections were within 10 percentage points of the actual change. Thus the projections were substantially improved.

A later projection was made for the study of technicians, using 1964 industry employment data as a base. As noted in the text of this report, the methods for industry projections represented improvements over those used earlier. The comparison is shown in Table 2.A11. Total employment rose by 21 percent; it had been projected to rise by 16 percent. In 25 of 29 industries the projection was within 10 percentage points of the actual change. The median deviation for the 29 industries was 6 percentage points. Some of the difference reflected Vietnam war defense expenditures, since defense-related industries were uniformly higher than projected.

Summarizing the experience of these three successive projections, and allowing for the differences in the length of the projection, we get:

	Median Deviation (Percentage Points)	Number of Years	Average Deviation per Year
1959-70	19.4	11	1.76
1960-70	8.5	10	.85
1964-70	6.0	6	1.00

That is, the error was reduced by over 40 percent from the first to the last.

Projections of occupational ratios

It has been noted in the text that the basic data by which the occupational composition of industries can be projected is among the weakest elements of the projection method used. There are insufficient observations on which to develop understanding of the factors affecting the relative use of occupations in industry. In making the projections, an attempt was made to project changes in the ratios of scientists and engineers because it did not seem plausible that the ratios would remain constant.

Examination of the two tables (2.A14 for the 1959-1970 study and 2.A15 for the 1960-1970 study) showing the changes in occupational ratios projected compared with the actual changes reveals no improvement in reliability. The median deviation between projected and actual in the first study was 22 percentage points, and 14 of the 18 projections were too high. The median deviation in the second study was 26 percentage points, and 13 of the 15 projections were too high. These high projections of requirements, which were later allocated almost entirely to engineers rather than scientists, reflected the ambitious notions of prospective growth of research and development at that time: they were requirements for an expansion of R&D that did not take place.

Table 2.A1
Estimated Employment of Scientists and Engineers, Selected Years, 1950-1970[1]

	1950	1959	1960	1963	1970
Scientists and engineers, total	556.7	1,057.9	1,140.0	1,280.8	1,594.7
Engineers	408.0	768.0	801.1	922.7	1,098.2
Scientists, total	148.7	289.9	302.9	358.1	496.5
Physical scientists, total	89.1	166.2	172.0	194.1	248.8
Chemists	51.9	95.4	99.7	110.0	132.9
Physicists	14.0	28.6	29.8	36.[illegible]	49.1
Geologists and geophysicists	13.0	20.9	20.4	22.5	30.6
Other	10.2	21.3	22.1	25.3	36.2
Mathematicians	13.8	31.7	34.2	43.6	74.3
Life scientists, total	45.6	92.0	96.7	120.3	173.4
Agricultural	16.9	29.5	30.4	38.5	49.3
Biological	19.9	42.5	44.3	51.3	71.1
Medical	8.8	20.0	21.5	30.5	53.0

[1] 12, pages 11 and 15

Table 2.A2.
Projected Increases in Requirements for Scientists and Engineers, Compared with Actual Increases in Employment, 1959-1970

	Original Projections[1]			Actual Percent Change In Employment 1959-1970[2]	Deviation of Projected From Actual, in Percentage Points
	1959	1970	Percent Change		
Scientists and engineers, total ..	1,096.3	2,032.2	85.4	50.7	34.7
Engineers	782.8	1,484.0	89.6	43.0	46.6
Scientists, total	313.4	548.2	74.9	71.3	3.6
Chemists	95.0	163.2	71.8	39.3	32.5
Physicists	28.2	57.2	103.2	71.7	31.5
Metallurgists	12.9	23.3	80.0	—	—
Geologists and geophysicists	22.0	31.0	40.9	46.4	5.5
Mathematicians	28.8	59.8	107.3	134.4	27.1
Medical scientists	29.8	52.7	76.7	165.0	88.3
Agricultural scientists	40.8	69.7	70.8	67.1	3.7
Biological scientists	37.2	64.4	73.1	67.3	5.8
Other natural scientists	18.7	26.9	43.6	—	—
Median deviation, 8 fields					29.3

[1] 2, page 48.
[2] 12, pages 11 and 15.

Table 2.A3
Projected Increases in Requirements for Scientists and Engineers, Compared with Actual Increases in Employment, 1960-1970

	Original Projections[1]			Actual Percent Change in Employment 1960-1970[2]	Deviation of Projected From Actual, in Percentage Points
	1960	1970	Percent change		
	(000)				
Scientists and engineers, total ..	1,157.3	1,954.3	68.9	44.4	24.5
Engineers	822.0	1,374.7	67.2	37.1	30.1
Scientists, total	335.3	579.6	72.9	63.9	9.0
Chemists	103.5	169.5	63.8	33.3	30.5
Physicists	29.9	59.3	98.3	64.8	33.5
Metallurgists	14.5	24.4	68.3	—	—
Geologists and geophysicists	23.2	29.1	25.4	50.0	24.6
Mathematicians	31.4	65.1	100.3	117.3	10.0
Medical scientists	31.4	59.7	90.1	146.5	56.4
Agricultural scientists	39.5	66.1	67.3	62.2	5.1
Biological scientists	40.7	76.6	88.2	60.5	27.7
Other scientists	21.0	29.9	42.4	—	—
Median deviation, 8 fields					28.9

[1] 3, page 8
[2] 12, pages 11 and 15

Table 2.A4
Projected Increases in Requirements for Scientists and Engineers, 1963-1975, and Interpolation for 1970, Compared with Actual Increases in Employment, 1963-1970

	Original Projections			Interpolation for 1970 (7/12 x 1963-70 Percent Change)	Actual Percent Change in Employment 1963-1970[3]	Deviation of Projected From Actual, in Percentage Points
	1963[1]	1975[2]	Percent Change			
Scientists and engineers, total ..	1,271.6	2,119.4	66.7	38.9	24.5	14.4
Engineers	924.9	1,466.5	58.6	34.2	19.0	15.2
Scientists, total ..	346.8	652.9	88.3	51.5	38.7	12.8
Chemists	107.5	194.7	81.1	47.3	20.8	26.5
Physicists	36.1	71.9	99.2	57.9	35.3	22.6
Mathematicians..	42.1	87.5	107.8	62.9	70.4	7.5
Life scientists ..	112.1	222.3	98.3	57.3	44.1	13.2
Other natural scientists[4] ...	49.0	76.6	56.3	32.8	39.3	6.5
Median deviation ...						14.2

[1] 5, page 85
[2] 5, page 87.
[3] 12, page 15.
[4] Includes geologists, geophysicists, metallurgists, and other physical scientists.

Table 2.A5
Comparison of Projected and Actual Net Changes in Requirements, Supply and Employment for Engineers, 1959-1970

	Figures as Originally Published	(net)	Adjusted for Revision in 1959 Employment Estimate[2]
Project changes			
Requirements:			
Projected, 1970[1]	1,484,000		
Employed, 1959[1]	782,800		
Net change		701,200	687,900
Supply:			
Graduates entering[3]	451,000		451,000
Nongraduates entering[4]	209,000		205,000
Deaths and retirements[5]	−187,000		−183,000
Net change		473,000	473,000
Difference: "shortage"		228,200	214,900
Actual changes			
Employment[6] - 1970			1,098,200
1959			768,000
Increase			330,200
Graduates entering[7]		345,000	
Projected net change in supply (473,000) adjusted for "shortfall" of 106,000 graduates		367,000	

[1] 2, page 49
[2] 768,000 ÷ 782,800 = .981, the adjustment factor (12, p. 11)
[3] 2, page 33
[4] 2, page 32
[5] 2, page 31
[6] 12, page 11
[7] 12, page 10

Table 2.A6
Comparison of Projected and Actual Net Changes in Requirements, Supply and Employment for Engineers, 1960-1970

	Figures as Originally Published		Adjusted for Revision in 1960 Employment Estimate[3]
Projected changes			
Requirements:			
Projected, 1970[1]	1,374,700		
Employed, 1960[2]	822,000		
Net change		552,700	538,900
Supply:			
Graduates entering[4]	294,700		294,700
Others entering:			
With degrees in other fields[5]	73,000		71,000
Immigrants and those without degrees[6]	105,400		102,800
Deaths and retirements			
Among those in the field in 1960[7]	—123,400		—120,300
Among new entrants[8]	—22,400		—21,800
Engineers shifting to other occupations[7]	—41,000		—40,300
Net change		286,200	286,300
Difference: "shortage"		266,500	252,600
Actual changes:			
Employment[9] - 1970			1,098,200
1960			801,100
Net change			297,100
Graduates entering[10]	308,550		
Projected net change in supply (286,300) adjusted for 13,850 additional graduates	300,150		

[1] 3, page 8.
[2] 3, page 16
[3] 801,100 ÷ 822,000 = 975, the adjustment factor
[4] 3, page 23
[5] 3, page 24.
[6] 3, page 25
[7] e, page 16
[8] 3, page 26
[9] 12, page 11
[10] 12, page 10

Table 2.A7
Comparison of Projected and Actual Net Changes in Requirements, Supply and Employment for Scientists, 1959-1970

	Figures as Originally Published		Adjusted for Revision in 1959 Employment Estimate[2]
Projected changes:			
Requirements:			
Projected, 1970[1]	548,200		
Employed, 1959[1]	313,400		
Net change		234,800	217,200[2]
Supply:			
Graduates entering, 1959-69[3]	277,000		277,000
Deaths and retirements[4]	—44,000		—40,700
Net change		233,000	236,300
Difference:		1,800	19,100
Actual changes:			
Employment:[5] 1970			496,500
1959			289,900
Net change			206,600
Graduates entering[6]		307,900	
Projected net change in supply, adjusted for 30,900 additional graduates		267,200	

[1] 2, page 49.
[2] 289,900 ÷ 313,400 = .925, the adjustment factor.
[3] 2, page 34.
[4] 2, page 32.
[5] 12, page 11.
[6] 15, pages 44, 46, 48. Actual graduations adjusted as follows to show those actually entering scientific fields: B.S x .25, M S x .40, Ph D. x 1.0

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Table 2.A8
Comparison of Projected and Actual Net Changes in Requirements, Supply and Employment for Scientists, 1960-1970

	Figures as Originally Published		Adjusted for Revision in 1960 Employment Estimate[3]
Projected changes:			
Requirements:			
Projected, 1970[1]	579.600		
Employed, 1960[2]	335,300		
Net change		244,300	220.600
Supply:			
Graduates entering[4]	256.300		256,300
Others entering:			
With degrees in other fields[5]	61,200		55,300
Immigrants and those without degrees[6]	7.900		7,100
Deaths and retirements:			
Among those in the field in 1960[7]	—33.800		—30,500
Among new entrants[8]	—11,500		—10.400
Scientists shifting to other occupations[7]	—16,800		—15,200
Net change		263,300	262.600
Difference		19.000	42.000
Actual changes			
Employment[9] - 1970			496.500
1960			302.900
Net change			193.600
Graduates entering[10]	296.000		
Projected net change in supply (262.600) adjusted for 39.700 additional graduates	302.300		

[1] 3, page 8
[2] 3, page 16
[3] 302,900 ÷ 335,300 = .903, the adjustment factor
[4] 3, page 23
[5] 3, page 24
[6] 3, page 25
[7] 6, page 16
[8] 3, page 26
[9] 12, page 11
[10] 15, pages 44, 46, 48 Actual graduations adjusted as follows to show those actually entering scientific fields B S x .25, M S x .40, Ph D x 1.0

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Table 2.A9
Projected Employment Changes in Selected Industries, Compared with Actual Changes, 1959-1970

	Projected Percent Change[1]	Actual Percent Change[2]	Deviation of Projected From Actual, in Percentage Points
Total, selected industries	29.3	14.6	14.7
Mining	28.7	—14.9	43.6
Construction	54.7	14.2	40.5
Manufacturing, total	30.4	16.0	14.6
Food	12.2	—0.4	12.6
Textiles and apparel	11.4	7.8	3.6
Lumber and furniture	12.8	—1.1	13.9
Paper	38.4	20.1	18.3
Chemicals	32.7	2[illegible].6	3.1
Petroleum and coal products	20.0	—11.5	31.5
Rubber products	30.1	55.6	25.5
Stone, clay and glass	31.8	6.0	25.8
Primary metal products	31.6	11.2	20.6
Fabricated metals and ordnance	20.8	13.8	7.0
Machinery	41.2	36.5	4.7
Electrical equipment	69.1	37.3	31.8
Transportation equipment	40.6	10.0	30.6
Professional and scientific instruments	54.9	33.3	21.6
Miscellaneous manufacturing	20.2	10.7	9.5
Transportation, communication, and public utilities	16.3	12.0	4.3
Engineering and architectural services	28.5	63.7	35.2
Median deviation, 19 industries			19.4

[1] 2; page 41.
[2] 10, page viii.

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Table 2.A10
Projected Employment Changes in Selected Industries, Compared with Actual Changes, 1960-1970

	Projected Percent Change[1]	Actual Percent Change[2]	Deviation of Projected from Actual, in Percentage Points
Total, selected industries	19.4	20.8	1.4
Construction	32.9	17.2	15.7
Paper	16.4	17.4	1.0
Chemicals	25.0	26.7	2.7
Primary metal products	9.9	6.9	3.0
Fabricated metals and ordnance	22.6	19.7	2.9
Machinery	15.4	34.1	18.7
Electrical equipment	50.4	30.7	19.7
Professional and scientific instruments	43.8	29.9	13.9
Motor vehicles and equipment	11.2	10.1	1.1
Aircraft, missiles and spacecraft	7.2	6.5	.5
Petroleum and coal products	4.0	—10.0	14.0
Communications	1.2	33.4	32.2
Electric, gas and sanitary services	5.8	12.3	6.5
Engineering and architectural services	49.8	58.3	8.5
Federal government	7.8	17.4	9.6
Median deviation, 15 industries			8.5

[1] 3 (Computed from information given in Pages 45-51.)
[2] 10, page viii.

Table 2.A11
Projected Employment Changes in Selected Industries, Compared with Actual Changes, 1964-1970

	Projected Percent Change[1]	Actual Percent Change[2]	Deviation of Projected from Actual, in Percentage Points
Total nonagricultural employment	16.2	21.0	4.8
Mining	–3.9	–1.7	2.2
Contract construction	20.7	10.9	9.8
Manufacturing	6.7	9.2	2.5
Ordnance	–2.9	–0.8	2.1
Lumber	–7.8	–5.2	2.6
Furniture	11.9	13.3	1.4
Stone, clay and glass products	3.9	4.3	1.4
Primary metal products	–0.5	6.7	7.2
Fabricated metal products	10.7	16.0	5.3
Machinery	15.4	23.1	7.7
Electrical equipment	17.8	24.2	6.4
Transportation equipment	2.9	12.1	9.2
Instruments	17.9	24.5	6.6
Miscellaneous manufacturing	10.0	7.1	2.9
Food products	–4.1	1.9	6.0
Tobacco products	–3.6	–8.1	0.5
Textile mill products	–1.9	9.4	11.3
Apparel	8.8	4.8	4.0
Paper products	11.0	12.8	1.8
Printing and publishing	9.3	15.8	6.5
Chemicals	14.0	19.4	5.4
Petroleum and coal products	–11.6	3.8	15.4
Rubber and plastic products	16.2	33.1	16.9
Leather products	–1.0	–7.8	6.8
Transportation and public utilities	3.1	13.7	10.6
Trade	16.9	22.6	5.7
Finance, insurance and real estate	16.7	24.7	8.0
Services and miscellaneous	24.8	33.3	8.5
Federal government	6.5	15.2	8.7
State and local government	37.5	35.6	1.9
Median deviation, 29 industries			6.0

[1] From unpublished data provided by Bureau of Labor Statistics, representing projections used in Bulletin 1512 (Ref. 5).
[2] Id. page viii.

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Table 2.A12
Median Annual Earnings of Engineers Compared to Those of Male Workers in Selected Occupations, 1958 to 1972

	1958	1962	1966	1969	1971	1972
Engineers	$7,734	$8,772	$10,821	$13,072	$14,029	$15,130
All male workers	4,068	4,814	5,809	6,899	7,388	7,991
Professional, technical and kindred workers	6,132	7,036	8,330	10,516	11,248	12,097
Salaried professional, technical and kindred workers	5,938	6,842	8,115	10,225	10,992	11,777
Salaried managers and officials	6,247	7,238	9,1[illegible]	11,284	12,456	13,473
Relative earnings of engineeers to those of:						
All male workers	1.902	1.822	1.863	1.895	1.899	1.893
Professional, technical and kindred workers	1.262	1.247	1.299	1.243	1.247	1.251
Salaried professional, technical and kindred workers	1.303	1.282	1.333	1.278	1.276	1.285
Salaried managers and officials	1.239	1.212	1.181	1.159	1.130	1.123

Source: Bureau of the Census, Department of Commerce
1958-1969 from *Statistical Abstract of the United States, 1971*, page 229.
1971 from Series P-60, No. 85 (1972)
1972 from Series P-60, No. 90 (1973)

Table 2.A13
Annual Percent Increases in Average Salaries, 1961-1973 for Selected Occupations[1]

	Percent Increase Over the Previous Year												Average Annual Rate of Increase,	Cumulative Increase,
	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	1961-73	1961-73
Engineers	2.6	4.4	2.9	3.2	3.7	4.3	5.4	6.2	5.5	5.7	5.2	5.1	4.5	69.7
Chemists	3.9	3.8	3.3	3.9	4.8	4.4	5.1	6.5	5.9	5.5	5.1	3.7	4.7	72.8
Accountants	2.8	3.3	2.8	3.5	3.8	4.6	5.7	7.0	6.7	6.7	5.6	4.9	4.8	75.0
Engineering technicians	[2]	2.9	3.6	2.3	2.8	3.7	5.1	5.8	6.3	6.5	5.1	4.7	[2]4.4	—
Drafting	3.2	3.6	2.6	[3]	1.5	3.5	5.3	5.8	4.9	5.8	7.2	6.2	[4]	—

[1] Bureau of Labor Statistics, *National Survey of Professional, Administrative, Technical and Clerical Pay, March 1973*, Bulletin 1804 (1973), pages 3 and 4. Data are based on a survey of establishments

[2] Not surveyed for 1961, average annual rate is for period 1962-1973

[3] Comparable data not available for both 1964 and 1965

[4] Comparison over this period was not possible because of changes in definition of the occupation

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Table 2.A14
Scientists and Engineers as a Percent of Total Employment in Selected Industries, Projected 1959-1970, Compared with Actual Data

	Original Estimates[1]			Actual Data[2]			Deviation of Projected from Actual, in Percentage Points
	1959	1970, projected	Percent change	1959	1970	Percent change	
Mining	4.2	8.6	104.8	4.3	5.2	20.9	83.9
Construction	3.4	4.5	32.4	1.5	1.6	6.7	36.9
Food products	.7	.9	28.6	.8	.9	12.5	16.1
Textiles and apparel	.3	.3	0	.18	.25	38.9	38.9
Lumber and furniture	.5	.6	20.0	.3	.9	200.0	180.0
Paper	1.7	2.7	58.8	1.8	2.8	55.6	3.2
Chemicals	9.0	12.4	37.8	9.2	10.2	10.9	26.9
Petroleum and coal products	7.5	8.8	17.3	6.5	8.6	32.3	15.0
Rubber products	2.4	2.6	8.3	2.5	2.6	4.0	4.3
Stone, clay and glass products	1.8	2.4	33.3	1.6	1.9	18.8	14.5
Primary metal products	2.6	4.0	53.9	2.3	2.3	0	53.9
Fabricated metal products and ordnance	3.0	5.7	90.0	3.8	5.1	34.2	55.8
Machinery	4.2	5.6	33.3	4.1	4.8	17.1	16.2
Electrical eqipment	7.6	10.2	34.2	7.8	8.4	7.7	26.5
Transportation equipment	6.4	10.2	59.4	6.4	7.3	14.1	45.3
Professional and scientific instruments	6.9	9.3	34.8	7.0	8.2	17.1	17.7
Transportation, communication and public utilities	1.6	1.9	18.8	1.1	1.4	27.3	8.5
Engineering and architectural services	30.3	30.3	0	40.7	35.8	—12.1	12.1
Median deviation, 18 Industries							22.1

[1] 2, page 40.
[2] 12, pages 5 and 20, 10, page viii.

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Table 2.A15
Scientists and Engineers as a Percent of Total Emloyment in Selected Industries, Projected 1960-1970, Compared with Actual Data

	Original Estimates[1]			Actual Data[2]			Deviation Projected from Actual, in Percentage Points
	1960	1970, projected	Percent change	1960	1970	Percent change	
Construction	2.2	3.2	45.5	1.6	1.6	0	45.5
Paper products	1.6	2.5	56.3	2.3	2.8	21.7	34.6
Chemicals	9.6	13.0	35.4	9.3	10.2	9.7	25.7
Primary metal products	2.5	3.7	48.0	2.3	2.3	0	48.0
Fabricated metal products and ordnance	3.3	6.7	103.0	4.3	5.1	18.6	84.4
Machinery	4.2	5.5	19.1	4.2	4.8	14.3	4.8
Electrical equipment	7.7	10.0	29.9	8.1	8.4	3.7	26.2
Professional and scientific instruments	7.4	10.1	36.5	7.5	8.2	9.3	27.2
Motor vehicles and equipment	3.3	4.4	33.3	3.1	4.2	35.5	2.2
Aircraft, missiles and spacecraft	12.3	21.0	70.7	22.6	24.8	9.7	63.0
Petroleum and coal products	7.5	10.7	42.7	8.2	8.6	4.9	37.8
Communications	2.6	3.5	34.6	1.6	2.0	25.0	9.6
Electric, gas and sanitary services	4.2	4.5	7.1	3.5	4.4	25.7	18.6
Engineering and architectural services	30.7	33.0	7.4	39.8	35.8	—10.0	17.4
Federal government	4.6	6.5	41.3	4.3	5.8	30.2	11.1
Median deviation, 15 industries							26.2

[1] 3, pages 45-51.
[2] 12, pages 9 and 20, 10, page viii.

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3. An Overview of Projections and the Supply Side

This chapter is based on Dr. Kidd's oral presentation and on his paper. The lead discussants were Lee Grodzins, Massachusetts Institute of Technology, and W. N. Hubbard, Jr., M.D., The Upjohn Company.

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I would note that the conventional analysis of fixed factors which looks at supply and demand as separate and unrelated events has its problems and that it tends to discourage people from looking at price and other adaptive mechanisms. That theme has already become and will continue to be a center of attention at this meeting.

It is my observation that the matrix of the kinds of decisions that different people make and the kinds of decisions to which projections are relevant is quite elaborate. So many purposes are served that individuals and groups will force continuing attention to projections. There is a widespread feeling that neither industry nor federal laboratories use projection data much, but on the other hand they seem to be of concern to those parts of government that deal with occupational outlook such as BLS or those who are concerned with kind and level of fellowships, and/or R&D money from the Federal government. Breneman and Freeman make the point that projections would be of little use in a central manpower planning system or as a provider of information to guidance counselors, or educational institutions. They feel that students are highly responsive to market opportunities, and their behavior will keep markets near equilibrium thus obviating the need for forecasts. A case can be made that these observations are not wholly correct since, when government provides fellowships, support for students, and general R&D support, a degree of rationality must be present in the procedure. If more people are trained at the graduate level than can find jobs, this is in effect an economic waste that might be curtailed if demand forecasts were considered in government policy formation. Even those who argue that almost total transferability exists between professional and nonprofessional fields must agree that training personnel for a particular field, a field in which the trained cannot find employment and hence must transfer out, is expensive and wasteful to the extent the training is not appropriate for other purposes. This thinking leads to the conclusions presented by Breneman and Freeman that forecasts are useful in: (a) evaluating governmental policies, (b) giving early warning of emerging problems, and (c) providing an informational and diagnostic device which directs attention to market problems beyond the purview of individual decision makers.

Other uses of forecasts tend to be more indirect. They are not used to make specific decisions, but rather to consider secondary and tertiary consequences of prospective changes in the labor market. For example, projections have drawn productive attention to the effects of an aging faculty on the nature and quality of teaching in the universities. If the lack of university positions for bright young persons persists over the next decade or so, there is the possibility that more productive research will be going on in non-academic centers rather than academic centers. The projections have also drawn attention to the question of training graduate students for non-academic careers, again based on the outlook for academic positions. These indirect uses of projections are valuable even if there is a wide range of error in the forecast. What is required at a minimum is that the sign not be wrong; by and large, the signs have been right.

Historical Character of Projections

In the recent history of projections, graduate enrollment and Ph.D. production have been overstated primarily because the effects of the market were not taken into account. For example, Federal support fell from 50,000 graduate fellowships in 1968 to 6,000 in 1974. In the face of this reduction graduate enrollment went up—first-time enrollment increased 2.9 percent in 1971, 2.7 percent in 1972, and 5.4 percent in 1973. In retrospect this is easy to account for. First, Federal support of graduate students through fellowships represents only a small percentage of the total support of graduate students. Thus the sharp decline in Federal support did not cause a critical change in the total support available. Second, alternate sources of support were substituted for the Federal reduction: students are probably working more; they are borrowing more; and families of graduate students are probably coming around to the pattern which has prevailed for law and medical students, that of providing more of the necessary funds for their education. The extent to which this is good or bad is another question. It's not good if pushed too far.

In the face of the market, defensive credentialing seems to be appearing. People are seeking the M.A. or a Ph.D. to protect themselves in those declining employment markets where academic credentials become a significant factor. Education is a case in point.

All in all, the effect on graduate enrollment of the cutback in Federal fellowship support has been muted for various reasons. While first-time graduate enrollments have increased, the output of Ph.D.'s has been lower in 1971, 1972, and 1973 than was predicted (Allan Cartter excepted). In 1973, 33,700 Ph.D.'s were awarded. OE predicted 38,000; NSF, 36,000; and the Commission on Human Resources (National Academy of Sciences) predicted 36,000. What is happening is a breakdown of the stable trend of the 1960's when there was a good correlation between first-time enrollment and Ph. D. output four to seven years later. Over the last few years a smaller percentage of students has continued on to a graduate degree. This is an important variable, and it is probably less stable than was previously believed. But again, we have an indication of change in the nature of the process in which Ph.D.'s are produced.

Some Unresolved Problems

Projections and predictions are interactive. To the extent that people believe manpower forecasts and act upon them, the forecasts are doomed to error unless those who make them predict the effects of their own forecasts. In the social sciences forecasts are not simply efforts to foretell what will happen, they can and do often influence the course of events. Many draw sharp distinctions between projections and predictions. Operationally, the distinction tends to break down as people insert judgmental factors in order to preclude obtaining silly results. The extent to which judgmental factors are introduced tends to determine the extent by which projections take on the character of predictions. But regardless, all forecasts or projections have an element of prediction in them.

There are several problems with the projections which have been made. Very little is ever said about the quality of the manpower training process or about the quality of the people being trained. Measures of quality are difficult to postulate, but they must be considered.

Two related problems are those of disaggregation in forecasts and substitutability. Disaggregated data of individual disciplines or areas will provide the basis for more meaningful projections of the gross numbers of Ph.D.'s awarded, but it is increasingly important to the specific disciplines for accurate information on supply and demand and the adjustment process. As the disaggregation becomes finer, the problem of substitutability becomes more difficult while it also becomes increasingly important. If the training or skills in one specialty are adequate to permit a person to work in another, then relative shifts in demand by field can cause large shifts in effective supply. The problems of forecasting supply and demand then begin to merge and become indistinguishable. It should also be noted that demand in precisely defined fields may be even more difficult to measure than supply. Another way of stating it is that the number of those with their training in a given specialty is an inadequate measure of the supply of persons capable of working in that specialty.

The relation among supply, demand, transferability, and information collection represents an extremely difficult forecasting problem both conceptually and operationally. Its complexity becomes even more so if graduate education becomes (as it should) capable of educating people for change, if it deliberately seeks to equip them to shift from one field of employment to another. Should current thoughts about rapid technological obsolescence of specialties and the need for retraining be translated into action, the difficulty of the task of defining the supply of persons trained for specific disciplines or fields will be compounded.

Underemployment is another feature which forecasts have not dealt with in detail. It is generally assumed that Ph.D.'s, particularly in science and engineering, will not be unemployed—at least not in large numbers. But there is the possibility of underemployment if we continue to train Ph.D.'s for one type of activity and they are then forced to shift to another. To date, adequate measures of underemployment have not been developed. Some possible criteria for measuring underemployment are these:

- *Income.* Is an individual's income lower in relation to the average income in the field?
- *Social productivity.* A Ph.D. physicist could be teaching in a community college and contribute disproportionately to society, hence not be underemployed even though his income might be low relative to his peers in universities.
- *Degree of use of skills.* Is a person employed in a position which allows the reasonably full use of the skills acquired?

However, I conclude that a definition of underemployment might not be as beneficial as simply having better measures of what highly trained people are doing, by occupation and income. Perhaps a better measure of what highly trained people are doing, by occupation and income, will give the necessary insights.

Finally, it seems that the central problem in forecasts lies in the inadequate attention which has been paid to market forces, the forces of adjustment, and the process by which equilibrium is arrived at. The question is not whether these forces should be taken into account, but how. Critical to this is the adequacy of data which would permit approaches to the question of the influence of prices, salary changes, and the whole equilibrium mechanism in the context of forecasts.

Lee Grodzins, Discussant:
Professor of Physics
Massachusetts Institute of Technology

I would like to digress from specific aspects of Dr. Kidd's presentation to comment on parts to which he alluded but did not stress. The first point is to the effect that projections are de facto forecasts; an accompanying disclaimer is the fine print never heeded, at least by those who will use the projections. The projectionist must live with the reality and include in the projection the effects of various decisions anticipated as a result of the projection.

For example, the deep and continuing cuts in graduate fellowship support had an initial effect of shifting populations of graduate students away from the prestigious schools and has had a net effect—as the prestigious schools found funds to recover their share of the total student body—of accounting for much of the net decline in the population of graduate students in the sciences. Projections made as forecasts would have predicted these consequences so that accountability would have been clear and a different policy might have been executed.

Demand almost always creates supply but supply rarely creates new demand; there was negligible demand response to tthe oversupply of chemists and physicists and what little there was, was transient. A strong case can be made for a manpower equation in which there is always a visible shortage of the total number of scientists and engineers so that demand is always driving supply, for when this occurs the sciences will be assured of attracting the strongest students, scientists will have better opportunities for finding their most effective careers, and the sciences and engineering will benefit from vital cross-fertilization as individuals switch fields to compete for and fill positions of greatest demand.

The supply-demand equation is also a problem in time and time delays, in pipelines and in feed-back loops. Projections must be made for five years in advance, at least, to meaningfully effect situations in which there is a five-year training period. Given the uncertainties in the manpower demands in any five-year projection, let alone the ten- to fifteen-year period which is actually relevant to an undergraduate's career plans, projections must be constantly updated, and mechanisms must be found by which the various time delays can be shortened so that the supply-demand system can respond to changes. Here, too, we see the argument for an undersupply of scientists for saturated fields have little flexibility; the recent experiences in physics show us that while there is a dramatic reaction at the entrance to the supply pipeline, with students staying away or switching graduate training, there is at most a sluggish response either within the pipeline or within the demand sectors.

Reference has also been made to my second point. The supply-demand equation is not a "chicken and egg" problem. If you need to build more bridges, you probably need more civil engineers; but a large supply of civil engineers does not mean you build more bridges, even though it sometimes happens..

The supply-demand equation has different meanings for different parts of the community. The funding agencies, employers, and students all have distinct views. It is important to interpret available information in such a way that each group understands the other's point of view so that a coherent approach emerges. This means there is need for both global information and microscopic information. No large organization will act on information too narrowly based—the global view must be present. But individuals and individual institutions never act on global data. They act on the information pertinent to their particular problem. Their horizons are limited, their interests parochial. The major task, one which seems capable of attainment, is to make assessments which are as meaningful for disaggregated groups as they are for entire fields of science and engineering.

W. N. Hubbard, Jr., M.D., Discussant

President

The Upjohn Company, Kalamazoo, Michigan

Information distributed about projected supply of and demand for scientific and engineering manpower has not yet had the clear effect of changing the behavior of either suppliers or consumers of that manpower. I would propose that the problem we are addressing is how to define and manage the behavior change we wish to occur as a result of the transfer of the information on manpower needs and supply that we are developing.

In order to make these data on calculated supply and demand effective in creating changed behavior, the traditional variables we consider must be extended. There are overriding variables which can cause gross deviations from the best currently calculated projections of manpower demand and supply, creating discontinuities of much greater magnitude than even the generous margins of error within the calculated projections.

One such overriding variable is the instability of the general economy, and another is the populist political trend that leads to a life style that assumes equality of access to outcome rather than equality of access to opportunity. Similar in magnitude is the questionable availability of capital for maintaining the rate of growth of productive enterprises that is assumed in calculated manpower projections. At the present time extrapolations of growth of our general economy are quite unreliable.

It has been emphasized in this conference that shifting government policy on direct research support is of a high order of importance in creating gross demand deviations from the relatively small ranges of errors that have been calculated in manpower projections. This is so, but a much more important source of gross deviations is the evolving policy of the government toward providing public services that are great consumers of scientific and engineering talent.

The provision of universal health services will have a greater impact on consumption of scientists than the broad deviations in health-related research support of the past five years. Health is only one example of the public services that are enormous potential consumers of scientific and engineering manpower; energy, environmental pollution control, and non-renewable resource substitutes are similar in impact. These sources of overriding variables in the socioeconomic realm and in the realm of policy toward public services have to be identified and their impact on the reliability of calculated projections estimated.

It is probable, in my opinion, that the importance of incremental technology is increased in a society committed both to public service and to growth. Over half the value of our gross national product is now in services and there is a broad commitment to improved quality of life as well as standard of living. Such a set of goals can be achieved only by improved productivity of service groups as well as producers of goods.

However, technology is not yet widely accepted as an important means of improving the productivity of the service sectors even though in optimizing these activities for effectiveness of public benefit it will be essential to accept and support technologies that allow increased efficiency.

For example, the unit cost of education is rising at a rate that may soon make the cost to the student intolerable. While tuition rates are rising, legislations are restraining their support of higher education and universities face a combination of falling endowment income and escalating institutional costs.

In order to arrest these trends toward disaster, a sharp increase in the productivity of the educational process is needed. Technologic innovation in higher education—particularly graduate and professional education—has been resisted heretofore but it is now essential to the improved productivity that is a condition of survival.

Another example of an intolerable rate of increased service costs is in the realm of health care. Diagnositc and therapeutic technology defines the limits of an effective productivity of the individual health practitioner, while efficiency of the practitioner is a function of the distribution system of which this person is a part. The distribution system has been notoriously resistant to technologic innovation and this had adversely affected the utility of innovations in diagnostic and therapeutic technology. Universal health service will require unprecedented efforts from the biological and clinical scientists, but will also create demands for measures of the effectiveness and efficiency of novel distribution techniques in actually improving health rather than simply expanding services. Without this controlling measurement, a simple expansion of services may not achieve its ultimate purpose of improving health.

A final example of rates of increased costs in the service sector that may soon become intolerable is the growth of government. Government is a natural monopoly and most difficult to regulate. At all levels it is the most rapidly growing enterprise in our society and the largest source of new jobs for scientific and engineering manpower. This totality of local, state and federal government is the most dynamic growth industry in our nation, and yet it is hardly recognized as a factor in calculating projected manpower demands in science and engineering.

The application of technology to agencies of government service has been resisted in much the manner that has been observed in education and health services. These three may serve as sufficient examples of service activities with overriding demands for manpower if their availability and productivity are to be improved so they can serve the public at a tolerable cost.

Since scientific manpower supply is a function of the educational process, I would call attention to some novel social variables of our time that have arisen external to the educational community but which will continue to force profound changes upon it, and will affect the calculated projections of output when we learn how to include them in our calculations.

All graduate and professional education is based on the idea of individual merit, identified through competitive selection. However, I have referred already to a developing life style that assumes equality of outcome rather than equality of opportunity which is more popular among the socio-economic group that traditionally has sought graduate education. This conflict between egalitarian and meritocratic values has led to significant changes in the environment of graduate schools.

The growing anti-institutional bias of graduate students adds to the challenge to traditional practices. We must reconsider the social utility as well as the intellectual validity of a graduate educational process in which only 15 percent of students reach their goal of a doctorate and in which the vocational destiny of the student is obscured by the disciplinary and departmental nonmenclature of his degree. The degree itself, under those pressures, has declined in value for many talented students whose favored life style denies institutionalized education as the optimum path toward personal vocational goals.

Faculty effort distribution cannot be immutable if increased productivity is to be achieved. The capacity to adjust between research and education is essential to responsiveness to changing social needs. The traditional academic model of research and teaching is a value judgment and the suitability of employment, overemployment or underemployment, is gauged against this isolated value judgment. It is not, I think, salary but rather "revealed truth" that is at the root of the notion of underemployment of scientists.

We must examine the whole range of social and economic needs that can most effectively be met by graduate education. Vocationally oriented programs of graduate instruction should be made available to meet these needs. Students make vocational choices, but the labels under which information is supplied to them tend to be disciplinary, or departmental. These traditional labels are of historic interest but do not represent the vocational component which affects a student's choice and decision. We have surreptitiously moved to that vocational level as we have made immunologists instead of biologists and have created all kinds of hybrids in bio-engineering and biophysics, but in many instances have declined to change the name of the certificate. In short, this reluctance to vary the traditional value judgments behind the academic doctorate needs to be changed if we are to have rapid adjustments to demand changes.

My points, then are these:

- There are overriding variables that have the capacity to make even the best predictions irrelevant, and these need to be recognized.
- There are massive changes in the nature of our economy and in the mood and value system of the students that come to us.
- If we are going to have a relief in the tension of the dissynchrony between supply and demand, then university faculties will have to look to their own houses and make adaptions to the educational process itself.

General Discussion

Several points were raised in the course of the discussion. These are summarized.

- There is a critical problem of lag between the time manpower needs are recognized and training can take place.

- Although total first-time enrollment has risen despite cutbacks in Federal fellowship support, there is a decline in the ratio of number of first-year enrollments versus total baccalaureates graduated. This suggests that the Federal action is having an effect, albeit one which is difficult to forecast.

- The decrease in ratio of first-time graduate enrollments to baccalaureates may represent a real decline in quality and a change in the distribution of graduate students among fields. It may not be wise to force students to work too much at the wrong thing off-campus or to go too heavily into debt. Also, the accentuation of graduate school as a middle-class opportunity, with denial of opportunity to those who can't afford it, is questionable.

- The removal or sharp reduction of the Federal support for higher education is more or less a declaration that there is no Federal responsibility in this area. It would be a national loss if we abandoned the willingness to insure that the best of our young people are able to go on to training in whatever field they wish.

- Decisions affecting graduate education have a political component when made at the Federal level. An OMB decision to decrease fellowships is one kind, and concern with equal opportunities for minorities and women is another. The effects of these decisions must be included in useful projections, and the reasons for the decisions must be fully understood, whether it be the result of an energy crisis or a Civil Rights Act.

- If annual Ph.D. production were to decline as much as 30 or 40 percent, there would still be an increase in the inventory of Ph.D.'s. However, it is not just the total, it is input that is significant; the age distribution and quality of the stock would certainly be affected. We must take seriously the early contribution to research of bright young scientists and engineers.

- The supply of manpower has direct impact upon the demand for Federal funding whenever on-going projects are considered. There are severe losses to the disbandment of laboratories which took years to build, the investment in training, in team coherence, in success, is so valuable that every effort is made to retain the structure and personnel as the goals and purposes shift. On the other hand, there is little evidence that the supply of individual, unattached scientists, a manpower pool, without clear focus, has any impact upon the demand for Federal funding. There has been no Federally funded project of any magnitude initiated in the last years because there are thousands of Ph.D. physicists available.

The formal paper prepared by Charles V. Kidd for this session appears below.

An Overview of Projections and the Supply Side

I. Introduction

My first assignment is to present an overview of projections, a chore accepted without adequate thought. Finding the field too vast I decided to comment on a few general matters that seem to be of general interest and significance. These include such questions as what are projections properly used for, how good have they been, and how precise do they need to be. That is the first part of the paper.

The second part of the paper poses some problems on the supply side and suggests some possible paths to solution.

Before proceeding to the substance of the paper, I should first like to suggest as a possibility that looking at the problem from the supply side and from the demand side, which has been the conventional procedure, may be partly responsible for past and current methodological problems. When methods for estimating supply are worked out with emphasis on factors affecting supply and demand is approached in terms of factors affecting demand, the effects of the market tend to be ignored, or played down. This is because market forces are neither supply nor demand but mechanisms which tend—however imperfectly—to bring supply and demand into balance. In addition, the feedback mechanisms that are constantly at work tend to be ignored when separate projections of supply and demand are made and the match between them is measured at some given time in the future. I shall return to proposals for dealing with these problems.

As another prefatory note, I want to make clear in case it is not obvious to everyone, that this report does not contain the results of any new research. It is a series of reflections based on the work of others, rather than an effort to deal systematically with all of the issues. The central purpose of the paper is to derive from events to date what some of the issues in projecting are for the future.

II. The Use of Projections

I take it for granted that projections are useful for a wide variety of purposes, that they will continue to be made, that they are now inadequate and that efforts to improve them are urgently needed. These propositions are not universally accepted, so I shall explain how I come to these conclusions.

On the first point—the need for projections, I have outlined in a rough way the kinds of decisions that could be made better if good projections existed, and the kinds of decisionmakers to whom good projections would be useful. (Chart 3.1). One could argue that every decisionmaker (governments, private employers, students, etc.) has a greater or a lesser interest in every kind of decision (governmental spending, personal choices, college and university decisions, etc.), but I have simply noted the most direct and obvious interests. The array of kinds of decisions that could be made better and the array of decisionmakers who would be added by useful projections is so large that efforts to project the labor market situation for highly trained manpower will continue.

Chart 3.1
The Uses of Projections of Supply and Demand for Highly Trained Manpower—Decisions and Decision-Makers

Decision to Which Projections Are Relevant	Decision-Makers: Colleges and Universities	Federal & State Government	Private Employers	Students	Employees	Counsellors
A. Legislation and Appropriations						
Research	X	X	X	X		
Institutional support	X	X				
Student aid	X	X		X		
Construction	X	X				
B. Personal choices						
College attendance	X	X		X		X
Field of study	X	X	X	X	X	X
Level of study	X		X	X	X	X
Choice of initial job			X	X		X
Career changes			X		X	
Retraining	X	X	X		X	
C. Allocation of Institutional Resources						
Student aid	X	X		X		
Construction	X	X				
Departmental budgets	X	X				
Faculty hiring, promotion and retirement	X	X				
D. Business Decisions						

Freeman and Breneman have analyzed the uses of manpower forecasting and analysis and they came up with three major uses:[1]

(1) A tool for evaluating governmental policies;

(2) An early warning system which may reduce adjustment problems; and

(3) An information or diagnostic device to direct attention to market problems beyond the purview of individual decisionmakers.

They believe that forecasts should not be used for, or are of little value in connection with:

(a) Operation of a central manpower planning system designed to ensure that the optimum number of students is trained in each field. (The authors believe that "students and other decisionmakers are highly responsive to market opportunities and can be expected, over the long haul, to keep markets at or near equilibrium.")

[1] Freeman, R. B. and Breneman, D., *Forecasting the Ph.D. Labor Market: Pitfalls for Policy*. National Board on Graduate Education, November 16, 1973. Working Draft, Mimeographed, p. 18

(b) Provision of information to guidance counsellors. (The authors believe that "students tend to ignore formal guidance. . . Direct observations, obtained by summer or part-time jobs, older friends, or professors are far more important information channels. . .")

(c) Advice to educators on the number of slots to b: offered in college courses. (The authors believe that "the supply of openings in universities is sufficiently flexible to permit substantial changes in graduates without centralized planning or forecasting. A particularly grievous error in linking educational plans to forecasts occurs in 'local labor market planning' which ignores the extreme geographical mobility of the highly educated labor force."

In an excellent article, Howard Bowen has challenged the utility of labor market projections on more fundamental grounds. He claims that the character of the economy cannot be predicted for periods long enough to be pertinent to educational planning, that is, 30-60 years in the future. Manpower requirements depend on what the country wants to do, and education itself is an active force affecting the future. In Bowen's view, there need be no fear of oversupply based upon estimates of future supply and demand because the economy will adapt to various supply levels. He has pointed out that education and training not used for the expected purpose are not wasted:

A Ph.D. in English or history may find his destiny in journalism, in the State department, in publishing, or in secondary education.[2]

Therefore (I extrapolate from Bowen's premise), one need not worry about the unemployment of those with doctorates.

One of Bowen s major theses is that

> Education at all levels is not something to be feared but something to be encouraged. It shoud not be "strait jacketed" by detailed central planning based on labor market considerations. Central planning of the educational system, which implies rationing places in various programs, is not only unnecessary but almost certainly harmful. . . The number of places in various programs and in the whole system would be set in response to student choices, not in response to dubious labor market projections.

Finally, Bowen has made the point that

> The manpower theory of educational planning is based on a grand misconception—the input-output or the means-ends fallacy—that permeates society. The world is regarded as divided into inputs, primarily in the form of work or effort, and outputs, primarily in the form of economic goods and services.

He has pointed out that inputs can be rewarding and exhilarating and outputs stultifying.

> Education is not designed to prepare people for whatever work flows from the blind and predestined imperative of technology; rather, it is intended to educate people of vision and sensitivity, who will be motivated to direct technology into humanly constructive channels.

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[2] "Manpower Management and Higher Education," *Educational Record*, Winter 1973, p. 9.

Certainly most if not all of us would subscribe to the thesis that student choice is preferable to a central, national manpower plan which would allocate places in accordance with forecasted future demand. There is first the practical consideration that experience to date does not generate confidence that the forecasts would be reasonably accurate. However, even if the forecasts were good, there are fundamental objections to determining the number of places in various fields of graduate education by a central manpower plan. Many find a central manpower plan objectionable because it would deny to a substantial proportion of students the opportunity to study what they choose, and because they believe that market forces are more efficient than government planning as a guide to allocation of resources. Howard Bowen is an eloquent and forceful advocate of this point of view.

However, I have some reservations with respect to the Freeman-Breneman-Bowen analysis. First, an effort to project is not necessarily an effort to establish central planning. Good projections should make free personal choices better informed. To say that projections encourage, or are useful only for central planning seems to me to impute purposes and intent to a technique that has in itself no philosophy or goals.

Moreover, federal expenditures for graduate education and for support of graduate students do inherently call for a certain degree of central planning however much one may object to the idea. The federal money must be made available for a purpose. The amount of money should be determined by the net utility of expenditures for graduate education compared with expenditures for other things. The utility is certainly measured in part by what kinds of jobs and careers graduate students have. Projections are, it seems to me, a useful way of assessing what kinds of jobs and careers they may expect and hence what the federal investment should be.

With respect to Howard Bowen's point that the shape of the economy can not be predicted 30 to 60 years in the future, I would agree, but would be satisfied if projections could be made reasonably precise for 3 to 5, or 5 to 10, years in the future.

With respect to the reservations of Freeman and Breneman on the usefulness of forecasts for counselling and institutional planning, I agree that sources of information and advice other than counsellors are most important to students, and that colleges and universities adapt fairly well to labor market changes. However, if good forecasts are made certainly they would be helpful to both counsellors and to colleges and universities.

Here it might be useful to comment on Bowen's thesis that education and training not used for the originally intended purpose are not wasted, and that one therefore need pay little or no attention to prospective supply and demand. I find this a congenial philosophy of education, but it does seem to me important to distinguish among levels of education in applying the philosphy.[3] Bowen's thesis is certainly applicable when elementary and secondary education are under consideration. An educated citizenry is necessary to the operation of a democracy, regardless of levels of employment or unemployment on any line of work. However, the increasingly vocational trends in both secondary and postsecondary education make manpower forecasts relevant.

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[3] For an elaboration of this theme, see, John K. Folger, Helen S. Astin, and Alan E. Bayer, *Human Resources and Higher Education* (New York: Russell Sage Foundation, 1970), chap. 7.

When graduate education is considered, the situation changes. Graduate education is less important than college, secondary or primary education as a means of providing the common base of knowledge and values necessary to the operation of society. To a greater degree than is true at other levels of education, graduate education is training for a specific kind of job and a specific career. Those with graduate training tend to work at the tasks they are trained for. Only about 20 percent of those with bachelor's degrees in liberal arts have jobs directly related to their training. However, about 90 percent of those with doctorates in science and 80 percent of those with terminal degrees in sociology, economics, and other social sciences have jobs directly related to their training. Since doctoral training is intended to prepare persons for work in a specific field and since a high proportion actually work in these fields, forecasting supply and demand is, in principle, a useful activity. It is not a tragedy or a complete waste to have a Ph.D. in English or history employed in publishing or secondary education. But it is an expensive way to secure capable people, and these costs should be kept low. Even so, given the fallibility of forecasts and the high costs of *not* being able to hire well-trained people when they are needed, one should err on the side of overproduction rather than argue, on the basis of shaky forecasts, the minimum number needed.

Since one legitimate measure of the utility of support for expensive graduate education is whether those trained will be employed at the tasks for which they were trained, forecasts of supply and demand are imperative, particularly when the Federal and state governments bear a substantial share of the costs of graduate education. There is not enough money for everything and choices must be made, in large part through decisions made through the political process, between investment—as, for example, between expenditures for graduate and other postsecondary education. In this sense, we do indeed have central planning for manpower and best efforts are needed to make this planning useful rather than harmful.

Some of the most productive uses of projections relate not to specific decisions by specific decisionmakers, but to speculation on the secondary or tertiary consequences of prospective changes in the labor market for highly trained persons. For example, one can point to a number of areas where the prospect of an oversupply of persons suitably trained for teaching and research in universities has invigorated consideration of change:

(1) The effects of an aging faculty on the nature and quality of teaching.

(2) The possibility that non-academic research centers may be relatively more productive than academic centers if positions for bright young persons are scarce in universities and the prospects for promotion are poor.

(3) Methods for training graduate students for non-academic careers.

(4) Implications of low rates of hiring and slow promotion for faculty morale and for governance.

Fortunately, productive discussion can be stimulated by forecasts with a large margin of error—but the direction of change must be accurate.

Even if projections prove to be erroneous, methodological advances are useful. As Ahamad and Blaug have pointed out, "Even a perfectly accurate forecast based on pure guesswork may be less useful for planning and policy than an inaccurate forecast obtained from a well-specified model. In the latter case, we are in a position to learn from our mistakes. . . , whereas in the former case we can only hope that we shall be as lucky the next time."[4]

III. A Brief Review of Projections

A. Criticisms of Projections

The development of projections during the 1960's was accompanied by charges that they were not useful, and even harmful. W. Donald Cooke, Dean of the Graduate School at Cornell, reviewed forecasts made from 1901 to 1934, and found them curious.[5] For example, the President of Harvard stated in 1901 that, "Everybody knows that there are too many doctors of philosophy for vacant college positions." In 1934, an article in the Association of American Colleges Bulletin stated that, "We have passed in our national history from a period of exploitation, speculation, and development into a level period of operation in which fewer engineers will be needed."

The later forecasts, which began to shift from the "everybody knows" form to a quantified approach, have not fared much better. The large errors embedded in the forecasts of the demand for academic made by the Office of Education, the National Science Foundation and the National Education Association have been thoroughly discussed by Berelson, Cartter and Folger. They have pointed out, in a series of analyses extending from 1960 to 1974, that the authoritative forecasts were in Allan Cartter's words, ". . .at best misleading and at worst counter to the facts."[6]

The Office of Science and Technology was the sponsor of a study in 1966 that seriously overestimated the future demand for Ph.D.'s in science and engineering.

As late as 1974, one observer came to the conclusion that, "Projections of manpower needs and probable supplies have been so superficial and unsubstantial and our current understanding is so limited that any attempt to channel the flow of students into particular fields (or into graduate education as a whole) has as good a chance of worsening as of improving the market outcome."[7]

He had good reason to be pessimistic based on the recent record. The NSF projections of 1961[8] held that 65,000 doctorates in science and engineering would be awarded in the decade of the 60's, but the actual figure was 78,000, an un-

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[4] Ahamad, B. and Blaug, M (eds). *The Practice of Manpower Forecasting*. (Jossey-Bass, Washington, D.C. 1973), p. 24.

[5] Journal of Proceedings and Addresses of the Association of Graduate Schools in the Association of American Universities. Twenty-third annual conference (Washington. AAU. 1971)

[6] Gordon. M.S. (ed.). *Higher Education and the Labor Market*. Article by Allan M Cartter, *The Academic Labor Market*. Carnegie Commission on Higher Education, (McGraw-Hill. New York) 1974, p 282.

[7] Dresch. S P, An Economic Perspective in the Evolution of Graduate Education. Technical Report Number One National Board on Graduate Education. Washington, D.C March 1974., p. 15.

[8] The Long Range Demand for Scientific and Technical Personnel. a Methodological Study NSF 61-65, 1961. (M. Cobern of NSF analyzed the projected and actual degrees awarded in *Evaluation of Prior Projections of Demand for and Supply of Scientists and Engineers*. (NSF. SRS, Nov 8. 1973)

derestimate of 20 percent. Doctorates in engineering were underestimated by 70 percent (11,000 projected and 19,000 awarded) and doctorates in science were underestimated by 9 percent (54,000 projected and 59,000 awarded). The projections were based essentially on extension of past ratios of science and engineering doctorates to total doctorates, with total doctorates assumed to rise at a constant 7 percent rate.

In addition, as I pointed out above, current data show that earlier projections of Ph.D. output have been, with the exception of Allan Cartter's projection, too high.

It is too early to assess the validity of the 1968 and 1969 NSF projections of supply and demand.[9] These are probably the most carefully done projections in the science and engineering fields. The clear statement of methods, assumptions, rationale and sensitivity of various factors in the 1971 report, and the care with which the projections were prepared make this the best of the projections based upon what might be called conventional manpower forecasting techniques.

The NSF reports bring into sharp focus the question how the basic technique can be modified by taking market forces more specifically into account.

B. Recent History and Recent Projections

In a nutshell, recent projections have overstated graduate enrollment and Ph.D. production, and the cause of the overestimate was an underestimate of the power of the market to bring about adjustments.

1. Enrollment

Take first enrollments. As we all know, the number of federal fellowships was cut sharply between 1968 and 1974. To be precise, the number dropped from 50,000 to 6,600.

In the face of this reduction, there has been no reduction in graduate enrollment. In fact, total graduate enrollment has increased, and the proportion of all graduate students enrolled full-time has remained virtually constant at about 50 percent.

A Carnegie Commission survey showed that first-time graduate enrollment increased by 2.8 percent between the fall of 1970 and the fall of 1971. However, first-time enrollment in private universities declined by 1.2 percent. Between 1971 and 1972, first-time graduate enrollment increased by 2.1 percent, and between 1972 and 1973 by 3.5 percent.[10] In each year enrollment in private universities increased by less (.9 percent and 2.7 percent respectively.)

Why has the number of graduate students continued to rise while federal fellowships have almost disappeared?

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[9] *Science and Engineering Doctorate Supply and Utilization, 1968-80* NSF 69.37 November, 1969. *Science and Engineering Doctorate Supply and Utilization 1969-1980* NSF 71-20 May, 1971

[10] CGS-GREB Survey

First, all federal support for graduate students provided only a small fraction, perhaps 10 to 15 percent, of the funds supporting graduate students even in 1968. (This would count as "support" all fellowships from federal, state and institutional sources, all earnings from teaching and research assistantships, all earnings from non-academic sources, earnings of spouses, loans and family contributions.) So, all things considered, a sharp decline in federal fellowships has not meant a sharp decline in funds for the support of graduate students. I know that I sometimes tend to forget this, and perhaps others do too.

Second, it does appear that there has been enough additional money from various sources to compensate for the decline in federal fellowships. Students are apparently willing to work more, to use savings to a greater degree and to borrow more in order to attend graduate school. Spouses may be working more. Parents must be contributing more, thus shifting the pattern of financing graduate study closer to the customary patterns for law and medical school.

Within the small overall increased number of first-time graduate students over the past three years, there have been marked shifts by field, and we are indebted to the National Board on Graduate Education for analyzing the figures.[11] They have shown that there have been reductions in first-time enrollment in fields where careers are primarily academic and increases in fields where career prospects seem brighter—health professions, city planning, dentistry, medicine and law, for example.

First-time enrollment in the physical sciences was down by 8.7 percent in the fall of 1972 as compared with 1971, while enrollment in education increased by 8.8 percent, humanities by 5.7 percent, social sciences by 4.7 percent and biological sciences by 7.1 percent.[12] The continuing increases in enrollment in education probably reflect what can be called "defense credentialling"—getting a master's or doctor's degree to increase the chance of keeping a job when the market is soft. This phenomenon incidentally is one that further complicates forecasting. That is, under certain conditions, worsening of career prospects in a field may tend to increase rather than decrease graduate enrollment in the field.

2. Ph.D. Output

Ph.D. output has been lower in 1971, 1972 and 1973 than most projectors expected. With the exception of Allan Cartter, all of them have been high for 1973. This is somewhat remarkable because most of the students who received Ph.D. degrees were already in graduate school when the projections were made. Changes of academic goals and attrition did not follow historic patterns, a phenomenon to which I now turn.

Actual and Projected Ph.D.'s Awarded, 1971-1973[13]
(in thousands)

Year	Actual	Haggstrom (C)	U S.O.E.	N.S.F.	Cartter	Comm. on Human Resources
1971	31.8	31.9	31 9	31.4	30.7	29.1
1972	33.0	34.5	33.8	33.7	31.3	32.1
1973	33.7	36.9	37 9	35.9	32.3	35.5

[11] National Board on Graduate Education, Doctorate Manpower Forecasts and Policy Technical Report No. 2 November 1973.

[12] GCS-GRFB Survey

3. Enrollment and Output

To begin with first-time graduate enrollment has proved difficult to forecast accurately. The most careful work is that of Haggstrom. In 1970, he projected the following percentage increases from the preceding year:

Fall of	High	Medium	Low
1971	11	5	8
1972	11	8	5
1973	9	8	7

As noted earlier, the actual percentage changes have been as follows:

Fall of	All Universities	Private Universities
1971	1.2[13]	-1.2
1972	2.1[14]	-.9
1973	3.5[15]	-2.7

Third, it appears that the job and career outlook has been primarily responsible for first-time graduate enrollment to rise less than even the most conservative projections called for. I doubt that the decline in federal fellowship support had much to do with this adjustment.

In any event, the market seems to be working, so far as enrollment is concerned. (One has to take into account the anomalous continuing rise in first-time graduate enrollment in education in the face of a dismal job outlook. Here, however, the response is a rationale response in the specific education job market. Teachers are enrolling for graduate courses to enhance their credentials in what promises to be a highly competitive market.)

The fact that total graduate enrollment—and first-time enrollment—are increasing slightly does not mean that the whole enterprise is in a steady state. There are in fact important trends not measured by total enrollment figures. Trends by field differ. In the past, forecasters have tended to assume that the number of degrees granted is driven in a quite predictable way by graduate enrollment. For example, one reads in some forecasts that the number of Ph.D. degrees to be awarded four to seven years in the future can be firmly predicted because

[13] Actual from NRC Summary Report 1972. Doctorate Recipients. Forecasts from Wolfle and Kidd. The Future Market for Ph.D.'s *Science*. Vol. 173, 22 Aug. 1971, p. 785.

[14] Peterson, R. E., American College and University Enrollment Trends in 1971. Carnegie Commission on Higher Education (McGraw-Hill, 1972), p. 10.

[15] Counc.' of Graduate Schools—Graduate Record Examination Board surveys.

the students who will receive these degrees are already enrolled. Haggstrom in fact did this for the decade of the 60's.[16] He found that, "Overall retention rates at the graduate level have been relatively stable. . . . The proportion of entering graduate students who complete doctoral programs has been increasing slightly (1960-1969) but steadily with perhaps a levelling off for men during the last two years." The data showed that for the entire decade of the 60's the number of doctoral degrees awarded varied only between 16 and 17 percent of the number of first-time graduate students 4 to 7 years before any given year. The comparable figure for women was 4 to 5 percent. For the combined group it hovered close to 15 percent.

However, the ratio reached a peak of 16.3 percent for 1970 and has declined steadily to 11.6 percent for 1973 (Table 3A). If the 15 percent ratio of the 60's had held up, 43,500 Ph.D.'s rather than 33,700 would have been awarded in 1973. Here we have another example of a ratio which held firm through the 1960's, but which has changed substantially over the last three years. The reasons for the change are that many students are not firmly committed to seek a Ph.D. or a master's degree when they enroll for the first time as graduate students, and generally they do not formally declare their goal. Moreover, those who enter fully committed can change their minds in the course of study. In addition, attrition—leaving without a degree—has to be taken into account. Accordingly, the numbers and kinds of degrees to be awarded to a group of a given size of newly enrolled graduate students or to a total enrollment group of any given size can vary widely. This did not happen in the 60's but it has happened over the past three years.

We are witnessing another market adjustment expressed as decisions to change degree aspirations or to remain in or to leave graduate school.[17]

It might be possible to forecast such changes with greater precision by such means as determining degree aspirations of first-time graduate students, and by questioning students in the later years on their degree intentions or their intention to remain in or to leave graduate school.

D. Observations

From all of the trends noted above—levelling off of graduate enrollment and Ph.D. production, and a reduction in the proportion of first-time graduate students who are later granted Ph.D. degrees—the dangers of relying on past trends and the penalty to be paid for ignoring market forces are evident.

First, the self-correcting forces put in motion by projections that correctly predict trends are not entirely dependent upon the precision of projections. Indeed, when projections are taken seriously, forces are put in motion that tend to

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[16] Haggstrom, G W. The Growth of Graduate Education in the Post-Sputnik Era. p. 50. Unpublished paper cited in Wolfle and Kidd. The Future Market for Ph D 's. (Science. Vol 173, 27 August 1971, p 793)

[17] Cain, G.D., Freeman, R B , and Hansen, L W., Labor Market Analysis and Technical Workers. Johns Hopkins Press, 1973. In this excellent report the authors note an additional factor that introduces a fairly quick and marked supply response to market conditions—decisions of undergraduates to pursue graduate work —later reflected in changes in first-time enrollment They cite (p. 68) the fact that only a third of the bachelors class of physics majors in 1970 expected to continue in the field, compared with 55 percent in 1967.

make them erroneous as predictions. Allen Cartter has noted this phenomenon in more specific terms: "My projections of 1964 and 1965 that the academic labor market would reverse itself in 1969 and 1970. . . could be called unsuccessful in the sense that few persons took them seriously, thus permitting them to become accurate predictions. Today. . . it is likely that projections indicating even more marked imbalances in the late 1970's and 1980's will be at least partially countered by adjustments in enrollment patterns."[15]

Table 3A.
Ph.D.'s Awarded Compared with First-Time Enrollment in Earlier Years

Year	(1) Ph.D.'s Awarded[1]	(2) Average First-Time Enrollment[2] 4 to 7 years Earlier	Percent Ph.D.'s Are of Earlier First-Time Enrollment
	(000)	(000)	%
1973	33.7	290	11.6
1972	33.0	244	13.5
1971	31.8	223	14.3
1970	29.5	199	16.3
1969	25.7	176	14.6
1968	22.9	152	15.1
1967	20.4	132	15.5
1966	17.9	118	15.2
1965	16.3	106	15.4
1964	14.3	96	14.9
1963	12.7	88	14.5
1962	11.5	77	14.9

[1] NRC Summary Report, 1972, Doctorate Recipients (Preliminary 1973 figure added).
[2] Haggstrom, Table 6, p. 35.

Finally, the fact that projections have not been precise does not mean that they are useless or harmful. If projections are to be useful rather than harmful they must predict trends accurately but they need not be precise. If the current widely accepted projections of a continuing soft market for academic jobs are correct, they will be useful because they will stimulate corrective action even if the precise degree of maladjustment is not accurate. If the general trend proves to have been misassessed, a lot of harm will have been done.

IV. Some Unresolved Problems in Projecting

From the record to date, it is clear that there is ample room for improvement in forecasting, and this section discusses some of the poorly resolved problems and some possible solutions.

[15] Gordon, M., op. cit.

A. Projections and Predictions - A Prologue to Methodological Improvement

Since the distinction between projections and predictions is interesting and has some implications for methodological developments, a few words on the nature of the distinction may be useful.

Those who undertake to look into the future to divine the supply of highly trained manpower generally distinguish between projections and predictions (or forecasts as Harold Goldstein has called them). Thus, Cartter has written that, "One should draw a careful distinction between projections and predictions; the former may illustrate the consequences of current trends and thus serve to alter the course of events. In a meaningful sense, successful projections may turn out to be poor predictions of actual events. . . . Thus, all manpower projections should be treated with great skepticism as predictions."[19] I have noted that, "To the extent that people believe manpower forecasts and act upon them, the forecasts are doomed to error unless those who make them predict the effects of their own forecasts. In the social sciences forecasts are not simply efforts to foretell what will happen; they can and do often influence the course of events."[20] Freeman and Breneman have noted that, "The hypothetical and provisional nature of the calculations is invariably stressed, often by distinguishing them as projections, not predictinns, despite the effort in obtaining the 'best' parameter estimates and the extensive use of judgmental assumptions to give good results."

The foreword to the latest N.S.F. projection, *1969 and 1980 Science and Engineering Doctorate Supply and Utilization* (p. iii) notes that, "It must, of course, always be understood that *projections are not predictions*. Projections are derived from statistical models based on trends and on awareness of current happenings. Thus, they produce a range of possible future situations based on definitive assumptions and no significant break in trends. Actual events may turn out to be different from some of these projections. . . . It is important that no false sense of precision be attributed to numerical values in view of the limitations of the data and methodologies, the complexity of the system and the unpredictability of future events."

Yet Cartter notes that he has used his own judgment to modify projections that seem unreasonable, and the N.S.F. projection referred to above has this to say on an extremely critical point: "In the case of nonacademic R&D positions, it has been assumed that doctorate absorption rates will be alternatively 10 percent and 20 percent higher than the doctorate-to-total-scientist ratio existing in the particular category in 1969. *This assumption is based on the conviction that in the past the utilization of doctorates was restricted by short supply.*" (p. 15. Italics added.)

Accordingly, the sharp distinction which we are urged to make between projections and predictions is in fact often blurred by the desire of the authors to avoid making projections which are obviously silly. It is further blurred by techniques which take market forces and future feedback into account. Nevertheless, the distinction is sound in principle and the user of the product should know when projections are modified by the judgment of the author. This information is, in fact, generally provided.

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[19] Cartter, A M , The Academic Labor Market in Higher Education and the Labor Market p 282

[20] Kidd, C V , Too Many Scientists? Britannica Yearbook of Science and the Future, 1973, p 425

B. Inadequate Measures of Quality

A prominent characteristic of forecasts of supply for highly trained manpower—and of demand, too, for that matter—has been that they have paid little attention to quality—to the quality of instruction, research or of the Ph.D.'s themselves. Attention has been centered on simple numbers—first-time enrollment, total enrollment, degrees awarded, and so forth. Even when data are collected and analyzed by field, the question of quality is generally ignored. This is obviously a difficult problem for which there will be no satisfactory answer for the foreseeable future.

However, one crude approach is possible. That is to assume that the quality of institutions or departments can be measured, and that on the whole the quality of the institution is related to the quality of those who are awarded degrees. This is obviously a shaky set of assumptions, but it is probably better to explore the possibility of taking quality into account than to ignore the problem.

C. Inadequate Projections by Field and Discipline

In various fields the factors affecting both supply and demand differ, and even when these factors are the same they have different effects on various fields. Accordingly, gross forecasts of total Ph.D.'s awarded do not necessarily indicate what will happen in specific disciplines or areas of study. This (together with the natural interest of counsellors, planners, faculty members, students at all levels, employees and employers in industry and professional associations) has led to the well known movement to produce supply and demand forecasts by discipline and by area. It seems inevitable that the need for such detailed data will increase, and that increasing efforts will be exerted to produce detailed forecasts. The results to date are spotty. The professional associations are a logical source of forecasts, but many of them have neither the resources nor the interest required for a competent job. A few—most notably chemistry and physics—have produced sophisticated analyses. Further stimulation of studies of forecasting and of production of forecasts in specific fields is clearly indicated. However, some of the limits to the utility of forecasts by discipline or fields should be mentioned. The narrower the fields covered, the greater the problem of substitutability. When training or skills in one specialty are adequate to permit a person to work in another relative demand by field can cause large shifts in effective supply. Here the problems of measuring supply and demand merge. The fact that demand in precisely defined fields is even more difficult to forecast than overall demand complicates the problem of measuring supply. Another way of stating this problem is that the number of those with their first training in a given specialty is an inadequate measure of the supply of persons capable of working in that specialty. The further into the future that forecasts are made, the greater the barriers to measuring supply in narrowly defined specialties. This problem is likely to become more complicated if graduate education becomes, as it should, capable of educating people for change and of equipping them to shift over a fairly wide range of job specialties. Moreover, to the extent that current thoughts about the rapid technological obsolescence of specialties and the need for retraining are translated into action, the greater will be the task of defining the supply of persons trained in narrow specialties.

A further complexity in forecasting by precise field is generated by the fact that every field is affected by gross factors common to all fields. For example, demographic trends and the rate of growth in G.N.P. and trends in federal financing of R&D and graduate education are powerful underlying factors that influence both global forecasts and forecasts by field. Unless common assumptions as to these underlying factors are accepted, the forecasts by specific field can not be usefully compared, and they are obviously not additive.

Despite the conceptual, methodological and practical problems in forecasting by discipline, more work should be done. It is not possible to know the limits of projecting by sector until the limits are tested, and the process of working on projections in itself raises questions significant to individual disciplines.

D. Inadequate Concepts of Underemployment

A recent Carnegie Commission report states this consensus: "It is not anticipated that there will be prolonged and widespread unemployment of Ph.D.'s. Rather we can expect a situation in which holders of doctorates will be forced to accept positions that would have been considered unsuitable in the past."[21] Since we face this situation, it seems to me that a prime area of inquiry is the definition and measurement of unemployment. This obviously presents issues of values that have to be sorted out. Is a happy and inspiring teacher of physics in a community college who has a Ph.D. in physics from a major university underemployed? Is the president of a bank who has a Ph.D. in the classics underemployed? Is underemployment, whatever it is, a condition necessary to accommodate to inevitable periods of imbalance between demand and supply.?

If projections purport to tell how many Ph.D.'s will be "needed"—either in terms of effective demand or in terms of numbers required if some defined social or economic goal is to be met—then the characteristics of employment that are to be considered as a legitimate part of the need must be defined. In other words do you "require" a Ph.D. who is teaching in elementary school?

Since there will in all probability be extensive underemployment among Ph.D.'s in many disciplines, and since the nature of employment is a legitimate parameter in defining demand, a clear definition of underemployment is needed.

One of the central problems of projection, and indeed of current labor market analysis, is to establish generally acceptable concepts of underemployment. Otherwise, "underemployment" may be a rug under which any amount of forecasting rubbish may be swept.

The problem is to decide the criteria by which underemployment is to be defined, and to attach quantities to the criteria so that the underemployed may be counted. A number of criteria could be used, separately or in combination.

Income is one criterion. A biochemist who earns below $5,000 per year, for example, is probably underemployed even if he works as a biochemist. But is a chemist who is a bank president underemployed or not? By the income criterion he is not. By the use of skill criterion he may be.

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[21] Gordon, M S , (ed) Higher Education and the Labor Market (McGraw-Hill Book Co) New York 1973 p 12

Social productivity is another criterion, but a slippery one. A Ph.D. in physics who teaches in a community college may be considered as contributing in an important way to society, and as using his advanced training to advantage. He would be considered as not being underemployed even though he does not conduct research and even though his earned income is low relative to university teachers. On the other hand the apocryphal taxi driver with a Ph.D. would probably be considered as underemployed, even though the classification would seem to deny social utility to taxi driving.

Reasonably full use of maximum skills is another criterion. This is different from the social productivity of a given kind of work. If this criterion were used alone to measure underemployment both the Ph.D. bank president and the Ph.D. community college teacher would be counted as underemployed. But would a vice president or a president of a university who has a Ph.D. be considered as underemployed. Probably not, but it might depend on who is doing the classifying.

Since it may be impossible to frame and apply a satisfactory definition of underemployment the way out of the difficulty may be simply to secure better data on the characteristics of the employment of Ph.D.'s—in terms of income, type of employer, skills currently used and so forth. This information could then be used as one way to assess the state of the labor market without using it to count the "underemployed."

E. Inadequate Attention to Market Forces

Once again I wander from my assigned sphere to deal with demand as well as supply by considering market forces in connection with projections. I rationalize this by considering the question of market forces to be such a significant question that no overview of the problems of projecting can be satisfactory if this question is excluded.

A more or less intuitive feeling that something was missing from fixed factor projections has led to the addition of judgmental "corrections." What was missing was a satisfactory set of measures for the effect of the market on the supply and demand for highly trained manpower.[22] In the early 60's Blank and Stigler studied the interrelationships among changes in salaries and the supply of and demand for scientists in an effort to define "shortage" and "surplus" in terms of relative wages. However, not until Richard Freeman wrote *The Market for College Trained Manpower, A Study in the Economics of Career Choice* in 1971 was there further serious work on the interrelationships among supply, demand, career choices and salaries of highly trained persons.

Economic analysis in terms of the interrelationships between price changes and demand and supply, and in terms of the responses of individuals to perceived career opportunities and incomes, raises serious questions with respect to the adequacy of projections b.sed fundamentally upon the extrapolation of such ratios as

[22] Another important kind of economic analysis is the idea of computing rates of return on investments in education Rates of return in a given field that are higher than rates of return in competing fields can be taken as evidence of a shortage This approach, like the market approach, is quite different from the projection of historic ratios Discussants may wish to consider this approach in greater deta

employment to output, student faculty ratios, and R&D expenditures per scientist. Projections based upon ratios do not take into account a wide array of market forces. These include the responses of individuals to perceived changes in prospects for satisfactory careers and in life-time incomes as evidenced in the decisions to attend graduate school, to continue in graduate school, to undertake given lines of study, to select given areas of employment, and to change areas of employment in response to changes in relative income and job opportunities. They do not take into account the decisions of employers to hire more or fewer highly trained persons as earnings levels rise or decline relative to other costs. They do not envisage the possibility of substituting machines for people, or vice versa, as relative costs shift.

The market forces also include shifts in wages and prices as supply and demand relationships change. Freeman has shown that there were indeed shifts in relative earnings among occupational groups—including academic scientists—during the period of sharply rising demand during the 60's. There was a marked rise in the relative wages of faculty members, and particularly natural scientists and medical faculty during the 60's.

In the context of this approach, the very concepts of "shortage" and "surplus" of highly trained manpower become inadequate and misleading because the terms shift the center of attention from the nature of the adjustments that can bring about equilibrium.

Based on experience and on analysis, the central point to be derived from consideration of market forces is that they will almost invariably tend to moderate any degree of disequilibrium foreseen by projections. Put simply, if there is an excess of demand over supply, market forces, exerted primarily through relative changes in earnings among different groups and by changes in personal and institutional decisions, will tend to moderate demand and to stimulate supply.

The interrelationships are, of course, far from being so simple. The lag between the time of student decisions to begin training and the time when they have completed training is a complicating factor. Another complicating factor is that there is a large non-economic element in many career decisions—as, for example, decisions to enter a school of divinity. Economic responses are sometimes unusual, as when a decline in the outlook for jobs leads to maintenance of graduate enrollment. Governmental decisions are important, largely unpredictable and often properly based on social and political rather than economic considerations. The kinds and extent of responses that would characterize a perfect market rarely exist in the market for highly trained manpower. Such factors as tenure, fixed salary schedules, controls over access to training and jobs, the influence of high fixed costs and joint cost problems all combine to produce sluggish and sometimes unpredictable results. Transferability of skills and shifts of occupation complicate the picture. Finally, there are large gaps in the data required for analysis of market forces. Nevertheless, the general consequence of taking market forces into account will be to project a closer approach to equilibrium than will result from the extrapolation of ratios.

Even though the problems involved in market analyses are complex, and perhaps partially unsolvable, certainly intensive research in this area should be a major part of efforts to improve projections. In this connection, Freeman and Breneman have described the potential gains from the market approach and proposed a research program in *Forecasting the Ph.D. Labor Market. Pitfalls for Policy*. (A Working Paper for the National Board on Graduate Education. November 16, 1973.) They specifically suggest the construction of a model which would take into account six kinds of responses, which I have elaborated somewhat, to a changing doctorate labor market: (1) student choices of fields of study and initial job decisions, (2) decisions of experienced persons, (3) employer hiring, firing, promotion and retirement policies, (4) salary determination, (5) responses by universities in terms of decisions relating to faculty (hiring, promotion, retirement) and students (enrollment, support) and (6) governmental initiatives and responses. The usefulness of models built around these factors can, within the limits set by the availability of data, be tested retrospectively.

In conclusion, it seems to me that one of the most significant developments in projecting the supply of and demand for high level manpower has been the increasing attention paid to market forces and that extension of this work is as important as any line of endeavor in improving projections.

4. Changes in National Priorities, Manpower Projection Techniques, and Requirements for Scientists and Engineers

Because Dr. Lecht's oral presentation followed his formal paper quite closely, only his paper is included in these proceedings. Lead discussants were W. T. *Hamilton, Boeing Aerospace Company, and Ralph K. Huitt, National Association of State Universities and Land Grant Colleges.*

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I.

An analysis of the impact of changes in national priorities for the utilization of scientists and engineers raises many questions concerning the uses and limitations of manpower projections, as well as indications of opportunities for their improvement. This paper proposes to assess the role of shifts in national priorities as one of the major sources for the discontinuous changes in demand that have outmoded many of the projections of requirements for scientists and engineers made in the past ten or fifteen years.

An appraisal of projections brings to mind an aphorism attributed to the American philosopher, Whitehead, that runs something like this: "Seek simplicity, but mistrust it." I would rephrase Whitehead's statement to read: "Seek manpower projections, but use them with caution." Manpower projections can be useful to government agencies, to industry, to educational groups, and to individuals making career choices because they help to reduce uncertainty. Projections can help provide a basis for choosing among the available options by indicating the implications of alternative developments, for example, an increase or a decrease in defense spending or in Federal support for fellowship programs in aeronautical engineering. However, projections are not the same thing as predictions. While individual projections based on continuing relationships from the past will often be borne out, for example, the size of the labor force in 1980, it is apparent that the social sciences are many light-years away from being able to make sustained quantitative predictions for a five- or ten-year period. This is true of manpower projections as it is also true of projections of birthrates or of the fluctuations in stock prices.

Many organizations and individuals have been concerned with the study of one or another of the forces that influence the utilization of scientists and engineers. Economists, such as Hugh Folk[1] or Richard Freeman,[2] have attempted

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[1] Folk, Hugh, *The Shortage of Scientists and Engineers*, 1970

[2] Freeman, Richard, *The Market for College-Trained Manpower*, 1971

to devise models of the labor market to assess the relationship between the supply of scientists and engineers, their earnings, and the demand for their services. The Department of Labor's Bureau of Labor Statistics has estimated future requirements for manpower, scientific and otherwise, by making use of the input-output analysis to project employment requirements in different industries based on assumed rates of growth in GNP and changes in the composition of the economy's output.[3] Others have attempted to develop techniques for anticipating the utilization of scientists and engineers in research and development derived from what are regarded as reasonable estimates of future research and development outlays and changes in operating expenditures—"performer costs"—per R&D scientist or engineer.[4]

Present research ..nniques, such as the input-output analysis, have made significant advances over the earlier projections techniques. They have made it possible, for example, to estimate the "indirect" demand for scientists and engineers generated by the chain of purchases and sales in the industries supplying goods and services to the firms producing the end products. These techniques can prove highly useful once the demand for the goods and services, including research and development services, is known or can be regarded as given. There have been substantially fewer advances in explaining why the large-scale changes in demand for scientists and engineers have taken place and where the changes come from. This has been especially true in accounting for the role of government, the course of many of the discontinuous changes in requirements for scientific manpower in the past fifteen years.

Insight into the Federal government's role in the shifts in demand for scientists and engineers can be obtained by an examination of the role of the federally funded R&D in the overall changes in research and development outlays in the 1960-1971 period. This relationship is summarized in Table 4.1:

Table 4.1
The Federal Government's Role in Changes in R&D Expenditures, 1960-1971[1]

[In millions of dollars]

Type of R&D	Changes in Outlays Between. 1960 & 1966	1966 & 1969	1969 & 1971
Total R&D	$8,536	$3,913	$671
Federally Funded R&D	5,240	921	143
Defense R&D	40	1,671	−1,091
Space R&D	4,495	−2,015	210
Non-Federally Funded R&D	3,296	2,992	814

[1] Derived from National Science Foundation *National Patterns of R&D Resources Funds and Manpower in the United States 1953-1972* NSF 72-300 1971 Tables B-5 B-9 pp 32-34

[3] U S Department of Labor, Bureau of Labor Statistics, *Tomorrow's Manpower Needs*, Bulletin No 1237, 1971; *Ibid*, *Patterns of Economic Growth*, Bulletin No 1672, 1970

[4] See National Science Foundation, *The Long Range Demand for Scientific and Technical Personnel A Methodological Study* NSF 61-65, 1961, Aronson, Robert L, *Federal Spending for Scientist and Engineer Employment*, U S Department of Labor, Bureau of Labor Statistics, Bulletin No 1663, 1970, p 2

Increases in the federally funded R&D were the source of approximately five-eighths of the overall increase in research and development spending in the 1960-1966 period. More than five-sixths of the growth in Federal outlays in this period—86 percent—stemmed from one program, the space program. The increase in Federal spending for the space program was the major single cause of the concern with "shortages" of scientists and engineers about 1963 or 1964.

The research cutbacks after 1966 were set in motion by a $2 billion decrease in Federal outlays for the space program between 1966 and 1969 followed by a decline of about half that amount in defense-related research and development between 1969 and 1971. Because of these cutbacks, federally financed R&D, after adjusting for price increase, declined at an annual rate of 4 percent a year between its 1967 peak and 1971.[5] The severity of the decline in the Federal government's R&D outlays for the space and defense programs was mitigated by large increases in non-federally financed research and development expenditures in the last years of the decade, and by modest absolute but large percentage increases in Federal R&D spending for civilian sector programs. The effects of the decreases in the Federal government's R&D spending coupled with cutbacks in defense expenditures for other purposes show up in the increase in unemployment and the concern with underemployment for scientists and engineers in the early 1970's for the first time in well over a decade. They were also evident in the decline in enrollments in college programs in engineering.

Changes in national priorities as they are reflected in government programs in health, pollution abatement, energy resource development, urban redevelopment and other areas can have consequences similar to those that took place because of the shifts in R&D expenditures. In effect, the activities undertaken to implement national priorities set up a series of demands for manpower at different levels of skill and occupational specialization in the public sector and, frequently even more so, in the private sector of the economy. The effects of the greater emphasis on health goals in the past decade illustrated by the enactment of Medicare and Medicaid, and also by the expansion of employer-financed health insurance, offer another instance of the significance of assigning a high priority to particular goals for manpower demand and supply.

Projections that seek to account for the anticipated consequences of the pursuit of national goals for scientific manpower utilization in the next five or ten years refer to social rather than to market demand. Yet in a society in which priorities and expenditures often undergo marked changes in response to emerging problems and opportunities, many of the unmet social demands of the present are likely to become translated into market demands for manpower, including scientists and engineers, in the next decade. Employment projections that attempt to take these aspirations into account can often provide a basis for anticipating future changes in job opportunities and manpower needs that would be lacking in extrapolations reflecting the Nation's current priorities and expenditure patterns.

II.

Changes in national priorities in the United States are typically, although far from exclusively, manifested in changes in legislation and in government programs and budgets. These changes influence the utilization of manpower

[5] *Annual Report of the Council of Economic Advisers*, 1972, p. 127

because of their consequences for employment within government, or the employment created in the private economy by government purchases from industry, or by the adoption of standards based on legislation which affect requirements for scientists and engineers in the private sector.

A pilot study recently completed by the author and others for the National Science Foundation assesses the significance of changes in the government's standards and regulations for the utilization of scientists and engineers in one important priority area—the abatement of air and water pollution and solid waste disposal.[6] The study illustrates an important instance drawn from a large group of activities in which national priorities are largely implemented by the introduction of standards leading to greater expenditures in the private sector. Automobile safety, efforts to establish a "miles per gallon" standard to economize on the use of gasoline, or airport noise control are other instances.

More than nine-tenths of the outlays for air pollution control in the 1970's, for example, are expected to represent private sector expenditures for such purposes as adding catalytic converters to automobiles or scrubbers to remove effluents from stack gases in industrial plants.[7] About two-thirds of the spending for solid waste disposal and something over one-third of the expenditures for water pollution control in the next decade will stem largely from the adoption of more severe regulatory standards in such legislation as the Clean Air Act and the Water Pollution Control Act.

To simplify data problems in a relatively modest pilot study, the expenditures for pollution abatement that generate the requirements for scientists and engineers pertain to five industries that are estimated to currently account for roughly 80 percent of the air, water, and solid waste pollution emanating from the manufacturing sector of the economy. They are the food, paper, chemicals, primary metals, and petroleum refining industries. The projections refer to two different scenarios illustrating differences in the priorities assigned to the control of pollution. One is a Present Policy scenario indicating the increases in scientific manpower requirements expected to come about as the standards in the pollution abatement legislation adopted through mid-1972 go into effect in the next decade. The Clean Air Act of 1970 or the Water Pollution Control Act with amendments, other than the 1972 amendments, are instances. The other, the Environmental Goals scenario, presupposes an extension to air pollution and solid waste discharges of the goal in the 1972 amendments to the Water Pollution Control Act of seeking to approach 100 percent abatement of most types of pollution by the mid-1980's. Weighting the levels of pollution abatement projected for the different types of pollutants by the estimated physical volume of each, the Present Policy scenario implies an approximately 65 percent efficiency in pollution abatement by the mid-1980's as compared to the 90 percent implied by the higher priority in the Environmental Goals alternative.

The differences in manpower requirements in the alternative scenarios come about because of the differences in the expenditures they specify for plant and equipment, operations and maintenance, and research and development to cope

[6] Lecht, L., Gutmanis, I., and Rosen, R. J., *Assessing the Impact of Changes in National Priorities for the Utilization of Scientists and Engineers*, National Science Foundation, Grant GR32464, 1974

[7] Derived from Council on Environmental Quality, *Environmental Quality*, 1972, pp. 276-277

with pollution. These outlays are summarized for the two scenarios in Table 4.2. The estimates in Table 4.2 refer to the increases in expenditures anticipated in the two scenarios in 1980 beyond those projected to occur because of growth in output in the five industries if the minimum levels of pollution abatement in effect in the late 1960's were continued through the next decade.

Table 4.2
Projected Increases in Expenditures for Pollution Abatement in 1980, Alternative Abatement Scenarios[1]

[in billions of 1963 dollars]

Type of Expenditure	Present Policy Scenario	Environmental Goals Scenario
Plant and Equipment	$32.3	$53.5
Research and Development	1.1	1.8
Operations and Maintenance	8.7	14.1
Total	42.1	69.4

[1] Source: Lecht, L., Gutmanis, I., Rosen, R. J., *Assessing the Impact of Changes in National Priorities for the Utilization of Scientists and Engineers*, National Science Foundation, 1974, Table 1-7, p. 1-22

The major differences in the expenditure totals for the two scenarios are those listed for plant and equipment and, to a lesser extent, to operate and maintain the pollution control facilities. The massive plant and equipment outlays include many expenditures for otherwise desirable items of equipment that have the side effect of producing fewer pollutants. Only the relatively minor "force account" construction part of the capital outlays, about 5 percent of the total, generates employment within the five industries. The projections, other than for research and development, are based on engineering estimates prepared for the U.S. Department of Labor of the capital outlays and maintenance expenditures required to reach different levels of efficiency in reducing pollution in the industries considered.[8]

The manpower figures listed for the pollution control scenarios show the anticipated increase in "direct" requirements for scientists and engineers in the five industries because of the greater expenditures for pollution control. They also include the indirect "second round" requirements in other industries that sell goods and services used in pollution abatement activities in these industries. The projections for 1980 are summarized in Table 4.3.

The projections suggest that the recently adopted standards for pollution abatement, other than the 1972 Water Act amendments, would increase requirements for scientists and engineers by an estimated 91,000 in 1980, and by over 165,000 if the more stringent standards in the 1972 amendments were

[8] Gutmanis, Ivars and Schapanka, Adele, *Pollution Generating Emissions and Abatement Costs in the United States, 1980 and 1985* prepared for the Interagency Growth Project U S Department of Labor, 1972

generalized to include the other types of pollutants. Three-fourths or more of the employment increases would be made up of engineers. The indirect requirements in the supplying industries are estimated to exceed the projected direct requirements for engineers by a margin of 2.4 to 1 or greater. The bulk of the increase for scientists is expected to take place within the five manufacturing industries. The massive indirect employment listed for engineers in the "second round" industries is largely attributable to purchases of plant and equipment. Operations and maintenance, and research and development outlays are of about equivalent weight as the source of the employment increases for scientists. The study also shows that chemists predominate heavily in the requirements for scientists while chemical engineers make up the largest, but far from predominant, category of engineers. The methodology by which the projections were derived, together with the estimates of employment requirements by occupational specialization within science and engineering and by industry, are discussed in detail in the report on the study.

Table 4.3.
Estimated Increases in Direct Requirements and Indirect Requirements for Scientific Manpower, Alternative Pollution Abatement Scenarios, 1980[1]

	Projected Requirements in 1980					
	Present Policy Scenario			Environmental Goals Scenario		
Category	Direct	Indirect	Total	Direct	Indirect	Total
Scientists	14,298	6,789	21,087	30,445	11,610	42,055
Engineers	19,787	50,516	70,303	35,639	87,965	123,604
Total	34,085	57,305	91,300	66,084	99,575	165,659

[1] Source Lecht, Gutmanis, and Rosen, *op. cit.*, Table I-5, p. 1-16

The techniques by which these and similar projections are prepared essentially involve the derivation of four types of measures. one is a projection of the annual flow of output in the industries considered, a flow usually represented in constant dollar terms. A second is a series of historical manpower coefficients translating the expenditures for the output of individual industries into man-years of employment. A third are estimates of productivity changes by industry over the time period covered by the projections to allow for the influence of technical advance, increase in capital stock per workers, or of the higher educational level and skills of the work force on manpower input requirements. A fourth is an occupational distribution measure to distribute the total manpower requirement into employment levels by occupation. A fifth measure which is frequently used to convert employment levels into job openings consists of indices of attrition rates by age and sex in each occupation to allow for losses because of deaths, retirements, and other withdrawals from the labor force.

III.

Researchers and decision-makers seeking to prepare or to appraise manpower projections are presented with a series of problems. Many of these are inherent in the techniques used to translate dollar purchases into manpower requirements, such as the input-output analysis. The techniques typically assume a constant technology over time, or, the changes in technology can be anticipated, primarily because they are expected to represent an extension of technology that is already available, at least in the development stage. The projections, as in the pollution abatement scenarios, refer to increments of expenditure and manpower, and the assumption generally made in the projections is that the industrial and occupational composition of the increment follows that of the total to which the increment pertains. The priorities and the standards that are currently expected to provide "surprise free" scenarios for the next decade are subject to change in response both to developments in the national economy and in the importance attached to other goals. For instance, the priority now being given to conserving existing energy resources and developing new ones represents a "surprise" that would have been difficult to anticipate in the climate of opinion three or four years ago.

Manpower projections derived from estimates of expenditures for different types of economic activity generally do not allow for the feedback effects of the expenditures, effects that often offset one another, such as the consequences of implementing the pollution control measures considered for costs, prices, and output in the industries affected, or in hastening the introduction of new technology. The Council on Environmental Quality, in its 1972 report, suggests some of what have been widely regarded as the likely consequences of the pollution control standards adopted in the early 1970's. The report summarizes a survey of some 12,000 plants in eleven industries affected by the pollution controls in then existing ligislation[9] The survey indicated that 200 to 300 plants would be forced to close down because of the pollution abatement regulations. Prices for the output of these industries were estimated to increase from zero to ten percent in the four-year period supplying the focus for the study, 1972 to 1976. The direct job loss resulting from the environmental regulations in these industries was projected to range between 50,000 and 125,000 over the four-year period, or from 1 to 4 percent of their anticipated employment level.

Over short time periods, say less than five years, it would be reasonable to assume, as in the Council's report, that the cost-price impacts would make for a decrease in overall manpower requirements. Over longer time periods the expectation of a significant reduction in requirements for these reasons overlooks several considerations. The expectation that cost-price impacts will predominate presupposes a static economy in which few things change other than the pollution regulations, and that the effects of introducing these measures then work themselves out through the economic system. In a dynamic economy such as our own the prospect of a large increase in operating costs because of pollution control measures would serve as a powerful incentive to accelerate the introduction of new technologies, or the more general use of technical advances that have been available before, which were more efficient in abating pollution. In the production of iron and steel, to cite an instance, the pelletizing process used in producing iron ore and the continuous casting processes for producing steel are expected to come into everyday use by 1980, in part because their arrival would be speeded up due to their lesser propensity and add to air and water pollution. In petroleum refining, environmental considerations are likely to encourage a shift to hydrogen refining, a shift hastened because this process gives off almost no carbon monoxide, nitrogen oxides, or particulates. The extent to which the

[9] *Environmental Quality* 1972, op. cit. pp. 287-288

technological advances will succeed in offsetting the cost increases otherwise likely to arise from the adoption of more stringent pollution abatement standards five or ten years from now is a question of judgment.

Similarly, the indirect effects of measures, such as the pollution control regulations on growth and output manpower requirements are often obscure. The judgment in the Council's report is that implementing the standards adopted in the early 1970's would reduce the pace of GNP growth by a modest amount, from the 5.2 percent a year initially assumed in the economic framework for the Council's study to 4.9 percent[10] However, this judgment abstracts from a number of elements which could offset, if not reverse, the GNP decline or its anticipated manpower impacts. The multiplier effects of the capital outlays in increasing economic activity and employment are one consideration. As the persons employed in producing the additional plant and equipment required for pollution abatement spend most of the incomes they earn for consumer goods and services, output and employment would rise in many industries. These increases could be offset by reductions in output and employment as costs rose in many of the industries affected by the pollution control regulations. However, the firms engaged in abating pollution would require additional resources for this activity, resources which frequently included significantly greater requirements for scientists and engineers. This kind of decrease in physical output, or the slowing down of its growth, need not lessen the demand for scientists and engineers, and it might often increase it.

The significance of the requirements listed for scientists and engineers for pollution abatement can be appraised by comparing the projected increase with the economy-wide utilization of scientific manpower in 1980. The Department of Labor's projections of the economy-wide utilization in the same year provide a benchmark for comparison. Since these estimates predate the more stringent pollution control measures adopted in the early 1970's, they presuppose a minimal reduction in the inventory of pollutants. Accordingly, the Department of Labor's projections could not be expected to allow for the effects of rapid growth in demand for scientific manpower in the fields related to pollution abatement for the supply of scientists and engineers. A high priority for pollution control would increase salaries and opportunities for advancement for persons working in this field. As opportunities increased, scientists and engineers from more slowly growing fields such as college teaching would be attracted to pollution abatement. Over time, a continuation of this type of priority would lead to greater enrollments in technical subjects concerned with pollution, enlarge the supply of scientific manpower, restrain the increases in salaries, and add to the economy-wide utilization of scientists and engineers. The magnitude of these changes can be illustrated by the judgment that half of the increase in requirements for scientific manpower for pollution control becomes translated into a greater supply of scientists and engineers. This adjustment, or even a larger one, would make for only modest changes in the Department of Labor's estimates, changes of under 5 percent. The relationship between the additional scientific manpower requirements for pollution abatement and the economy-wide utilization anticipated on this basis is summarized in Table 4.4:

[10] Ibid. p. 302

Table 4.4
Additional Requirements for Scientific Manpower Resulting from Pollution Abatement Priorities as Percentages of the Projected Economy-Wide Utilization in 1980

Category	Estimated Economy-Wide Utilization in 1980[1]	Additional Requirements: Present Policy Scenario	Additional Requirements: Environmental Goals Scenario	Additional Requirements as Percent of Economy-Wide Utilization: Present Policy Scenario	Additional Requirements as Percent of Economy-Wide Utilization: Environmental Goals Scenario
Scientists	514,542	21,085	42,055	4.1%	8.3%
Engineers ...	1,533,151	70,303	123,604	4.6	7.9
Total	2,017,694	91,388	165,659	4.5	8.0

[1] Adapted from U S Department of Labor, Bureau of Labor Statistics, *Tomorrow's Manpower Needs*, Bulletin No 1737, Vol IV, 1971, p. 18.

The estimates in Table 4.4 suggest that a high priority for pollution abatement, as in the Environmental Goals scenario, would involve a growth in requirements for scientific manpower amounting to about 8 percent of the projected economy-wide utilization in 1980. Continuation of the standards adopted in the early 1970's is expected to entail an increase of between 4 and 5 percent. These global estimates imply that a high priority for pollution abatement would be unlikely to bring about the bottlenecks for technical manpower lined with the space program in the early 1960's. However the percentages refer to overall requirements without regard to the industries involved or the occupational specializations. Adoption of the standards in the Present Policy scenario, for example, is estimated to add an eighth to the industry-wide utilization of scientists and engineers in the chemicals industry in 1980. The global projections, therefore, will frequently have limited relevance as a basis for policy.

Problems of feedback effects and countervailing offsets also occur in projections of requirements for scientific manpower by level of educational attainment. It would be desirable for educators and others to know how many openings were anticipated in 1980 for Ph.D.'s in chemistry because of the pollution abatement measures, or for graduate chemical and electronic engineers, or for persons with bachelor's degrees in physics. The problem with these projections is that they typically imply a one-to-one relationship between level of educational attainment in specific occupational specializations and jobs. In some instances, as in projections of requirements for Ph.D.'s in the sciences to teach in four-year colleges and graduate schools, customary tenure requirements as well as historical student-teacher ratios provide an element of stability to the estimates. In most areas, however, engineers and scientists of different levels of educational attainment, or, for that matter, engineers, scientists, and technicians, are to a considerable extent substitutes for one another. In periods when highly trained professional manpower is in short supply, educational requirements come to be lowered. Technicians take over many of the more routine tasks formerly performed by scientists and engineers, and B.S. engineers substitute for persons with more advanced professional training. In periods of glut in the scientific manpower market, persons with advanced degrees, including Ph.D.'s, may frequently find themselves in jobs and at earning levels previously regarded as unsuitable. Projecting requirements by level of educational attainment involves a series of judgments, expressed or implied, above the overall labor market prospects for scientific manpower in industry, government, and in college teaching.

IV.

This recital of the problems involved in devising more adequate manpower projections stresses their limitations as predictions while recognizing an important role for their use. Frequently, as in the case of the pollution abatement estimates, the projections essentially illustrate a hypothesis. The hypothesis in the instance cited is that the priorities assigned to the pursuit of goals, such as the control of pollution, can make a significant difference for the utilization of scientists and engineers. The findings are consistent with this hypothesis, allowing for a wide range of feedback effects and market adjustments. Differences in these wide range of feedback effects and market adjustments. Differences in these effects, like differences in the priorities given to pollution control, could make for a greater or a lesser change in the estimates of requirements for scientific manpower. In this sense, the projections represent points on a scale which could be shifted upwards or downwards as the substantive assumptions in the underlying scenarios were changed.

The changes in national priorities which become translated into government programs constitute parameters that contribute to defining the demand that is registered in the scientific manpower labor market at any particular time. The changes in priorities and programs are themselves "exogenous" to the market system in the sense that they originate outside of it and are responsive to different forces. Accordingly, an understanding of the relationship between shifts in national priorities and scientific manpower requirements involves considerations that extend beyond the familiar explanations in terms of supply, demand, and price.

There have been substantial advances in recent years in explaining changes in the supply and demand for scientists and engineers in terms of rates of return on investments in education, career choices, relative earnings, and similar factors. There have been fewer advances in explaining where the demand comes from, and why the frequent discontinuous changes in demand should take place. In particular, the more complete analysis of the scientific manpower market which might provide a basis for improvements in the predictive power of the forecasts should include a mode of analysis that takes account of the role of government as a variable with an important influence for the manpower utilization process.

Emphasis on the importance of government programs and expenditures is suggested by the evidence from what are, as yet, limited studies of the responses of unemployed professional workers, including scientists and engineers, to offers of employment. A study undertaken by Battelle Laboratories for NASA surveyed a sample drawn from 40,000 persons who had lost their positions between 1966 and 1970 as a result of cutbacks in the space programs at 30 establishments.[11] The minimum salary required by the unemployed professional workers in this group to accept employment, their "reservation price," varied markedly depending on whether or not a movement to a new community as well as a new job was at stake. These findings are summarized in Table 4.5:

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[11] Battelle Laboratories, *A Survey of Aerospace Employees Affected by Reductions in NASA Contracts* study undertaken for the National Aeronautics and Space Administration, 1971

Table 4.5
Minimum Salary Required to Accept Employment by Unemployed Professional Workers Laid Off in NASA Cutbacks Between 1966 and 1970[1]

Average Weekly Salary	Salary Amount
At time of lay-off	$275
To accept a position at present location	247
To accept a position in another community	304

[1] Source: Battelle Laboratories. *A Survey of Aerospace Employees Affected by Reductions in NASA Contracts*. National Aeronautics and Space Administration, 1971, xviii

The professional workers included in the Battelle survey who had been laid off were willing to accept permanent positions in their present locations at a 10 percent lesser salary than the one they had been receiving at the time of lay-off. The average "acceptable" salary decrease amounted to a reduction in earnings of $27 a week. The same group indicated that they would require a 12 percent increase in earnings over what they were receiving when they were laid off before accepting employment involving a change in location. The average increase required amounted to $29 weekly so that the differential favoring the home community reached over $50 a week. The persistence of joblessness could well have modified the pertinent reservation prices. However, these findings suggest that modest changes in earnings may be insufficient to encourage professionals, such as scientists and engineers, to abandon what they regard as desirable homes, good schools, a pleasant community, or seniority in a particular firm. Reliance on the self-regulation of the scientific manpower labor market, in these instances, can be consistent with considerable underutilization of scientists and engineers.

The reabsorption of unemployed or underutilized professionals laid off for reasons such as the space program cutbacks could well take the form of opportunities in their home communities or elsewhere in a variety of capacities generated by a resurgence of economic growth. The reemployment of many in the private sector could also stem from government programs arising from changing conceptions of national needs which would create new requirements for scientific and other manpower. Energy research and development programs, the space shuttle, mass transit, or the more extensive utilization of computer technology in health services are instances. While it would be unreasonable to expect the government to undertake such programs primarily to create jobs, the availability of highly educated and trained manpower can be an important consideration in determining the pace at which programs can be pursued, where the activities should be located, and the extent to which Federal support for special training and fellowship programs would be needed to achieve goals. These activities presuppose the availability of manpower projections indicating the supply of scientists and engineers expected to be available at current or other earnings to fill positions together with estimates of the numbers of positions to be filled.

V.

Two types of measures can serve to enhance the usefulness of the present manpower projections for scientists, engineers and for others. One could consist of technical advances in the present projections systems such as incorporating the effects of price changes for the coefficients indicating input requirements in the input-output matrix. The other could involve the creation of a manpower budget to focus on the consequences of the Federal government's programs and outlays for the utilization of manpower, including scientists and engineers, in both the public and the private sectors.

The Federal government's budget represents a statement of national priorities as these priorities are spelled out in the willingness of the Administration and Congress to commit dollars to the pursuit of goals in education, health, mass transit, national defense, pollution abatement, research and development, social welfare, or other areas. A manpower budget could provide the basis for an early warning system to trace through in advance the consequences of changes in the Federal government's priority choices, actual or under consideration, for manpower demand. A budget along these lines would present an overview of the areas where a lesser willingness to commit resources for particular goals, for example, the manned lunar landing, could be expected to diminish demand for scientists and engineers, and by how much, and the areas where new initiatives can be expected to increase requirements. A series of dollar and manpower budgets projected ahead for three, five, or ten years could show the anticipated consequences for scientific manpower of alternative courses of action, such as speeding up or slowing down of energy development outlays or of defense expenditures. A complete manpower budget would take account of the public employment created by the government programs, the employment in the private sector attributable to government purchases, and the employment in industry generated by the implementation of standards in legislation which entail large-scale expenditures by industry. A budget of this type would facilitate the transfer of scientists and engineers facing lay-offs, or seeking more attractive positions, or the placement of new entrants recently out of school, or the planning of programs in colleges and universities to educate and train scientists and technical specialists. A side effect of this more rational use of scientific manpower would be to minimize prospects for the manpower bottlenecks that often contribute to costly overruns in government-funded programs. As a first step in establishing a manpower budget, the Federal government's annual budget reports, especially the *Special Analyses* reports, should include a manpower section showing the expected consequences of the program activities listed in the budget for manpower requirements scientific and otherwise.

More research and improvements in analytic techniques can be expected to increase the potentials for manpower budgeting by making it possible to allow more fully than at present for the cost-price impacts on output and factor substitutions, for the feedback effects on supply, and for similar adjustments in the market for scientific manpower. However, technical improvements alone, even with the aid of supercomputers, are unlikely to significantly reduce the role of judgment in manpower projections. Changes in national priorities, demographic changes, technological advances, and shifts in the economy's growth rate will continue to outmode many of the projections of scientific manpower supply and demand in the future as they have outmoded others made in the past. They will not diminish the need for a consistent quantitative framework for assessing the consequences of alternative policies and developments, or the continuation of past trends and the emergence of new ones for the utilization of manpower, including scientists and engineers.

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On reviewing Dr. Lecht's paper, I find that much of it appears to parallel our activities at Boeing Aerospace Company in trying to predict requirements as we look ahead in the aerospace field. Boeing Aerospace deals primarily in the military aircraft, missiles, space-craft area, whereas commercial airplanes are built by the Boeing Airplane Company. Because both companies are located in the Seattle area, employees can be traded back and forth so we tend to complement one another as the need for certain kinds of manpower arises.

We try to "seek manpower projections, but use them cautiously" as was suggested by Dr. Lecht, and continually project manpower requirements by program and by skill for both the near-term and the long-term. Boeing's opportunities to use people are a function of the government contracts received and the private ventures embarked upon in the light of economical attractiveness to the company. Both government and private contracts are affected by national and international pressures, and by the pressure to make a profit. Requirements for scientists and engineers are difficult to predict with any degree of precision because there is a time delay; the problem is a dynamic one.

Boeing Aerospace has about 6,000 engineering personnel. More than 5,000 of these are graduate engineers and scientists, and about a thousand have doctorates. Requirements forecasts for our programs are made every two months. A group of organizations is charged with responsibility for monitoring the requirements, compiling those requirements, and looking at them by skill and by program through time so that the need for particular types of engineers, physicists, and chemists can be anticipated. The degree of certainty with which predictions can be made is not very great, though there is a greater opportunity to be certain today than in the past because there are a larger number of programs, all highly technology-intensive. We have a continual flow of engineers in and out of the programs. It is necessary to have the right level of engineer or scientist at the right time, but for economic reasons this person must be shifted when not needed on a given program.

At present Boeing is doing a reasonable job of predicting. We are a little shorthanded now, which is proper from an economic standpoint. In contrast, there was a period four or five years ago when Boeing Aerospace had twice as many scientists and engineers as its present base of about 5,000 persons. We did not accurately predict the future at that time; we expected that more commercial airplanes would be sold and that we would have more military contracts. The economic turndown was not anticipated, and when it came a large reduction in staff was necessary. Boeing Aerospace is now doing the same dollar volume of business as at its peak, but with half as many engineers and scientists. This economy has been achieved because of the availability of computers and a more effective use of professional staff. At peak employment Boeing was using engineers and persons with master's degrees and Ph.D.'s in jobs that could have been handled by less well educated people.

In the 1960's Boeing Aerospace Company was predominantly a builder of airplane and missile-type structures and actuation equipment, with a lesser emphasis on electronics, guidance, control, and navigation. Now 40 percent of our employees are in structural and mechanical activities and 60 percent in electrical and electronic activities. Any variation in the future will depend on contracts received and the activities we are engaged in but change is certainly inevitable.

Changes in emphasis bring about another problem. Boeing's classical business is being handled by older engineers who will soon reach retirement age. Their retirement is going to cause Boeing to shift entirely to electronics, if the trend is not reversed. When Boeing cut staff, it tended to hold on to the more senior people, those who had served the company longer. Consequently, a large group of people is marching toward retirement fairly rapidly. There are some young employees at the bottom, but not many in the middle age groups.

Ralph K. Huitt, Discussant

Executive Director, National Association of State Universities and Land Grant Colleges
Washington, D.C.

The crucial importance of Dr. Lecht's perception of the Federal Government as the big disturber of the peace in the manpower field is, I think, absolutely correct. All political systems must change; ours is not alone in making switches in priorities, but it may be that there is something peculiar to our system in the extreme changes that it makes.

Professor Gabriel Almond of Harvard pointed out a number of years ago that our system tends to swing from one extreme to the other. The extent to which the government responds and reinforces, or stimulates, is an open question, but certainly public policy reflects swings in public mood.

Everyone here has commented on what happened in space: a great boom, then a sudden cutoff. What is of particular interest is the drastic character of the cutoff, the fact that it occurred so quickly. When we first landed a man on the moon, the President of the United States said it was the greatest event in the history of humankind since the creation. Yet six months later, in his State of the Union message, the subject was not even mentioned. Other examples of striking changes in priorities and programs could be cited.

This tendency for extreme change will not diminish; in fact it is likely to worsen because as government grows, its effects on universities, on manpower, on the economy, and on other areas will increase. What can universities, as suppliers of manpower, do to cushion this effect? Dr. Lecht has proposed a manpower budget to be attached to the regular budget. Look at our experience. The President sends a budget to Congress, it is a proper budget in the sense that income is related to outgo and a deficit or a presumed surplus is mentioned, so all the elements of a budget are there

This budgeting procedure was initiated in 1921 with the Budget and Accounting Ac ust 132 years after the birth of the republic. Before then the President simply requested money when he wanted it, and nine separate committees (one called "appropriations," and eight called "autho..zing" committees) considered the necessary appropriations. Now, more than a half century after the Budget and Accounting Act, the Congress of the United States is beginning to try to develop some machinery for handling the budget itself.

Congress, however, does not "consider" the budget. What Congress does is to divide the expenditures and send them to 13 separate committees in the two houses, and then a separate committee takes care of the revenue according to a rhythm of its own. Congress is paying attention now to the possibility of relating income to outgo because it protested not the President's ceiling but his priorities. It has also learned that it cannot substitute its own priorities because it doesn't have any, and has no mechanism for making them.

If a manpower budget were added to the fiscal budget, there might be Congressional hearings and these could have an affect on public policy. There should be genuine public debate about the implications of the President's priorities. But even lacking such debate, it would be useful to have a manpower budget attached to the budget because the budget tends to increase every year.

Let me add a new point which Dr. Lecht did not mention. It is time that the Federal Government underwrites part of the institutional cost of the higher education enterprise. The Federal Government tends to call on the universities for what it wants, occasionally pays for what it wants for as long as it wants it, and then cuts it off and does not care much what happens to the overall enterprise. I am aware that a call for the Federal Government to put some institutional assistance into our universities invites greater intervention, but at the moment the only real source of new money for higher education is the Federal Government.

General Discussion

The discussion following the remarks of Dr. Lecht, Mr. Hamilton and Dr. Huitt raised several new points and expanded upon some already discussed. Various points of concern are given below:

- Can the manpower budget suggested by Dr. Lecht be useful if not based on a multi-year look ahead? We are not now and not likely to be in a position to be making Federal budgets with lead-time. Dr. Lecht replied that the President's budget document, in its section on special analyses, usually has Administration program estimates for the next two or three years. If expanded to five years, this would increase the significance of a manpower budget. Also, such a budget would provide opportunity for the consideration of alternatives and the possible need for a shift in priorities.

- Collapse or decrease of a major program like the Space program is not necessary to create large derangements in the labor market. It is only necessary that there be rapid growth for a while, followed by a leveling off.

- What about the capability of Federal agencies to make a manpower budget? And what about the feedback effect of an uncertain manpower budget on educational institutions? Dr. Lecht replied that the Federal Government already does a certain amount of looking at the manpower implications of its programs. A governmental unit called the Interagency Growth Project in the Department of Labor has been considering the impact of defense spending for manpower utilization for years. In regard to feedback problems, "It is better to be vaguely right than precisely wrong." If we look at estimated impact of federal programs over the next several years, we will often be vaguely right, or better. To disregard these various impacts would be precisely wrong.

- A manpower budget might have an inhibitory effect, causing curtailment or elimination of programs which might be justified on other grounds. For example, it is quite possible that a manpower budget for the Space program might have kept us from undertaking it.
- Is it necessary to project a manpower budget during the original budgeting process, when time is short, or might it not be appropriate to wait until the program is underway? Dr. Lecht indicated his belief that "sooner is better," and that experience with such projections would eventually reduce their complexity; he regards relationships among manpower-related programs as critical, leading to overview and early warning.
- Wayne R. Gruner* spoke of making a five-year manpower budget and illustrated some of the relationships to be considered (Figure 4.1). The upper part of the diagram shows total level of employment in some activity; the bottom diagram shows the rate of new recruitment required to maintain the level of employment secn in the upper curve. This is a scenario in which the level of employment doubles in ten years and then levels off. It is accompanied by a recruitment pulse in which the recruitment goes up to more than fivefold the level required to take care of replacement for attrition, and then drops off sharply again. This pattern is a difficult one to absorb in the labor market. This extreme kind of behavior is peculiar to labor markets that involve very low turnover rates and lifetime commitment to occupation (as in the case of academic teaching). The lower diagram can be modified considerably if you assume that the recruitment covers a very broad range of ages and that there is a rather high turnover.

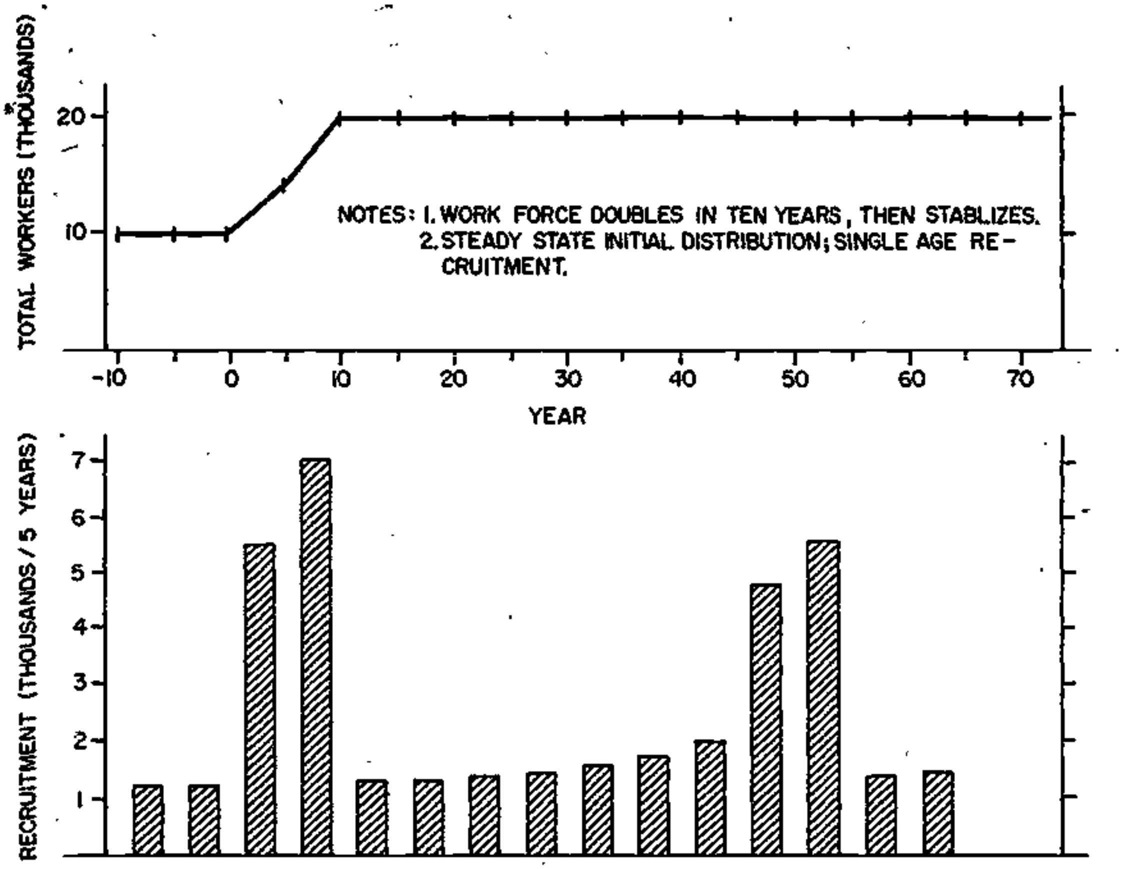
If we look at Dr. Grodzins' version of manpower flow, the baseline would be higher but the recruitment peak would be correspondingly higher also, so instead of rising four or fivefold and then dropping back to base level, it might increase two or threefold and then fall back. Even this would be a severe perturbation.

So if you assume overall social activity is a composite of many different smaller growth activities (the growth, for example, of programmers and the decline of mechanical engineers, as described in an earlier talk) then real labor markets would be made up of a great number of superimposed recruitment pulses of different kinds, magnitudes, and timing.

The clear message for students, faculty, and job seekers is that employment opportunity is a moving target and that their most promising weapon is flexibility.

* National Science Foundation

Figure 4.1
Comparison of Total Level of Employment in a "Growth Industry" and Rate of New Recruitment Required to Maintain That Level of Employment



5. Management of Industry Needs for Engineers and Scientists

This chapter is based on the oral presentation of Dr. White and on his paper. The lead discussants were G. F. Bolling, Ford Motor Company, and Margaret Gordon, Carnegie Council on Policy Studies in Higher Education.

Phillip C. White:
General Manager of Research
Standard Oil Company (Indiana), Chicago, Illinois

This presentation deals with current industrial patterns in manpower planning, and with methods of utilization of the available supply and demand data. A few industrial problems will be described and a few suggestions offered which hopefully will stimulate discussion about solutions. Much has been written on the need for better supply-demand forecasts and manpower management. For example, in August 1973 the National Academy of Engineering produced an excellent analysis of these problems with recommendations for future action.[1] Their recommendations, all of which have been touched on again and again in this seminar, include the need for much better trend analysis than has been performed in the past, for centralized manpower analysis in the government, and especially for government to respond to the impact of its own programs.

Industry Patterns in Manpower Planning

In order to obtain a more diverse industrial viewpoint, we talked by telephone to twenty-seven companies, attempting to reach the person in each company with direct responsibility for planning manpower needs and recruitment. Industrial manpower planning is internally generated; that is, manpower demand is determined by the business plan, with sales projections and new facilities of particular importance. The business comes first; decisions about manpower are a result of that business and not vice versa. Industrial demand then can be divided into various components as follows:

Industrial Demand Components

Increments to Staff	Maintenance of Staff
Sales Projections	Retirements
Contracting Level	Resignations
New Facilities	Deaths
New Lines of Business	Transfers

[1] National Academy of Engineering, *Engineering and Scientific Manpower. Recommendations for the Seventies*, 1973.

The president of M. W. Kellogg, a large construction firm, recently presented a paper on manpower needs in the field of construction engineering. He pointed out that given the manpower needed at the present time to construct and operate plants for coal gasification, oil refining, and the production of petrochemicals, fertilizer, and synthetic fuel, it is obvious that there will be a 10 to 20 percent shortfall of engineers. An interesting point was also made by the president of Kellogg about competitive bidding. Consider the consequences of four engineering contractors bidding on a single, large job such as an SNG plant. In preparing the bid, each contractor spends about 20 percent of the time that would be required for planning, engineering, and procurement phases of the job. Thus if four companies make competitive bids, an amount of time equal to 80 percent of the total time to perform the job is spent even before the job is started. Obviously this is a wasteful practice. Lump sum bidding or other methods would help reduce this large waste of resources.

Another factor in manpower planning is encountered with entry into new lines of business. A company may know what it wants to do, and may have established a market, but then faces decisions about the possible need to recruit new people. The problem is that it is difficult to judge new technology because not every new technology has a significant impact on the market. For example, in the early 1950's it appeared that expertise in radiation chemistry and radiation engineering in the process industries would be in great demand. The technology, however, did not have a commercial impact, and the bulge in demand for these particular skills never materialized.

Still another factor in manpower planning is replacement. As a nation we are reaching the time of retirement for many individuals who started out in the post-depression expansion of industrial research. There has been a steady growth of industrial R&D over the period from the mid-1930's to the mid-1960's, and now the replacement load may be larger than forecasts have indicated because there has not yet been much retirement in the major R&D population.

The general manpower picture is reflected in the responses to our telephone canvass of representative companies. Questions were asked about such topics as: general manpower planning; time span covered in planning; effect of planned new business; the use of projections; reactions to individual manpower projections such as those made by the Engineers Joint Council, NSF, and the American Chemical Society; ideas for improvement in the projections; and ideas on practices which might dampen the supply-demand cycle.

Some of the significant replies will be mentioned here. All of the substantive replies are given in the accompanying paper. One large chemical company reported that its projections were not particularly successful and that failure to project accurately contributed to a large layoff in the recent past. Their spokesman added that he thought his company might even have lost sight of the overall problem of stabilizing manpower planning. Two companies seem to be preparing to do something about stabilizing the cycle; one is a large chemical company, and the other is a large oil company. Each is working on a policy that would aim at a fairly contant level of hiring despite the economy at any particular time. Further, each hopes that more companies will follow its efforts to help achieve a more effective dampening of employment cycles.

In many companies, management does not recognize that a stable level of hiring is a form of social responsibility. Change to such an attitude might be brought about with the cooperative effort of industry, government, and the universities. This effort will take time. The situation, in some ways, is analogous to the movement to change attitudes about the hiring of minorities.

The Role of Supply/Demand Projections

Another significant finding of the telephone survey is that the projections supplied by government and private sources do not seem to play a key role in the planning of the twenty-seven industrial companies. They are aware of these projections, and the projections are taken as indicators of how the recruiting effort should be postured, but that is all. If the manpower situation is tight, companies are prepared to work harder at recruiting. However, expansion plans would not be curtailed because manpower is projected to be scarce at some future time.

One question which must be asked, then: If industry, government, students, and others are not using projections, then why do them? The answer is that a distinction between information transfer and behavior change should be made. If behavior change is the goal, then one must be especially careful about the quality of the information provided. Part of the problem with projections is that second or third-order derivative effects of demand and supply or interactions between them are clearly going to be overwhelmed by completely unpredictable government action. The smaller effects should not be ignored, but it is important to attempt to foresee the big swings and perhaps dampen them.

Another problem area is that of collecting data by survey. As an attempt to increase the sophistication of demand forecasts, a survey was conducted in 1972 by the Industrial Research Institute in cooperation with Engineers Joint Council and the Scientific Manpower Commission. This study, using January 1971 as a base, attempted to forecast demand for one, two, three, and six years. A report, *Utilization of and Demand for Engineers and Scientists in Industrial Research*,[2] was published in 1973 but it wasn't very persuasive for several reasons. Returns were not sufficient; 230 companies were contacted, but only 86 replied. As part of the survey, each company was asked to categorize its response in terms of reliability. Fully 75 percent of the respondents stated that their forecasts represented "best judgments" or were "only a guess." Quite a number of firms said that they anticipated no specific actions in response to the supply/demand picture which they perceived, or that they were only guessing about future change for the purpose of answering the questionnaire.

The use of questionnaires is a difficult method of obtaining data, but this approach should not be given up. A centralized effort would help. A single authoritative group—a government agency such as OMB, BLS, or NSF—should be in charge of the data acquisition. Perhaps there should be a statutory questionnaire, carefully developed and pilot tested. Such a questionnaire could be useful in determining year-to-year trends in requirements for various disciplines. We must admit that the present state-of-the-art in terms of demand surveys is not very impressive, and it is not surprising that schools feel there is not a good picture of manpower needs.

Improved Supply and Demand Management

Internal Supply

Our survey revealed that industry is doing what it can to generate supply by providing continuing education for its people. One company, while not planning

[2] The survey was published by Industrial Research Institute, Inc., New York, N.Y., April 1973.

itself to retrain B.S. chemists as chemical engineers, suggested that such retraining would be possible through a company sponsored arrangement with a local university. It is obvious that working to expand supply internally will help, but this can only partially meet increased demand.

Stabilizing Industry Planning

As previously mentioned, one way to obtain better overall management of supply and demand is to stabilize hiring. This would be useful, but how to go about spreading this practice most rapidly is not clear. An interesting approach to stabilized hiring is given in the following illustration. One company made a careful projection of requirements and then hired up to 80 percent of that level. The company might always be 20 percent short, but they appear happy with the results. Knowing how research directors work, perhaps that one carefully overbudgets by 20 percent so he still gets what he needs. If stabilized hiring were to be accepted as a kind of national responsibility, much would have been done to achieve strengthened manpower management.

Disaggregation

Disaggregation of specialties would be helpful. For example, industry is interested in corrosion engineers, process development men, etc., rather than chemical engineers *per se*. Some of these specialties are trained in only a few places in the country.

Role of Government

It is hoped that as a result of this seminar there will be a greater push toward defining and establishing the role of government in manpower planning. There is need for some entity to communicate our concern about manpower both to the Legislative and Executive branches of government through appropriate channels. This entity would demonstrate the need for manpower budgeting and emphasize the need for awareness of the possible impacts of government policies so that a moderation might be achieved if specific programs are determined to be unreasonable in their impact.

An example of government policy which could be altered quite easily is immigration policy. Despite the fact that the current demand for chemical engineers exceeds the supply, there are complicated and time-consuming procedures which are required by the government in order to obtain approval for the entry of professionals into the United States.

Feedback to Schools and Students

Feedback to colleges, universities, and secondary schools would be greatly improved if demand data were centralized. Information would be easier to deliver and it would be received with greater confidence. Another matter to consider is the reporting of future manpower demand and supply in the various trade journals, technical journals, and educational journals. Sometimes reports of impending shortages or excesses are really not justified in view of the uncertainty of the information on which the reports are based.

If there were nationally accepted, authoritative estimates of future demand, then industry could tell students of this demand. Industry's role should be to tell what an engineer or scientist does in industry without necessarily trying to recruit students to engineering. The role of guidance should be left to guidance counselors at the various levels of high school and college.

G. F. Bolling, Discussant:
Manager, Product Strategy Planning
Ford Motor Company, Dearborn, Michigan

Ford Motor Company makes several different kinds of forward projections in time. There are planning groups in economics, manufacturing, research, technical planning, and so on—over a dozen such groups in the company. Each group has a different projection time; some work on a five-year basis and others work on a ten-year basis. Manpower projections made by the personnel and organizational staff are generally done at least on a twelve month basis, but there can be a turnaround in three months if there is change such as we recently experienced when we knew that automobile sales were going to drop substantially.

Ford does not really use the projections that are available, although our manpower people do use the BLS statistics and depend on the availability of these kinds of statistics. As a rule of thumb, the automotive industry contributes about 16 percent to the GNP, so if one of the major corporations in this industry does not pay very close attention to the projections, then who in the twenty-seven companies surveyed by Dr. White does pay attention?

Ford has difficulty cutting off the peaks and filling in the valleys, and it has its own lags in obtaining particular types of engineers. Eighty percent of the engineers that Ford hires are mechanical engineers. They fill approximately thirty different kinds of jobs. Mechanical engineers are just one of the five basic kinds of engineers, so perhaps engineering should be subdivided and looked at more critically, not just as one great lumped mass.

Dr. White emphasized that companies should pursue minimum hiring goals regardless of the economy, and he stressed that companies should back their plans except where "survival is really threatened." Realistically, however, a threat to company profits occurs before a threat to company survival. Changes in profits are a strong incentive to change plans.

Dr. White suggested a central data collection agency and the need for industrial input of demand statistics. Such an agency would be a good idea, but certain demand statistics reveal company plans and could not be obtained. Company plans are closely related to intended profit, and it appears that unless every organization reveals its detailed plans, no one organization will be the first to start.

Care must be taken in preparing questionnaires because it is so very difficult to get adequate answers. One should avoid the "Edsel questionnaire syndrome"—the market survey used prior to the design of the Edsel simply asked the wrong questions.

In regard to the suggestion that industry speakers should stick to objective facts about career opportunities and not talk about supply and demand, I agree. Ford is currently starting a program which it calls a college sponsor program. There are between thirty-five and forty executives in the company who are in close contact with either deans or presidents of as many major universities in the United States. The purpose of these contacts is to understand more about university problems and to open a line of communications to the Ford Motor Company. Ford hires a significant proportion of the engineers in the United States, but finds that certain individual characteristics do not come out of mechanical engineering schools, and so is attempting to inform the universities of the type of individual it is seeking.

The recent history of Ford's hiring level of engineering graduates as a percentage of total engineering graduates in the United States is as follows: 0.2 percent in 1970 (a recessive period for Ford), about 2 percent in 1971 and 1972, about 3.7 percent in 1973. If the automotive industry has a turnaround in August 1974, the figure for 1974 might run to 0.6 or 0.7 percent versus a previously projected figure of 1.5 to 2.0 percent.

Ford has projections to the year 1983, and our personnel and organization staff assumes a shortfall in engineering. However, the money necessary for recruiting activities is projected by the finance staff, and this staff is not convinced that the shortfall is real, since the supply of engineers for any company can be made exactly the number it wishes to hire. If an organization needs someone, it goes out and competes for them. It will become more difficult in the automotive industry after recent changes, but nevertheless money is demand and it can be used to fill our needs.

Government manpower projections are producing a lot of answers, but what are the questions? It appears that people are looking for questions to fit the answers. Industry is probably not the place to find planners to couple with projections people, for the various reasons and objections that Dr. White put forward. If it is not industry, then is it government? If it is government, is the purpose to underscore policy? If so, how closely then should policy, planning, and projections be tied? Asking another way, how successful are projections and planning in relatively closed economies like the U.S.S.R.? That is a question which has not been discussed at this conference.

Finally then, projections are not as useful as knowledge of the perturbations in the system. In hindsight, ask if there was anyone in the projection business in 1963 and 1964 who considered the perturbation that would occur if funding of aerospace diminished, disappeared, or would be dislocated in any way. Today's question is, "What would happen to the oil industry and automotive industry if there were a crisis in energy that occurred drastically rather than gradually?" As a truism it can be said that projections are only as worthwhile as the statistics from which they are derived. If perturbations are to be analyzed, perhaps there should be thorough studies of the history of previous projections.

Margaret S. Gordon, Discussant:

Associate Director, Carnegie Council on Policy Studies in Higher Education, Berkeley, California

It is encouraging to learn that at least some employers are beginning to try to stabilize their manpower hiring plans. However, there are severe limitations on stabilizing activities, particularly when one considers the way changes in Federal programs affect the demand for scientific manpower.

Dr. Lecht is correct in his general position that there should be manpower budgeting. His position, however, might be phrased in a slightly different manner: perhaps there ought to be an analysis of the manpower impact of major government decisions. This would be analogous to environmental impact statements for various construction projects.

One topic which has not been discussed very much at this meeting is the field of health manpower. The enactment of the Medicare and Medicaid legislation in 1965 led to a general shift to the right of the demand curve for health manpower and health services. In the years following the implementation of that legislation there was a very sharp increase in the rate of inflation of the medical care component of the Consumer Price Index.

This demand curve may be heading toward another shift to the right. The Kennedy-Mills pact on health insurance legislation is probably bringing the day much closer when Congress will enact a national health insurance bill. The effect such a bill will have on the demand for health manpower obviously depends on the details of legislation that is passed. However, at the same time that the administration says it is supporting a national health insurance bill, it is making plans to cut back drastically on support of medical schools and other kinds of health training schools.

The administration seems to be very relaxed about the problem of supply of physicians and says the shortage of physicians seems to be disappearing. Essentially what is happening is that the inflow of foreign medical graduates has been continuing. Some projections assume that there will be a continuing steady or increased inflow of foreign medical graduates, despite the fact that there has been a substantial increase in the number of entrants to U.S. medical schools over the last six or seven years. In the face of the substantial increase in the supply of U.S. medical graduates, it is now unreasonable to assume that the demand for foreign medical graduates will rise or even remain constant.

What should be the U.S. policy toward depending on foreign countries to supply a significant portion of its medical manpower, particularly when those foreign countries tend to be relatively underdeveloped countries like the Philippines? I believe that as the wealthiest nation in the world we ought to be exporting highly trained health care manpower rather than importing it, and we ought not to be forcing large numbers of U.S. students to get their medical education in Mexico and other countries where a good many are going.

My general point is that there has not been enough analysis of international movements of highly educated manpower. We can no longer assume, for example, that U.S. salary levels for engineers and scientists are so much higher than salary levels in other countries. Rates of inflation abroad have brought salary levels closer together.

Dr. Breneman made the point earlier that increases in Federal fellowships and research assistantships have not apparently increased the proportion of doctorates granted in the sciences and engineering. The 1950's and 1960's were years of exceptionally expanding demand for highly educated manpower, despite the huge increase of supply that was occurring especially i .he 1960's. There were two main reasons for this expanding demand—one was an increase in the percentage of GNP going for research and development expenditures, and the second was the march of the cohorts of postwar babies through the school system and up into the colleges and universities. During this time period, the most pronounced increase in the proportion of degrees being granted was in education. A number of the degrees in the humanities and social sciences were also granted to those who were training to be teachers. Even though there were increased doctorates in science in terms of numbers, there was also an increased demand for teachers and college faculty in other areas, so this competition in the market may have kept the proportion of degrees in science from increasing.

There has also been some discussion at this conference of whether and to what extent Federal fellowships and other forms of support will affect the enrollment of graduate students. Dr. Kidd pointed out that Federal support has dropped drastically, yet the number of graduate students has been increasing modestly in recent years. The question to ask is whether fellowship support has a more basic influence on the behavior of students than demand in the fields for which the students are training. It appears that demand is more important than the behavior of fellowship support.

On the other hand, there is a need to disaggregate by field and type of institution. In 1971 and 1972, the large increases in graduate enrollment occurred at places like Mankato State. Leading graduate schools such as Harvard, Princeton, and Berkeley have been cutting back on their graduate programs largely in response to the loss of fellowship and other kinds of support. The best schools are not getting the increases in students. Thus consideration must be given to Federal support as it affects the highly qualified graduate schools which are a basic national resource. Dr. Allan Cartter has also stressed this point. The same consideration applies to medical schools.

The Administration seems to be reversing the position it took in 1971, calling for a drastic cutback in what was then adopted as the principle of basic capitation support of medical schools by the Federal Government. Nothing like the full cost of education was provided but the idea was that States and private sources of financing would supplement what the Federal Government provided for basic core support. If the United States is to maintain the high quality of its leading schools, there must be stable support from the Federal Government.

A final word about student choice. Student choice is very sensitive to market changes and students' perceptions of the market are reasonably accurate. As one aspect of this, women have been shifting their fields in a most dramatic way and are moving into traditionally male fields. This was brought out in the report I drafted for the Carnegie Commission on Opportunities for Women in Higher Education, yet many people continue to write as if this were not the case. Underrepresentation of women in field after field is claimed, without paying attention to what is becoming a very important movement.

This leads to the point that information on changes in student choices of field at the undergraduate level is extremely inadequate. One searches and finds, say, an article by Lee Grodzins on changes in physics enrollment, and something by the Engineering Manpower Council on engineering, and so on, but there is no basic general source of information on undergraduate choices and changes of field. Such a source very much needs to be developed.

General Discussion

Following Dr. White's presentation and discussion by Dr. Bolling and Dr. Gordon, a number of questions and comments were offered by participants. Various points included the following:

- Thomas D. Barrow* reemphasized Dr. Gordon's point about a lack of material balance within the United States on scientists and engineers.

* Director and Senior Vice President, Exxon Corporation, New York, New York.

Exxon, one of the largest multinational corporations, has about as many American scientists and engineers working abroad as in the U.S. Many foreign scientists and engineers work in this country as well as abroad. Thus when the manpower problem is considered strictly in U.S. terms, we should be cautious to note that some assumptions will work with respect to some fields, but not to others.

A 1970 report of the American Geological Institute[1] recommends that universities improve their planning in regard to disciplines and degree output, and that employers hire more evenly, avoiding peaks and valleys, in order to insure a more uniform flow of personnel through universities and industries. Exxon has been following the latter recommendation, at least in domestic activities. Its research organization, which is separately incorporated and therefore has different corporate policies than the domestic affiliate, has not followed this policy in the past, although it will in the future. The domestic affiliate has had less than 10 percent variation in the hiring of engineers and scientists over the last five-year period. The research affiliate, however, has cut staff 10 percent below the high for that same period, so there have been substantial differences within this single large organization.

- On the matter of foreign enrollments. There is an increase in the proportion of foreign students in graduate engineering schools. What is the industry view of hiring foreign students? Dr. Bolling replied that there is a strong tendency to hire U.S. students first, partly because of the difficulty of visa procedures. There is a question also of the quality of foreign students; overall quality may be a matter of total educational background, so foreign students are likely to be at a disadvantage.
- Assume that Ph.D.'s are in surplus to the extent that they become inexpensive to hire. Would industry substitute Ph.D.'s for bachelor's degrees simply because the Ph.D.'s are cheap? Dr. White responded that in research Standard Oil of Indiana hires 60 to 70 percent Ph.D.'s, so there is already a considerable use of Ph.D.'s. This might be increased by 5 percent. Dr. Bolling commented that Ford has hired more Ph.D.'s outside its research laboratories than ever before. This is true not only because salary differentials are narrowing, but also because the automobile is becoming a "higher-technology" product. There has also been an attempt at Ford to seed production with Ph.D.'s from the research laboratory. Dr. Barrow, speaking about Exxon, said that his company hired more Ph.D.'s in operations in the 1950's than it did in the 1960's or probably will in the 1970's for two reasons. There were fewer opportunities for Ph.D.'s in other areas then, so more were interested in Exxon; also, more Ph.D.'s in the 1950's tended to be generalists than those who are graduating in the 1970's. Good Ph.D. generalists are hard to find right now.
- Dr. Branscomb remarked that there is a need to distinguish between adjustment of the load level for universities and stabilization of the scien-

[1] American Geological Institute. Committee on Manpower. *Manpower Supply and Demand in Earth Sciences, 1969-1974.* American Geological Institute, Washington, D.C. 1970.

tific and engineering manpower pool. There has been much discussion about supply from educational institutions and the demand for the product of educational institutions, but there is a need to know what is going on in the community of people who are active scientists and engineers. The size of the science and engineering pool is affected not only by the rate at which new members are trained but also by the rates at which members of the pool move to other activities or return to the pool after other activities. We need to understand the rate at which people stop being scientists and engineers and start being either vice presidents or deans or unemployed or salesmen, and we need to know the rate at which scientists and engineers are created outside the universities. For example, the IBM Corporation has a number of full-time instructors on its payroll, providing training in specialties which it needs.

Adjusting the rates at which members leave and return to the pool is, within obvious limits, a more effective process for adjusting the size of the pool than is the adjustment of the hiring rate for new graduates. Perhaps creation of skills internal to the industrial system as well as the transfer of people in and out of the scientific and engineering areas is also more important than the hiring rate for new graduates. Thus, projections are more important for university load-leveling than they are for the management of the total science and engineering pool.

Dr. White disagreed, saying he thought projections should be applied to manpower management as it relates to both universities and the total science and engineering pool. Flexibility can be achieved by in-house training and by early retirement, but it is important to keep new blood flowing into the system in order to maintain creativity. Dr. Branscomb replied that there is a need to examine the full spectrum of company policies. This would include new hires together with the flow of scientists and engineers in and out of industry.

- To the question, "How successful are projections and planning in relatively closed economies like the U.S.S.R.?", Dr. Grodzins responded, saying that if anything, the U.S.S.R. is doing worse than we are. There is a great deal of planning there, but the planning groups do not do a good job of communicating with each other. *Many* countries are having manpower planning problems. The problems of increased entrances into higher education and the mis-matches between the needs of industry and the outputs from the universities seem to be quite universal.

- The flow of expertise and talent within a given organization is not nearly so difficult to understand as the flow of talent and expertise from one segment of the community to another segment. Within an organization the person involved is a known quantity, but the individual who changes organizations and at the same time becomes a generalist, or changes specialties, has a more difficult time. There is reluctance on the part of individuals and on the part of prospective employers toward such a move. No attempt has been made at the university level or at any other level to ease this transition. If there is one single situation for which projections would be especially useful, it would be in the formulation of policies which would make transfer between specialties easier.

- Fred P. Thieme* asked for thoughts on how the civil rights movement in higher education might affect manpower considerations. Dr. Gordon responded, saying that women and members of minority groups have special kinds of contributions to make in higher education. For example, an able woman professor has the capacity to stimulate women students, and a black professor has the capacity to understand the problems of black students. These special contributions should be recognized when recruiting and hiring, along with the more usual standards applied for faculty employment.

  One of the most spectacular changes has occurred in enrollments in medicine where the percent of women entering medical school has jumped from 7 to 20 percent over the previous six or seven years. Similar changes have happened in law school enrollments. Information at the undergraduate level is not so extensive. Richard Peterson conducted a survey for the Carnegie Commission of shifts in undergraduate majors in 1970 and the fall of 1971, which showed that women were moving into majors in architecture, city planning, agriculture, and so on, because of interest in the environment. Peterson also tried to trace the changes in degrees granted to women in the latter part of the 1960's. This study shows that there is an increase in the proportion of degrees granted to women in a variety of fields that had been considered traditionally male.

The formal paper prepared by P. C. White and D. G. Schroeter for this session appears below.

Management of Industry Needs for Engineers and Scientists

I. Introduction

Effective management of the supply and demand of engineers and scientific manpower has not been achieved in the United States. The shortage-oversupply cyclic imbalances are known to us all. Voluminous information is available on what has happened in the past. Much has also been written on the need for better supply-demand forecasts and manpower management. However, we are obviously still a long way from our goal. For example, the National Academy of Engineering in August 1973 produced an excellent analysis of the problem and recommendations for future action. These recommendations boiled down to: (1) need for continuing (versus ad hoc) systematic, soundly based, and timely manpower trend analyses, (2) national organization for such manpower planning and decision-making with leadership from the Executive Office of the President, and (3) evaluation of the manpower implications of national technology goals and improved programs for any consequent re-education and increased mobility of technical manpower.

* Special Consultant to the Board of Regents and Professor of Anthropology, University of Colorado, Boulder, Colorado.

My remarks will cover current industrial patterns in manpower planning, including how available demand and supply data are being utilized. I hope to give you a brief insight into industrial planning problems, together with some suggestions on how improvements can be accomplished, rather than what the problems are.

In accepting this somewhat belated assignment last month, it was clear that there would be no time for another "in-depth ad hoc study" nor is yet another study needed for what I wish to communicate today. Since I was asked to speak for industry, however, I felt it incumbent on me to seek beyond the experience of many years which I and my associates in Standard Oil of Indiana have had in dealing with this problem.

Therefore, we contacted 27 companies across the country, representing the oil, chemical, electronic, aerospace, pharmaceutical, engineering/construction, metals, foods, and automobile industries. In most cases, the person within the organization responsible for manpower planning activity was called by telephone. In all cases, the individuals called could effectively speak for their organizations. All persons contacted were very cooperative in responding, and all recognized the overall problem. No company will be identified by name in this paper.

II. Industry Patterns in Manpower Planning

Manpower planning by industrial companies is based on internal and external inputs of the best available facts on expansion of business, entry into new lines, technology changes, obsolescence, capital availability, and many other factors. Business plans come first, and from these the levels and kinds of manpower needed are combined into a manpower plan.

The pertinent components of the business plans usually start with sales projections with their concomitant requirements for technical service personnel in the field, and research effort in the lab. For companies heavily engaged in Government contract work, changes in contract level are reflected almost linearly in their engineering staff requirements. Any new facilities planned will represent a demand increment, both for the engineering necessary to build and the staff to operate. Should the enterprise be planning to enter new lines of business, this has particularly critical manpower implications. New skills may be needed which are in short or zero supply among the current staff. Requirements will span the entire organization, from R&D through the plant to the sales force.

All of the above increments represent changes up, or down, in the technical manpower needs of a company. They are additive to the annual hiring a company must do just to offset turnover, assuming a constant staff. Losses by death, retirement, resignation, or transfer to a nontechnical function, tend to be fairly constant year to year, unless perhaps there is an abnormal age distribution in the current staff. Hiring to fill such vacancies represents, or should, a stabilizing influence in industrial hiring patterns.

This replacement hiring, plus the net changes foreseen, are combined into an overall manpower plan. In the large companies, most, but not all, develop this plan through successive levels to an overall corporate plan in terms of numbers and discipline of engineers and scientists. This information is then returned to corporate recruiters to make them aware of the total needs in the individual divisions or subsidiary companies even though in many instances each operating facility operates independently. Most large companies attempt a five- to seven- or even ten-year manpower plan but admit that they are doing a poor job. Such plans are, of course, updated annually so actions are essentially based on a one-year plan. Only a few companies in our sample said they attempt computer modelling in their manpower plans.

In a number of cases there was really little need for detailed manpower information. These were stable industries (pharmaceutical, food) demonstrating slow steady growth. Such companies usually maintained excellent contacts at selected universities, and when they needed personnel, they went out and got them.

The major problem lies in carrying out whatever plans have been made due to the impact of economic, governmental, and other change. A recession and a shift in Government priorities, such as took place in the early 1970's, caused abandonment of many plans, a stop in hiring, and in some cases, even a lay-off. Serious impacts were experienced by those companies which are heavily oriented toward governmental contracts, such as aerospace. This story is well known and has been communicated many times. In fact, it was over-communicated and is one cause of our present rapidly developing shortage.

While the loss of Government contract support has a direct and by far the most significant impact on industrial employment of scientists and engineers, there are other Government actions which have an indirect effect. Regulations, such as those coming out of EPA, FDA, OSHA, and now the Federal Energy Office, inevitably mean that the complying company needs more technical men in the lab, in the plant, and even in the headquarters office. Of the companies surveyed in our study, only a few had a significant level of direct Government contracts. The indirect effects, however, have very definitely been felt by all the companies.

I would like to quote to you, without revealing sources, some of the comments we received. I believe they will give you a clearer picture of how industrial concerns approach this manpower problem than any summary I can offer.

> "We establish what we have to do on a project basis every August and forecast one year ahead. Then we place a probability factor on whether the project will run to fruition. This results in a total workload activity which is translated into a manpower level. We then employ people up to 80% of the forecast manpower level. Although the forecast is for one year, it has worked well and there have been no layoffs for over 15 years."

> "Planning is for one year and we felt that longer range planning is not meaningful. We do forecast needs in anticipation of the business we expect to do. The effect of Government contracts is not as great as in the aerospace industry. The energy crunch is showing its effect now. Also we now have an environmental department which we didn't have before. OSHA has had an impact also."

> "The planning cycle is precise and a lot of it is computerized. We plan seven years ahead and build the plan starting at the operating division. Input such as work project analysis, market demand, funding, and many others are included. A two-year operating plan results with a statement of manpower required by skill, which is the difference of the known in-house skills versus the needs. The seven-year plan is updated. Few operating divisions are unable to follow the plans. We have very little Government contract work and what we have is fairly predictable."

"Our manpower plan is on a 2- to 3-year basis and includes all input we can assess. Effective Government policy is also critical. Most of our work is for the Government. We plan for growth, and then if we see that the level of Government contracts will not match that growth, we increase our efforts to penetrate the civilian market."

"Manpower planning is on a 6- to 12-month basis, and we used to do 5- to 10-year projections. The disruptions in the aerospace industry caused us to essentially abandon these efforts. Now we conduct an information survey among our various subsidiaries and communicate the job vacancies we expect over the next 6-12 months. The effect of Government policies has been major."

"We don't do too well. Bad planning caused a recent lay-off. I believe we have gotten so embroiled in counting people that we have lost sight of the overall problem of stabilizing our manpower planning."

"Our plan is greatly improved this year. Each plant and division now sends manpower needs to the corporate headquarters. Every possible effect is considered and a one-year plan is made. We have a new policy approved by the Company's Board to dampen the hiring cycle. We will not go all out in a high need period and will not stop hiring during a recession. I believe we have all (i.e., major companies) been doing a pretty poor job in the past. We are a big company and think we can help dampen the cycle."

"We have a corporate-wide planning group which works up the entire manpower story. They get input from every subsidiary. We have a one-year, five-year, and 5- to 10-year plan. The plan may not always be followed, but at least it spots trouble areas. We are very concerned about better manpower planning and are working on a policy that would set a certain level of hiring each year despite the economy. If enough companies are willing to do this, we can then communicate the action back to universities."

I think it is very significant that the last two companies quoted, and they are both major, have already taken steps to consciously modify their hiring in an effort to dampen the cycle and stabilize demand. This is the key step on the industrial side that can contribute to solution of the problem.

III. Role of Supply/Demand Projections

Now you will note that while I have talked a good bit about how industry carries out its manpower planning efforts, I have said nothing about the use made of the numerous supply/demand projections prepared and so widely disseminated by both Government and private sources.

Considering the effort that is made to monitor these supply and demand trends, this information is not being used as extensively for industry's manpower planning purposes as might be expected. Of the 27 companies contacted, 11, although they were aware of the sources, did not find them useful except as overall knowledge of supply. Reasons for this lack of use varied. Although generally the supply data as published are viewed as quite valid, there were comments which revealed inadequacies of the data. For many purposes, just the supply of Ph.D. chemical engineers is not adequate. Aerospace wants corrosion know-how, the chemicals industry needs process control, etc. Another problem is the definition of an engineer (non-degree persons doing engineering work are reported in many surveys as engineers).

To give you a flavor of our findings, again let me quote a few comments regarding the use of supply data:

"Do not use any of published statistics."

"Are not used directly and are of secondary interest."

"Do not pay much attention, although recently have been concerned at low freshman engineering enrollment."

"Not much used except to anticipate costs of recruiting."

"Do not use when they become available. Particularly need information for engineers."

"We use EJC data, one example of a local situation relates to ceramic engineers. This is a tough one. Projects change, demand changes."

"EJC is very best available, John Alden even validates other sources. Haven't needed data on scientists since late 1960's."

"ASEE is best, due to breakdown by discipline. Generally aware of supply/demand situation. Do not use in terms of action."

Now as to demand data, these, as viewed by our sampling of U.S. industry, are wholly unreliable. Demand has been forecast very simplistically in the past by such measures as extrapolation of economic and other data, by Government agencies, ad hoc surveys of industry as conducted annually by Frank Endicott, and others.

Attempts have been made to increase the sophistication of demand forecasts. One of these was conducted by the Industrial Research Institute in 1972 in cooperation with the EJC and SMC. It was reported in April 1973 *(Utilization of and Demand for Engineers and Scientists in Industrial Research)*. This forecast used as a base January 1971 and attempted to forecast demand for 1, 2, 3, and 6 years. Each of the 86 companies participating was asked to categorize its response in terms of descriptive paragraphs on reliability. Fully 75% stated that their forecasts represented "best judgments" or "not a good estimate, only a guess." Only 10% were "fairly clear" concerning their future demand levels. Regarding available supply/demand, 50% assumed that their current experience would apply to the future. Finally, 75% of the respondents revealed that they anticipated no specific actions in response to the supply/demand picture they perceived or were only guessing about future changes for the purpose of answering the questionnaire. Thus, from the IRI experience, the business of forecasting demand is in its infancy. There are no current plans in IRI to repeat this survey on manpower. However, a broader survey on research trends by IRI is now in its third year. It includes anticipated hirings (or layoffs) for at least the coming year. It may offer a vehicle for collecting more extensive demand data, at least within that industrial group.

Another example of a sophisticated attempt to forecast demand has just been completed by the Engineers Joint Council, privately funded by industry. The EJC study attempted current opening analysis and three- and twelve-month forecast of openings. It contained turnover, losses, hiring forecasts by industry group and technical discipline. EJC warns of the experimental nature of this demand survey and states that the survey was done to develop methodology and illustrate the potential of such surveys. They cite weaknesses such as statistical reliability, scope of coverage, need for continued updating, and representativeness of the data.

From the status of demand projections today, it is evident that counsellors in high schools and university technical department planners have very little basis to use for control of their educational activities. As will be stated later, I believe that projections can be improved, made timely, more consistent, better defined, and certainly much more reliable. One factor that needs to be continually emphasized is the potential opportunity in the technical fields for women and minorities, particularly in engineering where underutilization is the worst. In 1973, only 1.2% of the U.S. engineering graduates were women, and 1.3% were black. Certainly better forecasts would help provide confidence as to the opportunities in these fields, which is such an important ingredient of convincing minorities and women to enroll in science and engineering.

IV. Enhancing Internal Supply

One way for a company to overcome an inadequate supply situation is to make better use of the manpower currently on its staff. Our survey of companies did not reveal any new ideas regarding such more effective use of internal technical manpower resources. Almost everyone has educational assistance plans whereby after-hours university courses are reimbursed. Most large companies have in-house continuing education programs. All felt that they were utilizing technicians to a high level of effectiveness and provided equipment and other support, such as computers. A few companies indicated that they believe the real manpower crunch in the next decade will be for very sophisticated levels of knowledge, that is for Ph.D.'s who are experts in specialized fields to meet the challenges of the very difficult future technology. It was felt that this kind of expertise can only be developed by training in the universities.

My own view is that there is significant room for better use of available talent. For example, better training and continuing education of technicians should have considerable impact. One innovative idea we ran across was to retrain B.S. chemists, who currently are in good supply, to chemical engineers. This would be done under contract with a local university, and perhaps on company time. But only so much can be done with internal supply.

V. Improved Supply and Demand Management

It is clear that if we are to improve the supply and demand situation overall, we need better management of both, management in which U.S. industry, the Government, professional societies, and the educational community must all be involved. In our discussions with this cross-section of U.S. industry planners, we found much concern and desire for action along with some existing good planning techniques and new ideas.

A. Stabilizing Industry Planning. First it is apparent that industrial scientist and engineer staff levels and hiring patterns must be stabilized in contrast to the cyclic swings of the past. Each individual company must improve its manpower planning. Some companies will need to take the step of corporate-wide centralization of such planning. Firm plans are needed for at least one year ahead, and reasonably firm commitments for five years. All of the traditional inputs need to be used, with the obvious flow from needs for technical work to the hiring goals provided recruiters.

Second, innovative planning techniques are needed and those in existence need much wider application. Some are already being used, such as a hiring target to produce a technical staff below maximum future need (say, 80%) and possibly contracting-out or postponing lower priority work. Division or departmental management can exercise its control based on dollars, rather than on specific manpower levels, thus providing technical managers with more options to dampen cycles. Minimum hiring goals, regardless of the economy, need to be set. It is evident that "dead wood" should not be allowed to accumulate in any department, only to be weeded out during a recession. One can conceive of a model that would relate manpower levels to a combination of parameters, such as return on investment, sales, manufacturing volume, etc., coupled with a hiring plan that would vary annually only 20% in reaction to change. This opposed to the past undesirable extremes of stopping hiring completely or maximum employment and even stockpiling in periods of manpower shortage.

To the extent that companies within an industry use a given specialty, such as corrosion engineers, it may be useful somehow, perhaps with governmental or professional society assistance, to pull together their stabilized manpower demands. The total might be enough, in many cases, to represent a substantial portion of the future supply in that individual technical discipline.

Third, given better and more stable manpower planning, individual company top management must back the plans, and recognize the company commitment as part of an overall effort at the national level. Exceptions should be discouraged except where company survival is really threatened.

Fourth, if better demand figures are available, their communication and use are essential if education is to react more accurately and reliably to dampen the supply swings. Better demand figures can result from the corporate planning improvements described. The communication step will require closer cooperation between Industry and education. The traditional activities of scholarships, summer jobs, etc., must be continued and expanded. New concepts, and perhaps an extension of successful but limited practices such as cooperative education at the undergraduate and the MIT Practice School at the graduate level, need to be greatly expanded to bring industry and education closer together.

B. Role of Government. In the introduction I mentioned the National Academy of Engineering August 1973 report, "Recommendations for the '70's." Rather than summarize the report further, I would commend you to its reading and remind you that it recommends a key role for Government in the future. In the past, such occurrences as widely changing funding of graduate work and of defense and space contracting have obvious and devastating effects on the manpower supply and demand situation. The very least we can ask of Government is to monitor the implied manpower supply/demand impacts of its policies and programs. Ideally we should seek moderation of those programs when they threaten a severe manpower impact. I would comment on one simple, very small example that apparently is occurring today. Despite the fact that the current demand for chemical engineers exceeds the supply, the U.S. Immigration Service and Department of Labor are still operating on the opposite premise. The result is that complicated and time-consuming processes are required to obtain approval for a chemical engineer to enter the U.S.

C. Feedback to Colleges, Universities, and Secondary Schools. We have stated that if industry (and others) can indeed provide better and more stable manpower planning, then demand data can be better defined and will be received with a considerably higher confidence level. Such demand information must be communicated to the entire educational system. The very recent experimental studies by the Engineers Joint Council and IRI provide a possible blueprint for future demand reporting. Whether it be the Engineers Joint Council, individual professional societies, the Bureau of Labor Statistics, the U.S. Office of Education, or the U.S. Office of Management and Budget (as recommended in the NAE report), responsibility for the collection and communication of the demand statistics must be centralized and so organized and funded as to provide a continually updated flow of valid, understandable and detailed information to the colleges and high schools. These data should reflect demand created by Government programs, as well as industry demand. Our educational institutions would then have responsibility for communications to students of the evident career opportunities and for the professional guidance of such students. Improvement of professional guidance is badly needed.

What more can be done to ensure a balanced response by students to the improved demand forecasts is not clear. Industrial support via scholarships, fellowships, and teaching awards will obviously help. Careful, thoughtful articles in the educational and technical journals, avoiding "scare or hard-sell" tactics, would also be helpful. The same applies to individual company activities.

I suggest that the role of industry, and other organizations which use engineers and scientists, when providing speakers and information to high schools at the local level, should be to stick to objective facts of what the various scientific and engineering jobs contain and to limit remarks about supply and demand to authoritative sources. The recruiting of talented high school students for career opportunities in engineering and science should be the function of colleges and universities, using such improved data as we have described.

One can even speculate about the utility of a nation-wide computer hookup that would provide college and graduate school counsellors with current data on course enrollments, as related to anticipated future demand. If available daily during "registration week", it might assist those counsellors in balancing student response.

May I say in closing, there is no doubt in anyone's mind here, I am sure, about the challenge we face to improve the total technical manpower planning process. I am optimistic about the effectiveness of the steps that are available to us. I further believe that we must act decisively and soon, and I am confident that U.S. industry will cooperate fully in any comprehensive program at the national level.

Thank you, and I appreciate the opportunity to present an industry viewpoint in this critically important Seminar.

6. Student Motivation and Career Choices, A Panel Discussion

Kenneth E. Clark, Presiding:
Dean, College of Arts and Sciences
University of Rochester

This panel discussion places emphasis on students; on what they do, and on what kinds of factors influence their career choices. If we examine the progress of an individual student from high school through graduate school and into a career, it becomes apparent that what has happened is orderly in form, and rational, in terms of the information available to that student. If we could somehow accumulate all those separate experiences, we would learn that the student knew more about the whole process of choice than any of us profess to know. A variety of numbers and formulas, and the like, are being presented at this meeting; perhaps at this session we can flesh out those formulas so as to better understand the manpower process.

Certain things are known about bright young people. They start out more interested in the world around them than anything else; they prefer to do things in the natural sciences. This is partly because they come to perceive in high school that if you aren't in the natural sciences, you aren't very smart. And besides, their high school social studies teachers seem to be fairly mediocre compared to their science teachers. In college, however, these students discover that poets and others can be pretty smart, and a number of them leave the natural sciences—it is a national trend that interest in the natural sciences is diluted by virtue of college attendance. The student who goes to college is broadened in interests and moves into domains not considered in the light of previous high school experience.

Another thing we know is that students chose occupations according to a fairly stable set of variables which are related to individual preferences and interests. These expressions of preference, or of motivation, are more important than aptitudes. Thorndike and Hagen, in *Ten Thousand Careers*, suggest that the variation of ability measures between different occupations is not as great as one would think. The important variables in career choice tend to be the motivational variables. People filter into careers in which they can do the things they want to do.

One wonders where students get the information which leads them to make the decisions they do. Looking at these students, we conclude that there is a rational, orderly decision process at work. Further, each of these individual summators of information does a better job than those who try to project behavior with mass statistics. If somehow we could understand better that small unit, the single human being, we would achieve more accurate results in our projections about student trends.

Another point worth noting is that we know something about the way in which individuals move into jobs and then change the nature of these jobs. The individual and the job interact. A person decides he is going to seek education in a particular area. He does so and after that continues to develop. Whatever the job, it is changed by virtue of this person's interests in the same way that he is changed by virtue of the job's demands. Something will be omitted from our analyses if we do not incorporate, in some way, understanding of the interaction between the demands of the job and the interests of the individual.

There are some interesting studies of this interaction. Men who eventually become admirals in the Navy Medical Corps are men who did not like being physicians; they were trained as M.D.'s, but they look like administrators. Men who end up as labor union leaders in the electricians' union are men who do not look like electricians; they look like politicians, and they got out of electrical work by becoming union leaders. Others get out by being electrical contractors; they look like entrepreneurs.

Nearly everyone changes his job a little bit to make a fairly good match, but a serious problem develops when a person makes a decision too soon and finds himself in a position where he and the job are not compatible. Such a person needs to be retrained. Another kind of problem occurs when a person is perfectly suited to his job, but the job is eliminated. This person must be retrained or else must find another place where his training and skills can be used.

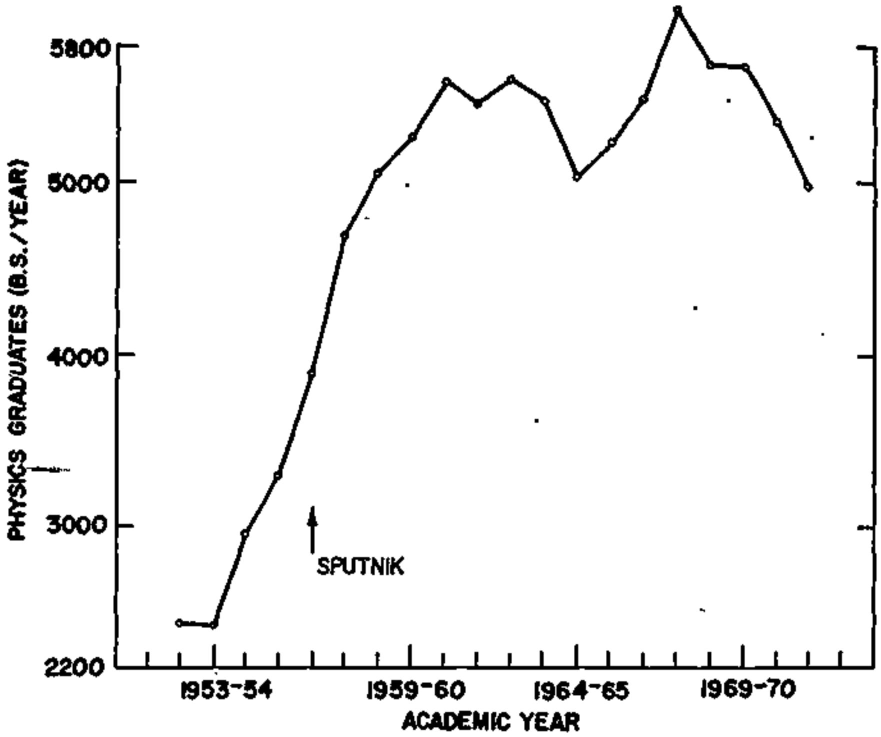
In short, then, this session deals with human beings—individuals—and how the whole business of manpower relates to individual decisions.

Lee Grodzins:
Professor of Physics, Massachusetts Institute of Technology

We are all aware of the complex factors which motivate career choices. We know that all too often, simplistic reasons are simply wrong. Permit me to remind you that the conventional wisdom still is that Sputnik, streaking across the stars, so glamorized the field of physics that students flocked to the field. The fallaciousness of that myth is demonstrated by Figure 6.1 (which many of us have come to call the anti-Sputnik graph), which shows the yearly output of baccalaureates in physics in the United States. If the space age opened the tap of physics majors then we should have seen a rapid growth of baccalaureates in physics starting three to four years after the satellite launch in 1957. But that did not happen. Instead, 1961 was the year of *saturation* of baccalaureates in physics; for the next decade the number of physics majors remained roughly constant. Did Sputnik not have an effect on the output of physicists? It certainly did—but in the graduate not the undergraduate enrollments. The satellite age ushered in rapid increases in graduate student support. And students followed that support. In the early 1960's the ratio of first-year graduate enrollments in physics to the number of B.S. degrees in physics a year earlier rose rapidly from 0.35 to plateau at nearly 0.55. You will not be too surprised to learn that that ratio started to fall in the late 1960's, when student support money declined, and is now back to about 0.35.

Having made the point that we must be skeptical of one-dimensional motivations, apart from those due to direct financial support of educational careers, permit me to record the observation that there is a commonality to motivating forces of undergraduates which crosses geographic boundaries and prestige classifications of schools. How else can we explain the fact that the specific percentages of physics baccalaureates matriculating to graduate education far removed from physics; i.e., medicine, law, economics, engineering, are about the same for MIT as for all the schools in the country? I suspect that student mobility carries career information rapidly among undergraduates so that fads in one area, such as the Northeast, spread quickly and become national trends.

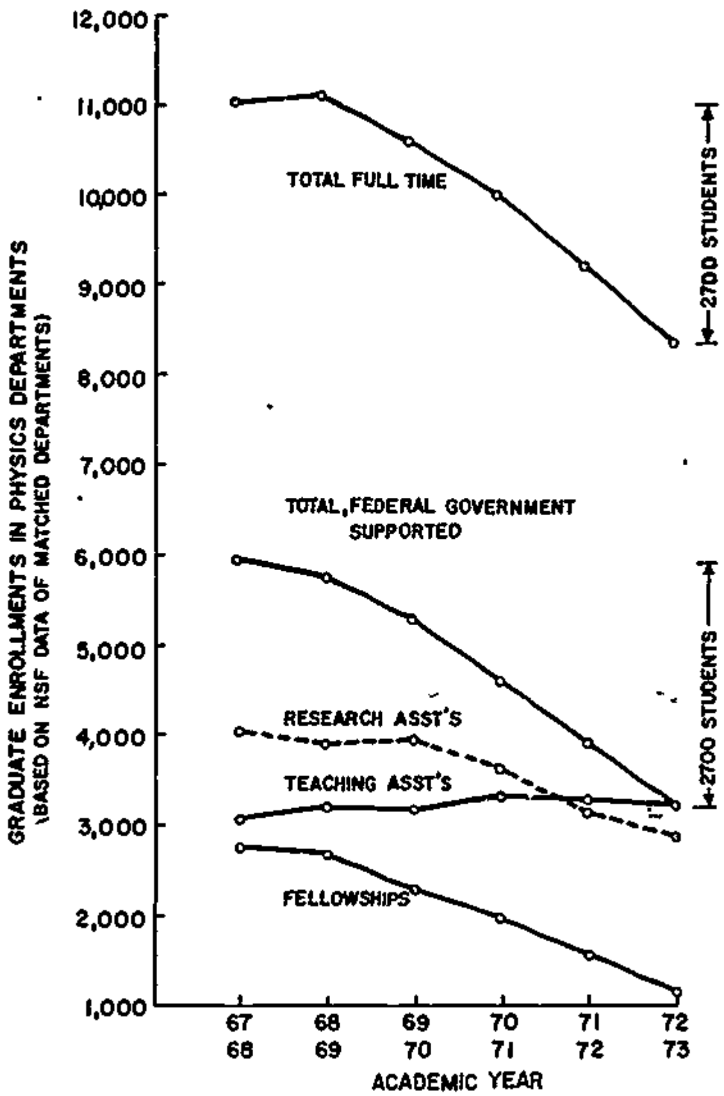
Figure 6.1
Bachelor of Science Degrees in Physics
Per Year, 1954-1970



The connection between enrollment figures—often used as the measure of student motivation—and financial support, is unequivocal. We first consider that connection for physics alone, then consider all graduate departments of science in order to show the effects of the massive reductions, in government fellowship funds specifically, on graduate enrollments, and to see how graduate schools have used what flexibility they have to soften the impact of those cutbacks.

Graduate school is a special market place with inertial forces which moderate rapid changes. But Government cutbacks of student support have been so great and pervasive that institutions have been unable to absorb much of the impact; the result has been a one-to-one correlation between the decline in government support and the decline in student enrollment. To demonstrate that correlation, consider Fig. 6.2, which shows the enrollments, according to type of support, for physics graduate students for the years 1967-68 through 1972-73. Overall, there has been a decline of 2,703 full-time graduate students. There has been a corresponding decline of 2,701 full-time students supported by government sources. Not only the magnitudes, but the rates of decline match. Can anyone doubt that Government support is a main driving force behind graduate enrollments and hence graduate education.?

Figure 6.2
Enrollments for Graduate Students for Years 1967-68 through 1972-73, as Related to Government Support of Students



Source L. Grodzins, based on NSF data

To see the effects of the reduction of fellowship support in all sciences, not just in one discipline, we present, in Table 6.1, the first year and total enrollments (full-time) by type of support, for FY 1969 and FY 1972, for all (matched) graduate departments and for engineering, physical sciences, and life sciences separately. The total number of first-year graduate students declined in those four years by 4,532; fellowship support declined by 3,953. The total student body declined by 4,951 students, much less than the precipitous drop of 11,523 supported by fellowships, most of which were Government supported; institutional funded fellowships actually increased. Teaching assistantships, which dropped for entering students, increased for all students. The details for the different fields differ, but the explanations are similar.

Table 6.1

Some Comparative Numbers of Full-Time Graduate Students & Their Support for 1969 & 1972

	FY 1969		FY 1972		Change	
	1st Yr	Total	1st Yr	Total	1st Yr	Total
All Graduate Departments						
Total Students	43,677	129,332	39,135	124,381	-4,543	-4,951
Supported by Fellowships	11 241	37,286	7,288	25,763	-3,953	-11,523
Supported by Res. Asst.	5,880	27,690	5,988	26,713	+108	-977
Supported by Teach. Asst.	11,304	31,518	10,194	33,547	-1,110	+2,029
Engineering Graduate Departments						
Total students	10,943	27,659	10,622	26,562	-311	-1,097
Supported by Fellowships	2,769	7,216	1,953	4,647	-806	-2,599
Supported by Res. Asst.	2,075	8,058	2,408	8,253	+333	+195
Supported by Teach. Asst.	1,434	3,885	1,552	4,180	+118	+295
Physical Sciences Graduate Departments						
Total Students	7,970	29,318	6,513	25,776	-1,457	-3,542
Supported by Fellowships	1,652	6,797	870	3,834	-782	2,963
Supported by Res. Asst.	866	9,135	854	8,062	-14	1,073
Supported by Teach. Asst.	4,129	10,019	3,472	10,249	-657	+230
Life Sciences Graduate Departments	7,057	22,644	6,518	22,246	-539	-398
Total Students	1,762	7,580	1,142	5,384	-620	-2,196
Supported by Res. Asst.	1,356	5,175	1,290	5,271	-66	+96
Supported by Teach. Asst.	1,888	5,319	1,695	5,714	-193	+395

Source National Science Foundation

The Federal government supports students mainly through fellowships and research assistantships, while institutions support mainly through teaching assistantships and partially through fellowships. The reduction of fellowship support was direct and unmitigated. The loss of support for research assistantships was one of the consequences of declining research support. The response of the graduate schools to these reductions was also different. Research assistantships are largely under the control of individual professors who obtain a direct benefit from maintaining their numbers and who can do so in part, since contract funding has some flexibility. Similarly, teaching assistantships, under the control of the department, are needed to carry out service load functions, which have not diminished. Fellowship students, however, have no guardian angels other than those who seek excellence in student bodies. But excellence, though readily defended in the abstract, is poorly protected in the realities. By and large, fellowships are considered, by most departments and by most professors, to be the sauce on the meat, making the meal memorable and worth a side trip, but not essential for survival.

Given these market place forces, what happened seems clear. The response to the drop in fellowship funding at the first-year graduate level was simply no response at all. The universities took the loss and had fewer students; and much fewer outstanding students. (First-year reductions in enrollments for all graduate departments correlate not only over the 4-year span, Table 6.1, but on a year by year comparison as well). The loss of fellowship support of those beyond the first year could not be ignored and teaching assistantships were diverted from first-year support to second-, third-, and fourth-year students who had lost their support. Moreover, universities added 3,000 teaching assistants and increased their institutional fellowships by another 1,000. These measures have done much to offset the loss of fellowship support in those fields where research assistantship support could be maintained. When, as in many of the physical sciences, this was not possible, the total loss of students has been even greater than the loss of fellowships.

The overview sketched here is confirmed in the more microscopic examination; physics, Fig. 6.2, is one example. Government support, in particular fellowships, is a principal driving force at this time behind students going to graduate school.

To the question, "Why do other people keep enrolling in graduate schools when fellowships have just about disappeared?", Dr. Grodzins responded, saying that if the student perceives a poor market place, he will stay away from that market place. Further, the student perceives graduate school as a lot easier than working. If he can possibly get support, he will go to graduate school. He thinks that graduate school will increase his options. He cannot believe that more education is going to give him a less viable position in the market place than less education. When confronted with the choice of subsidized graduate education or an undesired job, he chooses the former. If the graduate support is not offered, he chooses the latter.

Kenneth E. Clark:

The trouble with tackling the motivation problem by looking at physics students is that we are dealing with students who know they can make it in physics. If they can get in, they will. These students tend to be absolutely secure so that if manpower studies are oriented only toward them, then a very important part of the total group will be missed. Dr. Walter Oi will speak later in the conference about the student who assesses the uncertainties associated with a given decision.

The pre-medical student's assessment of the future is very interesting. Many students in this group have a low probability of being admitted to medical school, yet they stay in pre-med programs because the expectancy is fully satisfactory to them; they play the game in spite of the fact that the odds are strongly against them. Further, as Dr. Gordon has pointed out, some of the pre-med's end up studying medicine in the Philippines, because they believe it is worth that kind of investment in order to get ahead. Part of our study must include a look at the calculus in which the student is involved as he tries to maximize his lifetime earnings and his lifetime satisfaction.

Lowell J. Paige:
Assistant Director for Education, National Science Foundation

I would like to point out some observations that have occurred to me in my review of student motivation and career choices. For individuals in elementary grades and even through the eighth grade, there appear to be no reliable predictors for future vocational choice. Note that the NSF program, Careers in Science, begins at the secondary level. In the elementary grades ability is not a vocational factor or predictor to any extent. Ability may predict that a pupil will go on to college, but it is not a predictor of the field of specialization.

For the high school years, anecdotal experience seems just the opposite of the facts: thus, there is a need for more research if programs are to be developed for the purpose of motivating students toward science. For example, there are several intriguing points in the literature on motivation which run counter to anecdotal experience:

- Urban schools (large schools) seem to have a higher percentage of students going into science than rural schools.
- High school courses, good or bad, do not seem to influence career choices.
- High school teachers have little influence on career choices.

The literature also shows that high school science students, as a group, have the highest abilities, and that mathematical knowledge has a high correlation with career motivation in science.

Another point to be noted is that as students move through their elementary, high school, and college careers in the physical sciences (and to a lesser extent in the biological sciences) there is a continual outflow of career choices, but hardly any inflow. This may be changing with more open schooling and more choices, but it would seem consistent with our intuitions. Another somewhat surprising point is that the one best indicator of career intention is obtained by asking the student directly what he wants to do. Perhaps one way to answer questions about manpower, then, is to ask students what they plan to do.

Going on to college seems to be influenced by the following variables: sex, general academic ability, parental expectations, and social class. Teachers and peer groups also have some influence on the level of education to be sought. At the college level, the significant variables which influence career choice are: sex, individual interests, aptitude, and father's occupation. Another influence is peer group interest, and this is definitely the case in the choice of science. Socio-economic status has little bearing on career choice at the college level. In the early years of the undergraduate level, there seems to be no distinction between choice of mathematics, physics, or chemistry. There are no predictors which distinguish among these three areas. A student who can go into one of these areas could go into either of the other two. Another matter which runs counter to anecdotal experience is that blacks seem to be no more underrepresented in science than in other fields, except perhaps engineering. A surprising point which runs counter to what we hear from the colleges is that if prior influences toward career choices are removed, colleges have no effect on career choices; that is, the particular college that one attends seems to have no influence on career motivation. Even in college, however, science requires high ability and a knowledge of mathematics.

One last comment, and that deals with manpower analysis and national policy. The colleges and universities are confronted with affirmative action. It is clear that any reasonable action on their part must depend on the available numbers of minority students. The supply is almost non-existent in engineering and only slightly favorable in physics, mathematics, and chemistry. With these obvious needs we are trying to introduce programs which will motivate minority students to go into basic research in the physical sciences. We are trying programs at high school, college and graduate levels, even though we do not know what the motivational problems are.

Lloyd M. Cooke:

Director of Urban Affairs, Union Carbide Corporation, New York, New York

I wish to respond with a few insights and experiences which relate to the problems that face industry in attempting to establish realistic goals and timetables on recruitment and placement of minorities in science and engineering. There is a critical problem with regard to the supply of minority engineers. Last year there were only 400 to 450 minority engineers among the total of about 40,000 graduating engineers. With large companies such as IBM, Union Carbide, DuPont, Standard Oil of Indiana, etc., competing for these minority engineers, it is impossible to achieve our national goals of widespread placement at this time.

For example, at Union Carbide approximately 70 percent of the college B.S., M.S., and Ph.D. recruitment has been in the areas of engineering and science. There are just not enough women and minority graduates in these areas to enable industry to fully meet its affirmative action requirements.

The "role model" concept has been used in regard to the motivation of youth and is an important part of that motivation. Personally, however, as I have become more and more involved in minority and ghetto youth motivation I find that the problem goes beyond so-called "role models." Consider the implications of a different term, "zero factor" or "out-of-mindedness." For a person living in a society in which certain phases of that society are legally or otherwise excluded, one can survive only if he literally wipes out of mind the shortages or the lack of opportunities with which he is confronted. When I was growing up, building model airplanes, and deciding naively that I liked science and engineering and especially aeronautical engineering, my father (an architect) said to me, "Forget it!" This was my first lesson in wiping something out of mind.

Later I went into science, initially with medicine as an objective. In a pre-med program I found I liked chemistry, and with calculated risk decided on industrial chemistry. This is an anecdotal story, but I am now convinced that in working with minority youth it is essential also to have role models. It is also important to get youth into laboratories and industrial operations as early as possible during their high school years. For two years, Union Carbide has had a fairly successful program in its Nuclear Division at Oak Ridge. This is called a pre-co-op program, and interested Appalachian white, Indian, and black high school youth are brought to Oak Ridge; their teachers must indicate that they have potential for work in science or mathematics. The students are then located in laboratory groups or plant groups, as safety rules and laws permit. We began the first year of the program with ten students; the second year there were fifteen. As you might expect, these students have a tremendous impact on their peers when they return to high school. At one school, a student was talked into accepting a summer position the first year of the program. The next year there were eight or nine applicants from the same school, and of this group, no more than three had been tending toward mathematics or science as a possible career choice.

Another more general program comes out of a street academy operation in the Peter Stuyvesant ghetto district in Brooklyn. This is a program exclusively for youth who have failed to make it in the public school system, but who have sufficient interest in what is going on at the street corner school to become involved. Some 350 students have completed the program since its beginning seven years ago. Of these, 85 percent are either in college, gainfully employed, or in vocational training.

A key ingredient of this street academy program is a specific set of projects designed to demonstrate the relevance between an education and one's options and opportunities in life. In other words, the program attempts to remove the "zero factor." It is appalling to learn, and be reminded consistently, that most of these youth have not discerned that education is relevant to later opportunity. Even if they have been told, they do not believe that such a relationship could exist.

General Discussion

Following the panel presentation, comments, questions and responses were offered on a variety of topics related to the black experience, motivation and influence on career choice quality of Ph.D.'s, and departmental traditions with respect to support of students. Particular points were made as follows:

- It is time that we deal more carefully and consistently with information which we hope will affect the behavior of young persons. But the "we" has to be a collective; it isn't a single agency of government, and it can't be a single source speaking. Some black youth receive or perceive information which says that certain occupations are not open to them, while at the same time other sources are trying to say that these occupations *are* open. Young people are tested against a total system. Part of this test is their competence, part is their acceptability, and part may be accidental opportunity.

- There has been a rather striking change in the major field of study of black male students. There have been a number of programs at Southern black colleges to reorient students away from teaching careers. The percentage majoring in business administration and accounting has, as a result, significantly increased. Engineering enrollments have gone up a little. Even though more and more black students are going to Northern schools, a full forty percent still attend Southern black colleges. More Federal money should be spent for developing strong engineering programs in black colleges. There are now six black colleges with accredited engineering programs.

- A recent article in the *New York Times* reported that black kids at Evanston High School, a very good high school, had more or less segregated themselves and apparently were dropping out because of zero motivation to pursue an academic career. It seems that family environment and peer group pressures dominate everything else. Unfortunately, those things that can be brought to bear against these basic pressures, through counseling and anything else, are fairly superficial! Dr. Cooke replied, "Right now it's not hip or cool for a black to be with the man's system." Black students in the street academy system had been in the group that dropped out partly because of peer pressure, yet when these same youth are exposed to the fruits of academic success, they see a relevancy. They can go back into the public school and do well.

  Hugh Folk* noted a similar drop-out with British working class children. Welsh students are not motivated toward academics either; peer group pressure begins at a very young age. The very strong British class differentiation seems to account for these attitudes. Scottish children, however, are of a different tradition.

- Robert H. Dicke** presented an illustration (Figure 6.3) which shows comparisons of natural science doctorate awards to other doctorate fields plotted as a function of time. Two events might be expected to influence the curves: one, the beginning of federal fellowship support in 1946 to scientists; and the other, the space program. Also during this period beginning about 1946, science faculty were being better paid relative to non-scientists.

For the purpose of the aggregated figures, engineers are regarded as scientists and social scientists are classified as non-scientists. Figure 8 shows that the data from 1920 through 1970 plots essentially on a straight line with a standard deviation of no more than 10 percent from the mean in that whole period of time which encompasses both the depression and World War II. Apparently then, so far as these aggregated numbers show, various economic factors have not appreciably affected the motivation of students toward choice of science versus non-science degree programs, even though there are all sorts of reasons for the ratio to rise.

- In order to understand the student motivation which led to the almost constant ratio described above, an analysis of cohort data on file would be required. The data are available, but they have not been analyzed in terms of student perceptions and motivations. Existing longitudinal data sets such as that available from National Merit Scholarship surveys and Project Talent should be examined with reference to very explicit questions such as have been raised in this discussion.

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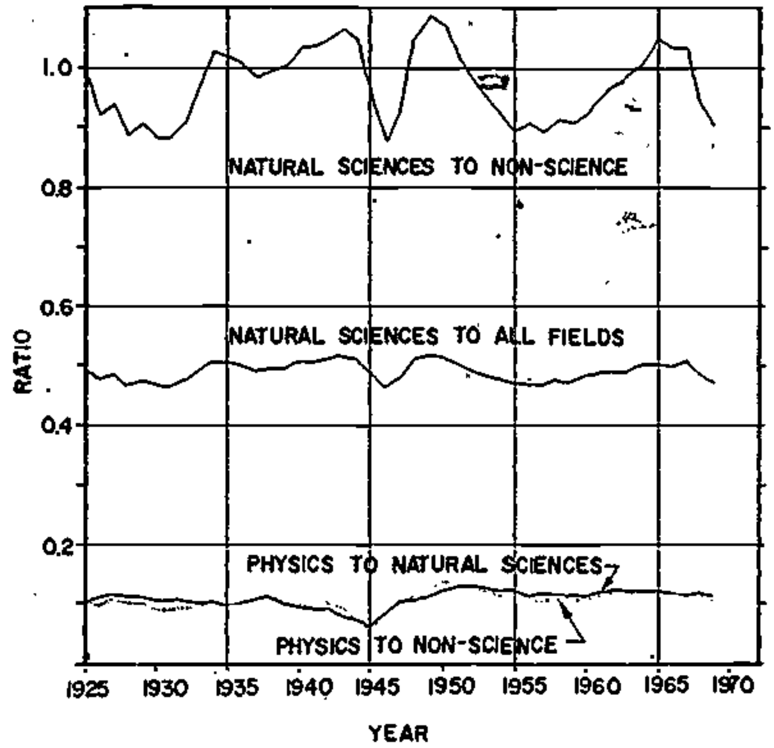
* Director, Center for Advanced Computation, University of Illinois

** Cyrus Fogg Brackett Professor of Physics, Princeton University

Figure 6.3
Comparisons of Natural Science Doctorate Awards to Other Doctorate Fields, 1925-1969



SOURCE: R. H. Dicke from "Manpower Demand Based on Need rather than Demand for Science" (NSB-72-136)

- Dr. Grodzins commented that at MIT it is not possible to predict what majors the entering classes will choose. Students are admitted on the basis of mathematical and scientific aptitude; 20 percent want to major in mathematics, 25 percent in physics, but the fact is that once started, students change fields and there is no way of predicting that. Dr. Clark responded that it appears that the fundamental motivations which influence career choice are relatively stable over time. There appears to be an orderliness of motivation over a period of time. This orderliness is heartening, since so much is unknown about the pressures which lead people to career choices, and about the degree to which those interests are intrinsic in the individual—so much associated with successes in some activities and failures in others that they can't be changed under any circumstances.
- What attempts, if any, have been made to study Ph.D.'s five, ten, and twenty years out of school in terms of their motivation for career choice? Dr. Clark answered that there have been such studies, but that

none are particularly fruitful. It appears that the proper kinds of questions to ask are those which ask the subject what he likes to do; preferences seem to correlate with actual career decisions. Questions about motivation, as such, don't work very well. For example, there may be nothing in common between psychologists who experiment with cats, or wire up monkeys, or watch the lever-pressing of rats, or counsel patients, or work in the ghetto, or go into school systems except that they wanted to do something to make human beings better.

- In regard to the study of Ph.D.'s as rated by the quality of the degree, examination of the period of the early to mid-1960's shows that the quality of students applying to medical schools dropped, while the quality of students going into the sciences rose. Further, when fellowships were cut, graduate enrollment at the prestigious schools dropped, so there are trends which reflect back on quality of the degree.

- Certain disciplines have a tradition of not admitting graduate students unless they can be supported, and there are departments at some schools in which 100 percent of the graduate students are supported. For these situations a loss in support means a cut in enrollment. On the other hand, there are departments without such a tradition; they may support only 25 percent of their students. This is just one of the irrationalities of the educational system.

7. 1972, 1980 and 1985: Science and Engineering Doctorate Supply and Utilization, Discussion of a Draft Report

This chapter is based on Dr. Falk's oral presentation, the questions and discussion which followed, and on the draft of his paper.

Charles E. Falk:
Director, Division of Science Resources Studies
National Science Foundation

NSF is in the process of revising its previous two projections of science and engineering doctorate supply-utilization relationships. We are in the midst of developing this latest projection, so this review illustrates some of the soul-searching which goes on while one is trying to produce credible projections.

In 1969 we developed projections of the supply and utilization of science and engineering doctorates. At that time we decided that we would review such doctorate projections on a regular periodic basis because of the potential of rapid change of inherent factors. In 1971 we produced the initial revision of the doctorate projections, incorporating new data and improving the methodology. Right now we are well into our second revision which has reached the following stage: we have revised the methodology and this new methodology is described in the draft paper. I want to emphasize that this is still a very tentative methodology because, as will be seen, some aspects turn out to be logical but not feasible with existing data; other elements of the methodology should probably be still improved even for the current projections.

Let me start out by mentioning a few of the new features of our current projection effort. Obviously, we now have additional data for three more years. This is especially important because when we made our last projections in 1971, it was clear that the technical manpower situation in this country was in the middle of a period of transition. At that time, demand and supply were at best in equilibrium, as compared to the shortage situations existing during most of the sixties. Furthermore, there were already strong indications that we were headed for a lengthy period of disequilibrium. The new data seem to confirm this. Another important change is represented by drastically new R&D expenditure projections which have been incorporated into our calculations. Our approach to academic employment is also different, as is our approach to projection of non-academic, non-R&D utilization.

We also have new base data from which to start our projections. The 1969 base, which was used in our last projections, had to be built up from a variety of surveys of different respondents and methodologies. This time, we have data that is based on a single survey. This information is the first product of one of the components of the new *NSF Manpower Characteristics System* which took the place of the *National Register*. I am referring to a new survey of U.S. science and engineering doctorates which is carried out for us by the National Research Council. Finally, we have extended our projection period to 1985.

These are some of the changes. I should also point out that there is one feature which we have kept the same. We are still only addressing ourselves to total areas of science, such as the physical sciences, and not to particular fields, such as physics or chemistry. It is not that we are unsympathetic to the need for highly disaggregated forecasts; we recognize that need. But we also recognize that interdisciplinary mobility is an important factor, especially when one looks at an individual discipline. We still know so little about this phenomenon that we believe that disaggregation of forecasts beyond the broad areas of life sciences, physical sciences, engineering, mathematics and social sciences will not be very meaningful.

Methodology

We have tried to use two different frameworks for these projections. One we call the basic model. It essentially extends recent trends. It assumes that past patterns will remain pretty much the same or follow trends similar to those observed primarily during the last five years. Many of these recent changes have been quite abrupt. Since we still do not really know whether these changes are of a long-term nature, we dampen them by basing our projections on the last ten years but giving twice the weight to changes observed during the last five years. The selection of a five-year period for this double weighting is not arbitrary, since it represents the period during which this system started to deviate from previous long-range trends.

Our market model modifies the basic model by incorporating some changes which could be expected from market interactions, namely, reactions of both demand and the supply to imbalances between these two features of the manpower system. In other words, if the utilization-to-supply ratio is less than 1 then our market model tries to reflect this. Typically, we show the effect on demand through a parameter we call enrichment, an increase in the ratio of doctorate to total scientists and engineers. Wherever possible we use actual data to determine future enrichment trends in the hiring of new scientists and engineers in various sectors of the country. Generally, since our basic models indicate relative surpluses, we increase the doctorate to total ratios. That is why we call it enrichment. This aspect of the market interaction tends to reduce manpower imbalances.

However, there are also negative market demand impacts due to factors which are responsive to markets other than the manpower ones. For example, consider the financial difficulties which universities are experiencing. If these will persist, as we assume, they will very likely have the effect of increasing the ratio of students to faculty. This, of course, will have a negative effect on the demand for academically employed doctorates.

On the supply side, these market effects would be reflected in either increases or decreases in the number of students that will obtain science or engineering degrees. I will discuss this feature later in more detail.

I should point out that even our basic model really incorporates some implicit market response components. Since our projections place special weight on the trends of the last five years, when the supply had already begun to react strongly to imbalances of the market, we are really using a static or non-recursive market approach. I will discuss later our attempts to convert this into a dynamic or recursive approach.

While our basic methodology might sound somewhat mechanical, it is not mechanical at all. For example, when we look at the relative decreases in new doctorates which are occurring now due to market imbalances, we do not just blindly assume that they will continue into the future. Rather, we examine the factors involved and make a judgment.

Our method is one of several which has been called the constant coefficient method. This is a little puzzling, because our coefficients do not necessarily stay constant. On the other hand, I would be the first to agree that our method is certainly a simplification of some of the undoubtedly more realistic, but up to now only theoretical, dynamic market models about which you will hear more later on in the conference.

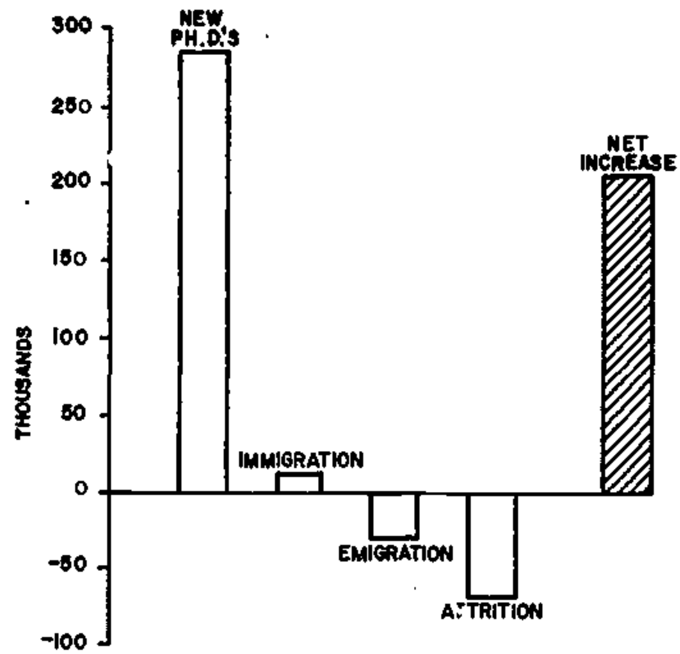
Supply of Doctorates

It may be useful to talk about supply and get an idea about the relative magnitude of the components. Essentially four elements are considered: the production of new Ph.D.'s, immigration, emigration, and attrition of the base (Figure 7.1). Attrition is a relatively important factor, but it is completely outweighed by the production of new Ph.D.'s. We have revised our supply model somewhat from the one we used for the last study (1971).

Science and Engineering Doctorate Degrees. The *basic model* consists of actual data and projections to 1985 of five phases of the higher education process: entrance into college, acquisition of baccalaureate degrees, entry into study for an advanced degree, then to the earning of Ph.D.'s, and the magnitude of total enrollment for advanced degrees. Trends are taken by sex only up to the entrance to college. After that, we collect and develop information by sex and by major field. What we do essentially is look at continuation rates in this process and the trends which have occurred. Half of the 18-year-old population went to college in 1970, 15 percent are likely to obtain science and engineering baccalaureates, 4 percent will probably enter into graduate science and engineering study, and 1 percent of the group will obtain a Ph.D. degree in those areas.

There are a variety of problems which should be mentioned. For example, assumptions about the ratios of first-year graduate students completing the Ph.D. degree may not be correct. For a long time that proportion has stayed constant, but in the last two years it has decreased markedly. As Allan Cartter and others have pointed out, some of the reasons for this change have clearly been one-shot phenomena, such as the discontinuation of the draft. However, other reasons, such as the response to a labor market which was not very favorable in the very early 1970's when these students were in the middle of their graduate programs, could be of a more enduring nature. Now, the dilemma is this: even if labor markets will continue to be somewhat unfavorable, will students continue to react the way they have over the last four years? Or was there a one-time adjustment when we passed from a very favorable labor market to one which was not so favorable? We cannot ignore the recent changes. What we have to decide is whether we should extrapolate the trend of the last two years over the next fifteen-year period, or whether we should consider it as a one-shot phenomenon and ignore it, and keep the doctorate-to-first-time-graduate-student ratio constant at its last value.

Figure 7.1
Incremental Science and Engineering Doctorate Supply, 1972-1985

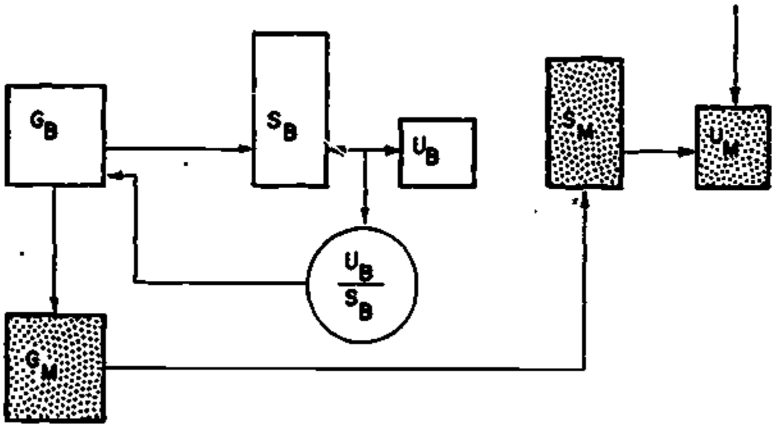


SOURCE: National Science Foundation.

As for the market aspects of our supply model, I think that probably everyone here is in agreement that market factors play an important role with respect to supply. We tried to incorporate a market feedback loop based on the supply-to-utilization ratio derived from our basic model. This feedback factor was to be applied to the percentage of baccalaureates entering graduate school. Figure 7.2 shows how this model would work. We start with the basic utilization and the basic supply. We then take the ratio of the two and use it in the feedback equation shown in the chart. G represents the percentage of baccalaureates that will enter graduate school in the basic model. This market graduate entry ratio GM, resulting from application of the feedback factor, produces a modified number of new Ph.D.'s and thus a revised supply SM. This in turn produces a change in utilization, because fewer graduate students mean fewer Ph.D.'s employed in academia. This adjustment process can go on ad infinitum. However, we planned to use only one cycle.

We realize that this feedback equation is not valid over the full range of U/S because with zero utilization the expression blows up and becomes infinite. However, this should not be bothersome since in real life a very small U/S is very unlikely.

Figure 7.2
Market Feedback to Supply (one-stage)



$$G_M = G_B - K\left[\left(\frac{S_B}{U_B}\right)^n - 1\right]$$

B - BASIC

G - $\frac{\text{ENTRIES TO GRADUATE SCHOOL}}{\text{BACCALAUREATE RECIPIENTS}}$

M - MARKET

S - SUPPLY

U - UTILIZATION

SOURCE: National Science Foundation

However, we experienced a more serious problem. For practical purposes, we have only two data points, namely, data points in the late 1960's when the ratio of utilization to supply was 1, and one in the early 1970's when this ratio had slipped. This then meant that if we were to use the model in our computations, we had to assume the feedback to be linear. That did not work out when we put actual numbers in the equation. It became very clear that a linear feedback loop was too strong. I believe that with an exponent n less than 1, one can have a workable feedback loop with reasonable results. However, any choice of exponent at this time would be completely arbitrary. Thus, at this time, with our limited data we will be unable to use this feedback concept in our calculations. In three or four years when we have more data points of G under various U/S conditions, we can probably get a reasonable fit to the feedback equation and use it in actual projection calculations. This experience illustrates a point which should be kept in mind. It is frequently much easier to build theoretical models than to apply them.

Utilization in the figure represents the number of scientists and engineers that are engaged in "science and engineering profession." What is excluded are those who are employed in activities which do not necessarily use the skills to which they trained. This is not necessarily unemployment. It includes those who are employed outside of science and engineering. It is the total of all scientists and engineers available at a given time minus those that are not working in science and engineering.

Immigration. Until the rapid growth of U.S. graduate education after World War II, immigration represented a large share of this nation's doctorate labor force. These doctorates are projected in both models to continue to immigrate at the same level estimated for Fiscal Year 1973, which is considerably lower than in previous years due to changes in immigration regulations in 1971.

Emigration. Not all doctorate recipients from U.S. schools are added to the U.S. supply. About 15 percent of the science and engineering doctorate recipients in the 1971-1972 academic year were not citizens of the U.S., and nearly 11 percent of the recipients indicated they expect to be employed in another country upon completion of degree requirements. Since these projections are approximately the same as that of previous years, our projections continue the 1971-1972 rates.

Attrition. This is ascribed only to death and retirements, and was computed for the total doctorate population by five year age groups and for each scientist/engineering field. Both men and women were assumed to exhibit the same patterns of attrition.

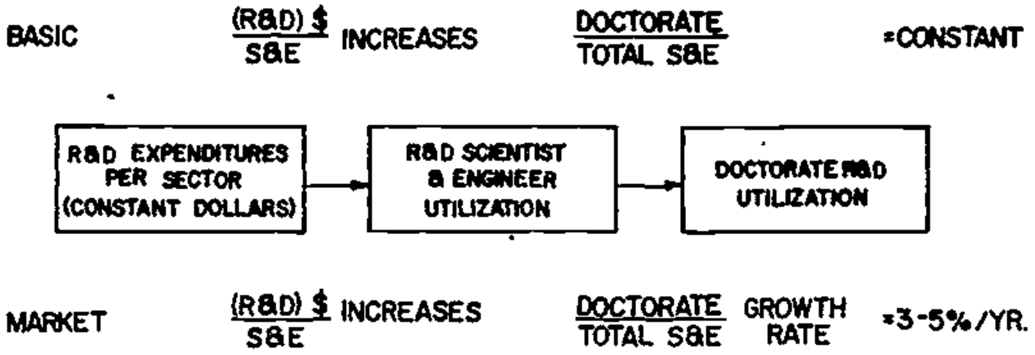
Utilization

As in the last NSF study, market activities are divided into the three functional areas in which scientists and engineers perform—R&D, academic teaching, and other. The "other" category includes those engaged in non-academic, non-R&D activities which still utilize their skills as scientists and engineers, including production, consulting, etc. The functional distribution of science and engineering doctorates in 1972 was: 38 percent in teaching, 47 percent in R&D and 15 percent other. Total science and engineering employment has been projected by work activity in relation to projected changes in economy and enrollments in colleges and universities.

R&D Activities. We start with a projection of R&D expenditure (Figure 7.3). Last time we used a fairly simplistic R&D funding projection based on GNP. We simply projected an R&D expenditure to GNP ratio to 1980 and then calculated R&D expenditures from a BLS projection of GNP. I am increasingly convinced that this R&D to GNP ratio is not a very useful or even meaningful concept because these two parameters are not necessarily related. Certainly one can see this from recent time trends of this ratio. It has dropped from 3 percent in the mid-sixties to its current value of 2.4. If one extrapolates the R&D funding/GNP ratio to 1980 and 1985 and then uses projected GNP figures one gets a ridiculously low figure for future R&D expenditures.

There are two, more sophisticated forecasts of R&D expenditures available now. Both are based on review of the behavior of R&D expenditures in different sectors of the economy and attempt to relate these expenditures to other parameters, such as sales in industry. We have used these new R&D expenditure projections; it should be pointed out that they indicate considerably lower 1980 R&D expenditures than those which were used in our previous projection. Having established expected future R&D expenditure levels, we translate them into R&D scientists and engineers by using R&D cost per scientist data. In doing this, we assume that the cost per R&D scientist and engineer will continue to increase along recent trends which have been fairly well established. We finally move from total R&D scientists and engineers to R&D doctorates by using established numbers and trends of ratios of these two parameters. In the market utilization model we use similar procedures. However, while in the basic model we assumed the ratio of doctorates to total scientists and engineers to remain constant, in the market model this ratio for the newly hired doctorates grows by 3 to 5 percent per year, depending on the sector. The 3 percent growth rate for industry was based on an Industrial Research Institute survey. This enrichment assumption is based on the projected easily-available supply of doctorates who are expected to get some of the jobs presently held by non-doctorates.

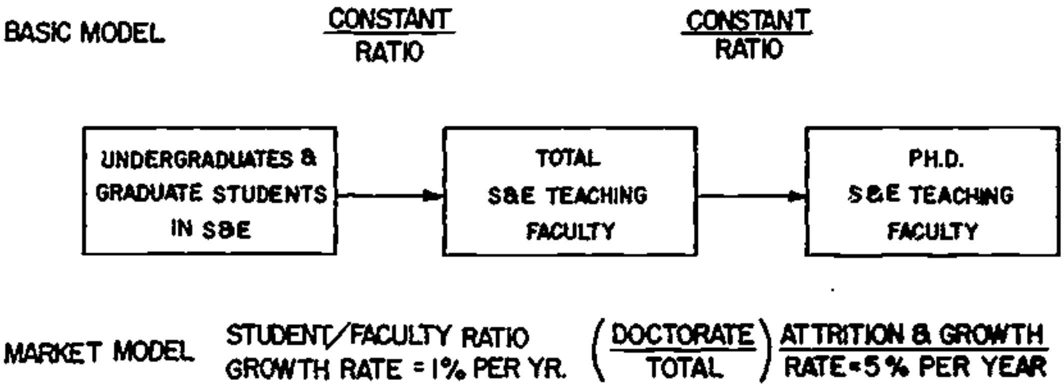
Figure 7.3
R&D Utilization Model



SOURCE: National Science Foundation

Academic teaching. With respect to teaching utilization, an approach is used based on projected science and engineering enrollments and student-faculty ratios (Figure 7.4). In the basic model we assume that the ratio of students to faculty would essentially remain constant and the ratio of doctorate faculty to total science and engineering faculty also remain constant. In the market model both ratios are increased. Two-year colleges and four-year colleges and universities are examined separately because not only are their growth rates very different, but their utilizations of doctorates are different also.

Figure 7.4
Teaching Faculty Model



SOURCE: National Science Foundation

The procedure for deducing teaching utilization differs from previous methods, yet it needs still more modification. For example, if the necessary information on teaching load factors can be obtained, we will try to develop separate faculty-to-student ratios for graduates and undergraduates so that service load aspects of different disciplines are given appropriate consideration.

Results

Numerical projections are not ready to be presented even in preliminary form. As indicated before we will still be making improvements in the doctorate production and teaching utilization parts of the model and will also review all other areas of our methodologies. However, there is a simple approach that gives an indication of what our projections are likely to indicate (Figure 7.5). This will also illustrate that one can come to certain conclusions without necessarily going through a very fancy model.

Figure 7.5
Rates of Growth of Supply and Utilization (percent per year), 1972-1985

SUPPLY	
NEW DOCTORATE ADDITIONS TO LABOR FORCE	+7.0
ATTRITION OF EMPLOYED LABOR FORCE	-1.6
NET MIGRATION	-0.4
TOTAL SUPPLY	+5.0

UTILIZATION		
RELATED PARAMETERS		
R&D FUNDS (CONSTANT $)	+1.4	
UNDERGRADUATE STUDENTS	-0.5	
GRADUATE STUDENTS	-0.9	
DOCTORATES	BASIC	MARKET
R&D	+0.6	+2.7
ACADEMIC TEACHING	-0.5	+0.7
OTHER S&E ACTIVITIES	+3.9	+6.5
TOTAL UTILIZATION WEIGHTED AVERAGES	+0.7	+2.7

SOURCE: National Science Foundation

Consider the following scenario. With respect to supply, the new doctorate additions to the labor force are of the order of 7 percent a year. This does not mean that the number of doctorates produced per year will increase by 7 percent.

Rather, it indicates that if one takes the total number of doctorates produced per year and compares this to the total number of doctorates existing at that time, the ratio is 0.07. This annual new doctorate production figure comes out of our basic supply model. It is not too different from what Allan Cartter is projecting now. Attrition of the labor force on average is about 1.6 percent a year. Net migration, is another parameter affecting supply and amounts to about 0.4 percent per year. Supply, then, is base plus new doctorates minus attrition, minus net migration. If one combines all of these factors one then obtains a likely increase of the doctorate supply of the order of 5 percent per year.

Attrition does not reflect under-utilization but is simply due to death and retirement. The net migration is actually a net emigration and reflects the fact that a number of students who come to the United States to get their Ph.D.'s return to their own countries at the end of their graduate training, and thus are removed from the system.

With respect to utilization, first consider some related parameters. R&D funding shows an average increase of about 1.4 percent in constant dollars per year. In any case, the increase is relatively modest, and this relatively modest increase represents one major difference between the present study and the last one when a 4 percent increase in constant dollars was shown.

With respect to teaching utilization, again using our model, undergraduate students are expected to decrease on the average by about half a percent a year. Most of this decrease is expected to happen in the first half of the 1980's. Graduate students would actually be decreasing a little more rapidly. These decreases in students are not just due to demography because the demographic effects only come into play toward the end of the fifteen-year period. They reflect some of the trends discussed earlier, such as fewer students going to college and fewer going into graduate school.

What does all this add up to in terms of utilization? The chart suggests that R&D utilization increases even less than R&D expenditures because the cost per R&D scientist and engineer is expected to continue to increase. In academic teaching, we project fewer doctorates in 1985 than there are now. This is not so completely out of line if one considers Allan Cartter's report that only about 34,000 faculty in all fields will be hired in the 1970's when things will still be going relatively well as compared to the early 1980's.

Finally, there is "other" science and engineering utilization, which represents our projection of the number of Ph.D.s who are likely to be engaged in science and engineering activities other than R&D or teaching. This is the area we expect to increase most rapidly.

Now, all of these combined give a 0.7 percent per year increase in utilization according to the basic model. The market model shows a projected utilization increases at a minimal rate of 2.7 percent. Again, remember that there are two factors at work in the market model. One is enrichment—more Ph.D.'s per total scientists and engineers. However, in academia, we project the student to faculty ratios to increase. Since a good many Ph.D.'s are employed in academia, this aspect of the market model causes the number of doctorates employed in higher education to go down.

So then if one has, at best, a 2.7 percent annual increase in utilization and a 5 percent increase in supply per year, one obtains a 2.3 percent annual imbalance. Compounded for fifteen years, this produces quite significant imbalances.

Of course, one should look at alternative assumptions and test the sensitivity of this model. We have as yet not done this in detail. But it can be illustrated that really major changes would be required to bring the system into balance. Considering one factor at a time, it would practically take a doubling of the project R&D funding growth rate coupled with market enrichment conditions to erase the projected imbalance. At current inflationary rates this would mean annual increases of at least 10 percent in current dollar terms. Or the average doctorate production rate would have to be reduced by over 30 percent from that of today to produce a balance under market conditions. Since the doctorates for the next few years are already in the academic pipeline, this 30 percent reduction in average rate would imply a considerably greater reduction by 1985. One could, of course, have combinations of these factors. Even then, however, the magnitudes of the changes required are so large that realization of balance is somewhat unlikely. Our conclusion is that the outlook is fairly grim.

General Discussion

Following Dr. Falk's presentation a number of questions and comments were offered by the participants. The sense of the discussion was as follows:

- With regard to the term "R&D," how sensitive are results, not just to the standard NSF definition of the term but to the dynamics of the definition in the sense that the definition does not include activities such as manufacturing engineering which is comparable with product engineering and development in some industries? The reply was that the manufacturing engineer is included in the "other" category which is derived by taking the Bureau of Labor Statistics projections for total scientists and engineers, subtracting them from those which come from the projection for R&D and teaching, and then deducing the number of Ph.D.'s from existing Ph.D. to total ratios using an enrichment growth rate of 5 percent per year. It is this "other" component which shows the largest increase, and it is in this category that the manufacturing engineer, the production engineer, the control engineer, and the sales engineer, etc., are included.
- Do you include a factor for energy R&D? A factor as such has not been worked out, although extensive studies of manpower impact are underway. The governmental R&D funding for energy is about $2 billion a year in current dollars as compared to a total R&D budget of the United States of $30 billion (about 6 percent). There exists a crude estimate of the possible manpower impact of this program. In the Dixy Lee Ray report (AEC)[1] it is stated that the proposed energy R&D program would use about 5 percent of the total number of scientists and engineers. But we do not know what the impact of an energy crisis would be on the non-R&D scientist or engineer. If we opt for more exploration, new oil rigs, coal gasification plants, and so on, more scientists and engineers will be required. On the other hand, if we experience future shortages of energy, this could have an opposite impact in such areas as the transportation industry.

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[1] *The Nation's Energy Future*. A Report to Richard M. Nixon, President of the United States, submitted by Dixy Lee Ray, Atomic Energy Commission; December 1973

- Are there any inferences to be drawn from the projected gap between supply and utilization? Yes, the fact that relatively few people are going to get a chance to be active in R&D or academia means that the new doctorates should be prepared for other things. This leads us to topics like changes in value structures, reduction in overspecialization, and the need for more generalists who can move from one type of activity to another, etc.

- Has a model been attempted which is based on the demands for raw materials substitution? For example, in the United Nations a debate is going on with countries that supply a whole variety of raw materials, stemming from the recent oil embargo situation. This suggests that, in terms of utilization of raw materials, there may be a shift to technologically-derived substitutes. Perhaps such a module could be inserted in the model. It could have a large impact. Such a model has not been attempted by NSF.

- Questions of impact arise in regard to major capital spending programs of private industry involved in energy. What, for example, are the effects of various kinds of capital investments? If such new capital investment consists essentially of reproductions of existing types of plants, then this might possibly imply much smaller utilization of engineers and scientists. On the other hand, if new technologies are to be used, then there would have to be large design and development programs. But if a new technology is in its operating phase, fewer scientists and engineers might be needed.

- With reference to a specific four-year, sixteen billion dollar capital spending program, one participant reported that most of this spending is to be in new technology which does not duplicate existing effort. The limitation seen is not on capital so much as it is on available scientific and engineering personnel, not only in chemical engineering but in a number of other disciplines.

- A question was asked about the carryover of the 2.3 percent of scientists and engineers who are under-utilized or not able to be absorbed in the market. That is, are they carried over to become a part of the supply in the following years?

  Since the model does carry over, it was suggested that this could be a deficiency in the model because of the fact that diffusion from R&D type activity or engineering activity into other activities is a substantially irreversible process. When a person leaves technical activity and takes on administrative activity or changes field, or whatever, at the age of forty-five or thereabouts, he is no longer part of the technology labor pool. It was pointed out that such persons would still be counted in the "other" science and engineer labor pool. The deficiency would only be in the number of people who have nothing to do with science and engineering.

- It was suggested that the numbers coming out of the models are concentrated or focused almost entirely at the interface between the universities and first use, and that it is important that this not be the pressure point.

  Counter to this was the idea that people going into higher education should be aware that there is a good chance that they will not be employed in academia. They may, nevertheless, be perfectly happy. Much of the unhappiness in the early 1970's came from the fact that expectations were not met.

Assuming then that there is some kind of pyramid distribution of excellence or quality in the science and engineering community when students are trained, then the substantial numbers of people who are near the bottom of that pyramid must be trained with a flexible career in mind. By the same token, if this transfer out of the science and engineering activity is concentrated at the lower levels of intellectual attainment where the largest numbers are found, then these projections do not have to put a large stress on research-oriented or development-oriented people.

- A final word of caution was offered by Dr. Falk who emphasized that the figures quoted are intended to give only rough indication of the situation. They do, however, suggest trouble, although a great deal of double-checking is still needed. Some of the assumptions and some of the coefficients may be changed. Nevertheless the numbers should give a feeling of the order of magnitude of imbalances which might be likely to occur.

The formal document prepared by Charles E. Falk for this session appears below.

1972, 1980, and 1985 Science and Engineering Doctorate Supply and Utilization*

I. Introduction

This study is designed to be a tool for planners and policy-makers. Hopefully it will contribute to an understanding of the processes by which part of the doctoral supply and utilization system operates and of the interrelations of the

*NOTE

The National Science Foundation is in the process of revising its previous two projections of science and engineering doctorate supply-utilization relationships. These new analyses will be published as an official NSF report. (Report was published as NSF 75-30, *Projections of Science and Engineering Doctorate Supply and Utilization, 1980 and 1985.*) However, as in the past, drafts of the report will be circulated to other experts for review and comments. This document was specially prepared for the April 1974 Science Manpower Seminar of the National Science Board. It represents the first review draft of the methodology and assumptions that are being used now to generate projected supply and utilization numbers for 1980 and 1985. The computations of these figures have not been completed at this time, but are expected to be ready for presentation at the seminar.

The report is the combined product of many individuals in the Division of Science Resources Studies. The main objectives of this document and its presentation at the NSB Seminar are the provision of information to Seminar participants and the development of constructive criticisms and comments for the improvement of the methodology.

system's components. It projects likely configurations of the supply and utilization of doctorates to 1985 and is premised upon a variety of explicit and implicit assumptions about the future. The nature of these assumptions make it necessary to preface this report with three *caveats* which should be borne in mind.

First, the projections in this report are set within a framework of specified economic growth and the established educational system. They assume a continuity of past trends and relationships (with a heavy emphasis on recent years) and therefore do not anticipate unforeseeable future discontinuities. Thus, while the projections involve attempts to create a limited number of scenarios that are most likely to represent the future, they are constrained by their environment.

Second, only the supply and utilization prospects of persons with science and engineering doctorate degrees are analyzed. While these prospects have been considered in relation to the overall situations for the total science/engineering work force, the implications for doctorate degree recipients should not be imputed to nondoctoral scientists or engineers nor to recipients of doctorate degrees in other disciplines (e.g., Ed.D., M.D., J.D., D.B.A., and Ph.D., in arts, humanities, law and business).

Third, the time frame of the study extends somewhat beyond the expected span of those students already in the higher education pipeline; thus, the results for the latter years of the projected period are more speculative than those for earlier years.

There are many scenarios of the supply and utilization of doctorates which could come to pass. All of these possible configurations were not developed. Instead, two major configurations were utilized. One, the *Basic* model, reflects past and present patterns of doctorate supply and utilization with special emphasis on recent behavior. A second, *Market-Related* model, takes into consideration imbalances between the projected Basic doctorate supplies and utilizations and adjusts both utilization and supply accordingly. These two models represent a range of possibilities into which doctorate supply and utilization patterns are likely to fall in the projected period.

This study is the third NSF report on the subject of the supply and utilization of science and engineering doctorates. The previous studies spanned the 1970's, terminating the projected period at 1980.[1] This study extends the horizon by five years to 1985. This report, however, differs from its two predecessors more significantly than simply extending the previously used methodology to a new time horizon or incorporating information on more recent trends. It uses a more fully developed model of Ph.D. production, a somewhat different approach to academic faculty projections, a more sophisticated R&D funding projection, and the previously mentioned recursive market feedback to student career decisions.

The late 1960's and early 1970's saw a levelling off of R&D funding and concurrent, relatively short-lived, unemployment increases for scientists and engineers. One product of these events has been an increased interest in the examination of the supply of and the demand for scientists and engineers. As a result, a number of projections have been developed by various authors. Some of these studies concluded that a surplus of new doctorates was imminent for the

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[1] *Science & Engineering Doctorate Supply & Utilization. 1968 80.* NSF 69-37. 1969; and *1969 & 1980 Science & Engineering Doctorate Supply & Utilization.* NSF 71-20, 1971.

1970's and early 1980's. Others have questioned the assumptions about the supply of doctorates, contending that the market mechanism would serve to reduce the supply in response to an unfavorable job market, thus decreasing and eventually eliminating the imbalance between supply and demand (or utilization).

Inherent in the projections are some basic premises that either tend to encourage or discourage the production or expanded demand for doctorates. Some of these premises are listed below. First shown are those that would foster an increase in the demand for or supply of new doctorates in the face of shortages of R&D and college teaching positions; these are called "inflationary factors," A second group encompasses those that tend to decrease the supply of or demand for new doctorates; these are called "deflationary factors."

1. Inflationary factors

a. A doctorate may still have a relative advantage over less educated contemporaries in the same field even if doctorate starting salaries remain higher than those of others. However, with an "oversupply" of doctorates, their salaries will tend to converge toward those of nondoctorates.

b. The doctorate degree constitutes a "ticket" to a special and frequently preferred professional or academic life style (regardless of economic considerations). This phenomenon is likely to continue.[2] It has been shown that this enticement can have a great impact upon the career and educational decisions of students.

c. Increasing educational requirements are being placed upon many jobs. Over the years the educational prerequisites of jobs increased as job content changed and as secondary and higher education became more universal. In the future the concept of "appropriate" utilization of doctorates may be broadened even further to include new activities in which extensive technical knowledge is desirable for the management and performance of non-research or non-educational activities. Thus, the doctorate degree may become a prerequisite for positions currently being filled by non-doctorates, in part because of the availability of doctorates and in part because of the increasing technical content of the positions.

2. Deflationary factors

a. In apparent reaction to perceived unemployment problems of scientists and engineers and other factors, such as disenchantment with technology, it has been noted in the past few years that students at all levels of education—secondary, undergraduate and graduate—have been less prone to select a major in science and engineering (excluding social sciences) than students of the mid-1960's. It is not known if this disaffection with the natural sciences and engineering is a phenomenon which will pass as employment opportunities improve and as new societal programs with technological inputs are created, or if it is part of a long-term movement away from these disciplines. Some recent anecdotal evidence indicates that this trend may be reversing itself.

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[2] E.g., Bailey, D. and Schotta, C., "Private and Social Rates of Return to Education of Academicians" in *The American Economic Review*, March 1972, and Notes to this article by L. Figa-Talamanca and J. A. Tomaske in *The American Economic Review* of March 1974.

b. In the early 1970's proportionately fewer college-aged persons have been entering college, possibly in response to the slowdown of job opportunities for college graduates. Projections of job opportunities indicate a potential surplus of college graduates in relation to available jobs of the type now being filled by graduates.[3]

c. College students will be discouraged from continuing their education to the doctorate level if: (1) the reduced growth (in comparison to the 1960's) in the demand for college faculty and researchers continues as expected; and (2) the level of earnings of doctorate degree holders approaches that of master's and bachelor's degree holders.

d. The expected decrease in the number of graduate students may necessitate an increase in tuition charges to support university costs. This will further hinder the opportunity for education and limit the number of students opting for the doctorate. This factor would be aggravated by reduced Federal support of graduate students.

e. Some students of the economics of education have come to believe that there may have been an over-investment in higher education in the past two decades in relation to the numbers and nature of employment opportunities that have become available.[4] This had led to some under-and unemployment of college graduates, especially in many less developed countries (LDC's). It may also have discouraged students from these nations that study in industrialized countries from returning to their homelands. Recognition of this oversupply of college graduates in the LDC's may have led to reductions in the numbers of their citizens sent to schools in the U.S. This has been reflected in 1972 enrollment data.[5]

It is not expected that all of the above-mentioned factors will prevail, but that each set will exert a countervailing force upon the other.

II. Summary of Factors, Methods, and Assumptions

Two sets of supply and utilization models for science/engineering doctorates have been developed for this study. The Basic Supply model incorporates past trends of doctorate production in relation to the college-aged population and propensities to enter and complete college and graduate study. The Basic Utilization model reflects current (1972) patterns of utilization of the doctorate labor force. The underlying rationale for the Market-Related models is that both supply and utilization of any labor force component respond to the marketplace.

The discrepancies between supply and utilization are expected to influence potential science/engineering students, enticing or discouraging them from entering graduate school programs leading to doctorate degrees. Thus the

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[3] Rosenthal, Neal H., "The United States Economy in 1985, Projected Changes in Occupations." *Monthly Labor Review*, December 1973.

[4] See Ivar Berg, *Education and Jobs: The Great Training Robbery*, Boston: Beacon Press, 1971, and Special Task Force to the Secretary of Health, Education, and Welfare, *Work in America*, Cambridge, Mass.: The MIT Press, 1973

[5] NSF survey data to be published as, *Graduate Student Support and Manpower Resources in Graduate Science Education, Fall 1972*

Market-Related Supply model incorporates a feedback loop from the degree of utilization of the doctorate labor force to the propensity of baccalaureates to enter graduate study and thus also to the number of doctorate degree awards. The Market-Related Utilization model assumes market-conditions to be reflected in job credential standards, which are likely to change in response to a greater supply of doctorates. This phenomenon has been experienced in past decades, first with respect to secondary school graduates and more recently, with respect to college graduates.

Several assumptions underly both models of utilization. Work presently being performed by doctorates will continue to be carried out by doctorates in the future. A second predication assumes that the preserve of the doctorate will increase, with new doctorates replacing non-doctorates in all pertinent activities. Especially in the Market-Related model, doctorates are expected to be employed more profusely in non-academic, non-R&D technical positions such as management, public administration and production. Finally, while some information on mobility among disciplines exists, because of the lack of dynamic information, it is assumed that mobility among science and engineering or non-science fields will remain constant during the projected period.

The following two tables summarize the major components, rationales and assumptions which form the foundations of the models. Other detailed methodological descriptions, including appropriate references, can be found in Chapter III. (As can be noted, the Magnitude and Sensitivity columns are blank; these will be filled in subsequently.)

Table 7.1
Summary of Supply Models

Factor	Rationale/Assumptions	Method	Magnitude	Sensitivity
1. *All college students* (Both models)	Males and females will continue to exhibit different behavior patterns. Different fields of study will exhibit different behavior patterns.	Separate projections were made at each stage of the model for individual fields of science and by sex. The only exceptions are the new entrants to college which were projected by male and female groups, but not by field.		
2. *Entrants to college* (Both models)	Parts of the college-aged population will continue to aspire to a college education for a variety of reasons, including the potential to increase their earning ability, cultural and social benefits, etc. Trends in the rate of college entrance of the college-aged population are projected to continue in a pattern based on the past decade, with trends of the second half of the period being given double weight.	Projections are made on the basis of population reaching 18 years of age in each year up to 1985. These projections are not dependent upon birth rates since the 18 year old populations to 1985 have all been born.		

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Table 7.1
Summary of Supply Models

Factor	Rationale/Assumptions	Method	Magnitude	Sensitivity
3. *Baccalaureate degrees awarded* (Both models)	Trends in proportions of college entrants continuing to the baccalaureate degree will follow recent patterns. The period from college entry to baccalaureate award is not equal for all entries. However, the time pattern for baccalaureate completion is assumed to remain constant over the projection period.	Future degree recipients are based upon entrants and proportions graduating within a given period of time. Each year's graduating class is composed of the cohort of the entering class assumed to graduate within the appropriate number of years. Trends of the past decade are extrapolated with double weight assigned to the last five years.		
4. *Entrants to graduate study* i. (Basic model)	Ratios of graduate school entrants to baccalaureates, by field and sex, will continue to follow patterns that have been established in the past.	Trends of the past decade, weighted double by the last five years, are extrapolated to 1985. Each cohort of baccalaureate recipients entering graduate study is assumed to do so within a constant time distribution. Each graduate school entry class results from the addition of the appropriate cohorts of baccalaureates.		
ii. (Market-Related model)	Potential entrants to graduate school are influenced by labor market conditions for doctorates during the same year.	The ratios of first time graduate school enrollments to science and engineering baccalaureates are reduced by a factor proportionate to the utilization : supply ratio projected from the basic model. The proportionality constants are derived from 1964-72 data.		
5. *Science/engineering doctorates awarded* (Both models)	Since the proportions of graduate school entrants ultimately receiving a doctorate were relatively constant during the past decade, they are assumed to remain constant during the projection periods. It is assumed that once commitment to enter graduate study has been made, student plans will not be influenced by future or present labor market conditions.	Generally, rates of awards to doctorate graduate school entrants of the mid-1960's were used without change. The same constant completion rates and time distributions of entry to completion were applied. The number of doctorates awarded each year results from the addition of the appropriate cohorts of each entry class expected to obtain degrees in that year.		

Table 7.1
Summary of Supply Models

Factor	Rationale/Assumptions	Method	Magnitude	Sensitivity
		No explicit allowances were made for changing patterns of foreign study entry to graduate school or time required for degree completion.		
6. *Immigration of foreign-trained doctorates* (Both models)	Immigration patterns reflect U.S. employment opportunities relative to those in other countries and U.S. Immigration regulations. Although immigration regulations have made entry of scientists and engineers more difficult since 1971, it is expected that Immigration will continue, but at levels abated from those of 1960's. It is also assumed that doctorates will continue to represent the same proportion of immigrants that were observed in the 1960's.	The levels of immigration, by field, experienced in the 1973 Fiscal Year were continued unchanged for the entire projected period, as were the shares of these immigrants assumed to have doctorates.		
7. *Emigration of doctorate recipients from U.S. universities* (Both models)	These primarily represent citizens of other countries returning to their homeland and are not influenced by U.S. labor market conditions.	Emigrants were projected to continue their 1966-72 absolute trends by individual field.		
8. *Attrition* (Both models)	Both men and women doctorates will exhibit death and retirement rates similar to those estimated for all men in the labor force. Although women, in general, have a weaker labor force attachment than men because of familial responsibilities, it is assumed that women doctorates will have as strong an attachment as all men because of their investment in their careers.	Death and retirement rates are applied to each 5-year age group of the labor force by field in each year. These rates are projected to remain unchanged throughout the projected period. They are directly derived from those published by the Bureau of Labor Statistics.		

Table 7.2
Summary of Utilization Models

Factor	Rationale/Assumptions	Method	Magnitude	Sensitivity
1. *Teaching Faculty in 4-year colleges and Universities**				
A. Enrollments and Student : Faculty Ratios (Both models)	Full-time-equivalent teaching faculty will be proportional to the number of undergraduate and graduate students taking science and engineering courses.	The graduate enrollment data were added to derived undergraduate science and engineering student numbers. The latter were obtained by assuming that the ratio of undergraduate students taking courses in each field of science/engineering to total undergraduate enrollments would be proportional to the science/engineering to total baccalaureate ratios.		
1. A. (cont.)				
i. (Basic model)	It was assumed that student: faculty ratios would remain constant at the 1972 level through the projected period.	Student faculty ratios were derived by dividing the sum of undergraduate and graduate students by the total teaching faculty. This procedure was carried out for each field.		
ii. (Market model)	Because of an expected continuation of financial pressures on academic institutions, the student : faculty ratio in this model was projected to increase.	Same as above, but student: faculty ratios were increased by one percent per year for the 1972-85 period.		
B. *Doctorate faculty*				
i. (Basic model)	Doctorates are assumed to continue to represent the same proportion of the teaching faculty as they did in 1972.	New doctorate employment is projected as a constant share of growth and replacement needs of the total science/engineering teaching faculty.		
ii. (Market model)	Doctorates are assumed to represent a progressively growing share of the teaching faculty because of the greater availability of doctorates and the desire of the institutions to upgrade the credentials of their faculties.	A compounded growth rate of 5 percent per year was applied to the doctorate to total ratio for openings due to the growth and replacement needs of teaching faculty for each year.		

*Faculty and students, unless noted, refer only to those in science and engineering.

Table 7.2
Summary of Utilization Models

Factor	Rationale/Assumptions	Method	Magnitude	Sensitivity
2. *Science/engineering Faculty of 2-year Colleges*				
A. Enrollments and Student : Faculty Ratios (Both models)	Total enrollments in 2-year colleges and technical institutes are expected to continue to grow faster than in other sectors of the higher education system.	U.S. Office of Education projections of unrollments were used and projected to 1985.		
i. (Basic model)	The total student to science/engineering faculty ratio was assumed to remain constant over the entire projected period.	The total projected numbers of students were divided by the student : faculty ratio to obtain the number of science/engineering faculty.		
ii. (Market model)	The 2-year colleges are expected to aspire to improve the quality of education they provide.	Same as above using a decrease in the student : faculty ratio of one-tenth of a student per year for the projected period.		
B. *Doctorate faculty*				
i. (Basic model)	Between 1969 and 1973 the rate of enrichment of these institutions' science faculties increased at an estimated annual rate of 6.6 percent. Two of the factors which may have attributed to this—the ample supply of new doctorates and the growing role of these institutions in providing the first two years of traditional undergraduate education—are expected to continue in the projected period.	A compounded growth rate of 6.6 percent per year was applied to the doctorate to total ratio for openings due to the growth and replacement of science/engineering faculties.		
ii. (Market model)	In view of the greater availability of doctorates, a higher percentage of doctorates are expected to be hired to fill faculty growth and replacement needs.	Same as above—with a 9.9 annual percentage rate of growth.		

Table 7.2
Summary of Utilization Models

Factor	Rationale/Assumptions	Method	Magnitude	Sensitivity
3. *R&D Doctorates*				
A. R&D expenditures and total science/engineering employment. (Both models)	The number of R&D workers is proportional to available R&D funds with cost per R&D worker continuing along past trends.	R&D expenditures are projected on the bases of component activity trends in each of the major sectors that finance R&D—Federal Government, industry and academia. Distribution of R&D funds to performing sectors are projected on the basis of recent trends. Total science/engineering R&D employment in each performing sector was assumed to be proportional to R&D funds, with allowances for changes in the costs per worker projected on the basis of past trends.		
B. *Doctoral scientist/engineer employment in R&D in academic institutions.*				
i. (Basic model)	Doctorates are projected to continue to represent the same share of employment as in 1972.	New doctorate employment is projected as a constant share of growth and replacement needs of the total science/engineering research faculty.		
ii. (Market model)	Doctorates are assumed to represent a progressively increasing share of the R&D faculty because of their availability and the desire of institutions to upgrade the credentials of their staffs.	A compounded growth rate of 5 percent per year was applied to the doctorate to total ratio for openings due to the growth and replacement needs of the research faculty for each year.		
C. *Doctoral scientist/engineer employment in nonacademic R&D*				
i. (Basic model)	Doctorates are assumed to continue to remain at the same proportion of total scientist/engineer R&D employment.	New doctorates were projected as a constant share of the growth and replacement needs of total nonacademic R&D scientists/engineers.		
ii. (Market model)	It was assumed that enrichment will take place as perceived by managers of industrial R&D.	A compounded growth rate of 3 percent per year was applied to the doctorate to total ratio for openings due to the growth and replacement needs of R&D scientists/engineer staff for each year.		

Table 7.2
Summary of Utilization Models

Factor	Rationale/Assumptions	Method	Magnitude	Sensitivity
4. *Other science/ engineering activities*				
i. (Basic model)	Doctorates will continue to be engaged in other than R&D or academic activities in proportion to the opportunities generated for all scientific and engineering personnel in these activities.	The current and projected numbers of total scientists/ engineers engaged in non-academic, non-R&D activities were determined by subtracting those in R&D and academic teaching from the total employed. The current numbers of doctorates in "other related activities" were determined in the same fashion. The current doctorate/total ratios were then applied to the projected numbers of scientists and engineers in "other related activities."		
ii. (Market-related model)	An increasing proportion of openings for non-R&D, non-teaching scientists and engineers will be filled by doctorates because of a relatively abundant supply and their reduced differential cost to employers.	A compounded growth rate of 5 percent per year was applied to the doctorate to total ratio for openings due to the growth and replacement needs in these activities for each year.		

Backdrop

A system of manpower projections assumes implicitly or explicitly a set of national environments during the projection period. The environment for the utilization of science and engineering doctorates is determined by the economic climate of the country, the nature of the higher education system, the working-life patterns of the labor force and position of the U.S. with respect to other nations.

The basic vital signs of an economy are the levels and rates of growth of a few key economic indicators. These measures provide the foundation upon which the projections of utilization are directly based, and, indirectly, the projections of supply as well. These indicators projected for 1985 are shown in the following table, compared with their 1972 counterparts.

It is estimated that of the nearly 900 million dollars in additional goods and services produced in 1985, compared to 1972, 70 percent will be the result of increased productivity of the labor force and 30 percent from added workers. Economists, such as Edward F. Denison, have attributed part of the past growth of the U.S. economy to the increasing quality of the labor force, as represented by the increasing educational attainment of workers.[6] Implicitly, the expectation of continued growth of the economy is derived in part from the inputs of scientific, engineering and other technical workers. The continuing increase in demand for doctorate scientists and engineers is an outgrowth of such expectations.

Table 7.3

Basic Economic Indicators Underlying the Doctorate Supply and Utilization Projections, 1972 and 1985

Indicator	Unit	1972	1985	1972-85 Average Annual Percentage Change
Gross National Product (GNP)	Billions of $ 1972	1,155.2	1,942.5	4.1
Gross Private Product (GPP)	"	1,019.7	1,767.6	4.3
Total civilian labor force	millions	86.6	105.7	1.5
Employed	"	81.8	101.5	1.7
Unemployed	"	4.8	4.2	—
Private man-hours	billions	144.8	170.9	1.3
GPP per pvt. man-hours ..... (productivity)	$ 1972	7.04	10.34	3.0

Source. Kutscher, Ronald E., "The United States Economy in 1985, Projections of GNP, Income, Output and Employment," *Monthly Labor Review*, Dec. 1973

Other aspects of the backdrop, implicit in both the GNP and the supply and utilization projections of this report are:

- That institutional framework of the economy will not change significantly within the projected period, and the participation of people in the labor force will follow past trends.
- That on the international scene a detente between the major powers will have been reached by 1985, but that continued guarded relationships will not allow significant reductions in defense expenditures.
- That fiscal and monetary policies, combined with socioeconomic policies will progress toward achieving a balance between full employment and diminished inflation without interfering with the long-term economic growth rate, although mild economic cycles are to be expected.
- That all levels of government will continue to attempt to deal with a wide variety of domestic problems, with State and local governments playing an increasing role in the operation of economic and social development programs. It is also expected that the role of technology and technologists will become more important to the operation of programs dealing with national, regional and local problems.

[6] *Sources of Economic Growth and the Alternatives Before Us*. New York: Committee For Economic Development, 1962.

* That the patterns of education will continue past trends—with 2-year colleges increasing their share of undergraduates—and most graduate school enrollees entering directly or soon after receiving undergraduate degrees. The role of continuing or mid-career education, while expected to grow, is not expected to detract significantly from the traditional undergraduate and graduate education patterns.

III. Supply and Utilization Models

SUPPLY

This study utilized two supply models. One reflects trends of the last decade, with special emphasis upon the events of the past five years. A second model (Market) has been designed to utilize the first (Basic) one as modified by recursive feedbacks from the utilization projections.

Science and Engineering Doctorate Degrees

The Basic model consists of actual data and projections to 1985 for five phases of the higher education process: entrance into college, acquisition of baccalaureate degrees, entrance into study for an advanced degree, earning of Ph.D.'s, and magnitude of total enrollment for advanced degrees. A description of the phases, with the assumptions and methods of the projections made for each phase, follows:

Rates of entrance into college of 18-year-old population cohorts of each sex were ascertained for the period 1944-1972. These rates were then developed for the future from a trend projection based on rates of the last 10 years, utilizing a straight-line least squares regression method and weighting the trends of the more recent five-year period twice as heavily as those of the earlier five-year period.

This phase of the model also indicates for each sex the time-pattern of entrance into college of those from each population cohort who ever enter. This pattern, or "spread" of entrance, has remained virtually static (except for a variation for males for a brief period in war and post-war years) and is held constant for the future.

The total number of entrants into college for each projected year is arrived at by summing the number of entrants in that year from each relevant age-cohort.

Rates of completion of undergraduate and first-professional degree training were ascertained for the period 1952-1972 for each sex. These rates were then developed for the future from a trend projection based on the rates of the last 10 years, utilizing a straight-line least-squares regression method and weighting the trends of the more recent five-year period twice as heavily as those of the earlier period.

The time-pattern, or "spread" of completion of this stage of the higher education process is also demonstrated in this phase of the basic model. The spread has remained constant for each sex and is held at the same rates for the future.

The total number of baccalaureate and first-professional degrees for each projected year is arrived at by summing the number of such degrees earned that year by members of each relevant entrance-cohort.

Rates of entrance into advanced-degree study were ascertained for each broad science and engineering field, for each sex, for baccalaureate cohorts of the period 1952-1971. Future rates were developed from trend projections based on the rates of the last 10 years, utilizing a straight-line least-squares regression method and weighting the more recent five-year period twice as heavily as the earlier.

For each sex-field, the percent of entrants into graduate study who enter within specified numbers of years after acquisition of the baccalaureate is indicated. (This pattern, or "spread" of entry, has remained constant for each sex-field in the past and is held constant for the future.)

The total number of entrants into advanced-degree study each year is arrived at by summing the number of entrants from each relevant baccalaureate cohort.

The rate of acquisition of the Ph.D. degree among entrants into advanced-degree study was determined for each broad science field, by sex, for graduate-study entrants of the years 1955-1964. (The period of observation of past data covers entrants of these years and Ph.D.'s through academic year 1970-71.) Because of the lack of data indicating a particular trend, it is assumed that the future rate of acquisition of the degree will remain constant at the most recently observed level.

Of those from each cohort of entrants into advanced-degree study who attain the Ph.D., in each sex-field, specific percentages of entrants are shown to acquire the degree within certain numbers of years after entry. This pattern, or "spread" of acquisition of the degree, has remained constant in the past and is held constant for the future.

In each sex-field, the total number of Ph.D.'s earned each year is arrived at by summing the number of Ph.D.'s earned that year by members of each relevant entry cohort.

Rates of retention in advanced-degree study for entrants into such study in the period beginning 1955 were ascertained for a number of years (typically six) after initial entry. (The percentages of entrants who remain enrolled for specified numbers of years may differ from field to field, for each sex, and over time.)

The total number of enrollees for advanced degree study in each year through 1985 is obtained by summing the numbers from each relevant cohort of entrants enrolled in study that year.

Market-Related Model. This model constitutes a variation from the Basic Supply model in that it incorporates a recursive feedback from the status of the employment market for doctorate scientists and engineers to the fraction of science and engineering baccalaureates entering graduate school. Freeman[7] and others have demonstrated the existence of this type of feedback effects and episodes during the last twenty years, especially those in the early seventies. The Basic Supply model does not completely ignore market factors since it places special weight on recent trends, which certainly reflected market feedback. However, future markets are not taken explictly into consideration. Consequently, the Basic Supply model probably provides doctorate production figures that are on the high side.

[7] R. B. Freeman. *The Market for College Trained Manpower.* Cambridge: Harvard University Press, 1971.

If one thus considers that a weakening of the labor market for doctorate scientists and engineers will adversely affect decisions of science baccalaureates to enter science, one can state this in the following expression:

$$G^i_{Mt} = G^i_{Bt} - K^i \left[\frac{1}{R^i_{Bt}} - 1 \right]$$

where (all symbols and numbers pertain only to science and engineering):

M = market model

B = basic model

G = rate of entry of baccalaureates to graduate education

U^i_{Bt} = number of doctorates employed in R&D, academic or appropriate "other" positions as projected by the Basic Model

S^i_{Bt} = total number of doctorates available for employment as projected by the Basic Model

$R^i_{Bt} = \left(\frac{U}{S}\right)^i_{Bt}$ = rate of utilization of doctorates

K = constant

t = year

i = area of science (physical sciences, social sciences, etc.)

This equation will be used to develop the numbers of new science and engineering doctorates in the Market Related Supply model using for all other steps the methodology developed for the previously described Basic Supply model. These numbers are expected to be generally lower than those generated by the Basic Supply model since the Basic model projections generally indicated somewhat of an over-supply of doctorates, i.e., $R^i\ B_t$ was generally smaller than 1. The value of the Constant K will be calculated from the only two data periods available, the 1964-67 period when there was essentially no non-utilization of science and engineering doctorates, i.e., $R^i\ B_{1964} = 1$, and 1972 when R_B was as low as .89 for social scientists. Using averages for actual data on baccalaureate and first-year graduate enrollment figures one obtains K^i from the following expression:

$$\frac{G^i_{64\text{-}67} - G^i_{68\text{-}71}}{\frac{1}{R^i_{72}} - 1} = K^i$$

Averages of G for three year periods will be used and since neither G^i_{72} or R_{71} data are available, the R_{72} figure will have to be utilized as the closest approximation to R_{71}.

Immigration and Emigration

Foreign-trained scientists and engineers have played a significant role in the scientific and technical activities of the United States, and, until the rapid growth of U.S. graduate education after World War II, represented a large share of this nation's doctorate labor force. Foreign-trained doctorates are expected to continue to migrate to the U.S. even in face of potentially unfavorable employment conditions for doctorates and stricter immigration regulations, because relative employment opportunities as well as economic and political conditions in the immigrants' countries may serve to mitigate the potential dampening effect of the employment situation in the U.S. These doctorates are projected, in both models, to continue to immigrate at the same level estimated for Fiscal Year 1973—which is one-half to two-thirds the pace of previous years—as a result of changes in immigration regulations in early 1971[8].

Emigration

Though the total supply of science and engineering doctorates in the U.S. is improved by the immigration of foreign-trained doctorates, not all doctorate recipients from U.S. schools are added to the supply. About 15 percent of the science and engineering doctorate recipients in the 1971-72 academic year were not citizens of the U.S., and nearly 11 percent of the recipients (not necessarily confined to non-U.S. citizens) indicated of emigration could be expected in the future. It is also conceivable that the numbers of foreign students, especially from less developed countries, could decrease, and this has been indicated by recent graduate school enrollment data.[9] Several factors have influenced this decline, including reduction of Federal funding of graduate education, overabundances of professional workers in less developed countries and the increasing costs of obtaining an education and living in the U.S.

Attrition

Attrition of doctorates from the labor force was ascribed only to deaths and retirements and was computed for the total doctorate population by five-year age groups, for each year of the projected period for each science/engineering field. Men and women were assumed to exhibit the same patterns of labor market attachment by age. The attrition rates applied were those for all men in the labor force by age.[10]

It is assumed that women doctorates, rather than exhibiting the working life patterns of all women, would behave more like men because of the time, effort and capital invested in their educations and their careers. In addition recent anecdotal evidence indicates that women doctorates may benefit more from more favorable labor market conditions than men due to efforts made by employers to compensate for sex discrimination of the past and attempts to comply with the equal opportunity employment goals of the present.

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[8] For detail on FY 1972 immigration see *Science Resources Studies, Highlights.* "Immigrant Scientists and Engineers Decline in FY 1972. Physicians Increase Sharply". NSF 73-311. August 1973

[9] Unpublished NSF data

[10] Fullerton, Howard N., "A New Type of Working Life Table for Men." *Monthly Labor Review.* July, 1972

UTILIZATION

Two utilization models were developed in this study—the first, or Basic model, relies upon current (1972) utilization patterns and trends of the last half decade to project the utilization of all scientists and engineers and the share doctorates will represent between 1973 and 1985. Total science and engineering employment has been projected, by work activity—academic teaching, R&D, and other scientific/engineering-related activity—in relation to projected changes in the economy and enrollments in colleges and universities. Doctorate employment in these activities has been projected as shares of the new positions that result from growth and replacement needs in the projected period. In the Basic model, enrichment trends—the proportion of new positions that were or would have been filled by nondoctorates but are projected to be filled by doctorates—are based on present utilization patterns or trends of the past few years (where such data were available). In the Market-Related model, the enrichment was projected to progress further in every sector and activity on the basis that an increasing number of doctorates will be used because of their availability and relative reductions in their cost.

The utilization models have been divided into the activities which scientists and engineers perform—academic teaching, R&D, and other related science/engineering activities.

A. Academic Teaching

Requirements for doctorate teaching faculty depend on three factors—the workload in terms of enrollments and student: faculty ratios and the proportion of teaching faculty represented by doctorates. In both models doctorate academic teaching faculty utilizations were projected as products of projected total science and engineering enrollments and student : faculty ratios.

Basic Utilization Model. Total science and engineering enrollments in four-year colleges and universities were obtained by summing graduate enrollment as obtained above (see section under supply under the Basic model) and undergraduate enrollments. Total graduate enrollments in each year to 1985 were obtained for each field by summing the numbers of students from each relevant cohort of entrants enrolled in study that year. Undergraduate enrollments for each year projected were developed by assuming that the ratio of undergraduate students taking courses in each field of science/engineering to total undergraduate enrollments would be proportional to the science/engineering to total baccalaureate ratios.

Student : faculty ratios were derived by dividing the sum of undergraduate and graduate students by the total teaching faculty. This procedure was carried out for each field. Finally, new doctorate employment was projected as a constant share of growth and replacement needs of the total science/engineering faculty. These ratios were held constant in the Basic Utilization model to preserve for four-year colleges and universities.

For two-year colleges, U.S. Office of Education projections of enrollments were used and projected to 1985. The total number of students were divided by the student : faculty ratio to obtain the number of total science/engineering faculty. A compounded growth rate of 6.6 percent per year was applied to the doctorate to total ratio for openings due to growth and replacement of total science/engineering faculties. This rate of enrichment is the same as that actually experienced in these institutions between 1969 and 1973.

Market-Related Utilization Model. As can be seen in the Market-Related Supply Model, certain adjustments were made in graduate enrollments due to the feedback from imbalances arising in the Basic Supply and utilization projections. For undergraduate enrollments no adjustments were made. Thus, the adjusted graduate enrollments were added to the numbers of undergraduate students to obtain adjusted total college enrollments (excluding two-year colleges). The two-year projections are derived from their own trends in relation to the 18 and 19 year old population.

In this model, student : faculty ratios in four-year institutions are increased by one percent per year for the 1972-85 period, in consideration of the colleges' financial plights of recent years and their attempts to improve productivity and to hold down the growth of their costs. Then, total science/engineering faculty to be utilized in four-year institutions was derived in the same manner as in the Basic Utilization model. Enrichment of faculty teaching positions, in terms of the doctorate share of total faculty, in the Market-Related model is projected to increase in four-year colleges and universities at a somewhat arbitrary 5 percent compounded rate of growth (of new positions and of those resulting from death and retirement replacement needs). The rationale for this growth is based on the greater availability of doctorates and the desire of institutions to upgrade the faculties' credentials.

In two-year institutions, the student : faculty ratio was decreased by one-tenth of a student per year for the projected period, as these institutions aspire to improve the quality of education they provide. Finally, in view of the greater availability of doctorates, an even higher percentage of doctorates to total faculty are expected to be hired for new openings. Thus, a 9.9 percent compounded annual improvement in the doctorate to total faculty ratio was projected to 1985. This represents a 50 percent improvement over the actual experience of the last few years.

B. R&D Activities

Basic Utilization Model. The second major activity of doctoral scientists and engineers is research and development. The number of scientists is based on expenditures devoted to the performance of R&D. These expenditures were projected, within the framework of GNP projections in terms of constant dollars, for each of the R&D financing sectors and translated to the R&D performing sectors of the economy on the basis of current national patterns of R&D funding and performance. Major emphasis in the funding projections by sector is given to the subsectors or activities which account for major portions of the activity. For example, within the Federal Government, funding of such objectives as defense, space, health and agriculture were examined; while in the industry sector, all major SIC groups such as chemicals, and electrical equipment, have been studied. Relationships of company R&D funding to sales are used as the basis of industry projections. Two R&D expenditures projections exist currently.[11] These differ by about 10% and the average of the two was used.

Total science and engineering employment estimates are generated by projecting change of R&D costs per employee on the basis of 1961-72 trends (about

[11] Falk, Charles E "Dynamics and Forecasts of R&D Funding," *Technological Change and Society*, June 1974, and NSF - currently in press

one percent annually) and applying the results to projected R&D funds available for each sector. Doctoral employment, as a share of total employment is projected to remain at the 1972 levels through 1985 in the Basic model to simulate the 1972 situation. No enrichment of total science and engineering employment by doctorates is projected in the Basic Utilization model.

Market-Related Model. In this model, adjustments are made for academic employment enrichment, which is projected to increase at a compounded rate of 5 percent a year, and similar enrichment in the nonacademic sector of 3 percent yearly.

C. Other Science/Engineering Activities

Basic Utilization Model. The last sector of utilization of doctorates comprises a variety of non-teaching, non-R&D activities of scientists and engineers. Included are such activities as: administration of science/engineering related activities, consulting, production control and clinical practice (primarily for psychologists). Of the total number of scientists and engineers employed in nonacademic, non-R&D activities in 1972, less than five percent had science/engineering doctorate degrees. Total science/engineering employment in these activities has been projected by BLS within the frame of the overall GNP and employment projections cited previously in this paper.[12] Doctorate employment is projected as a proportion of total scientists and engineers employment in nonacademic, non R&D activities. The Basic Utilization model assumes no enrichment of doctorates in this sector.

Market-Related Model. This model of utilization incorporates a 5 percent annual cumulative enrichment, on the assumption of an abundant supply of doctorates and the anticipated narrowing of differential cost to employers of doctorates and nondoctorates.

RELATIONSHIP OF BASIC AND MARKET MODELS

The progression from the Basic to the Market-Related models in these analyses represents the initial phases of a continuing recursive process that reflects the operational mode of the real world—if it were to act "rationally" in economic terms. Ideally the Market-Related Supply model should generate a second order Market-Related Utilization model with feedbacks on the supply model. This, in turn will influence the market again and these interactions continue *ad infinitum*. Thus, any external modification of the supply or the utilization will have recursive repercussions on the other element of the labor market. Attempts to influence supply, for example by decreasing support of graduate students, will produce reductions in the demand for teaching faculty—which then may produce feedback to reduce the supply even further. Thus, if one tries to intervene in the production or utilization processes, one should be fully aware of the multiple recursive effects.

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[12] Rosenthal, Neal H., "The United States Economy in 1985, Projected Changes in Occupations," *Monthly Labor Review*, December, 1973.

IV. Doctorate Scientist and Engineer Utilization in 1972

In mid-1972, 236,000 persons with doctoral science and engineering degrees resided in the U.S. Of these, 228,600 were in the labor force—225,900 employed and 2,700 seeking work. The remaining 7,600 were either retired or not seeking work for other reasons.[13]

Table 7.4 indicates that 93 percent of the doctorates in the science/engineering labor force were employed in technical activities, 5.4 percent were engaged in non-technical activities, and unemployment claimed 1.2 percent. (Comparable unemployment rates at the time of the survey were 4.7 percent for the total civilian labor force and 1.9 percent for all professional and related workers.[14]) It is tempting to define the 5.4 percent of the doctorate labor force employed in non-science/engineering related work as being "underutilized." However, economic evidence disputes such an assumption. First, there is no relationship between the unemployment and nonscience employment by field of doctorate (see Table 7.4) and second, the income data from the survey show higher earnings for the "non-science related" workers than for their colleagues in science-related employment. Thus, while the very presence of unemployment is an indication that underutilization probably exists, there is no definite measure of its magnitude.

As one might expect, a strong relationship was found between doctorate level employment in science and engineering and the employment of persons with doctorate degrees in the respective disciplines. Table 7.5 distributes the science and engineering jobs filled by doctorates by the field of degree. In all but mathematician and the social scientist jobs, less than one percent were filled by non-science doctorates. In each employment field, except for mathematics, more than 80 percent of the positions were occupied by holders of degrees in the respective fields.

Educational institutions employed nearly 60 percent of science and engineering doctorates in 1972; however, the proportions varied widely, from 80 percent of the mathematicians to 36 percent of the engineers. Industrial and other business organizations employed 22 percent of all doctorate scientists and engineers, but nearly half the engineers and less than 5 percent of the social scientists. Governments employed about 10 percent of all doctorates, but 5 percent of the mathematicians and 12 percent life scientists. (See Table 7.6.)

Functional activities of these doctorates were not as clearly determined as other parameters. The survey produced the numbers of individuals "primarily engaged" in each of these activities. On this basis, activities relating to the conduct of R&D—research, development, and the administration of R&D—accounted for more than 40 percent of all doctorates. This also varied by field of employment—nearly 60 percent of the engineers were primarily engaged in R&D

[13] Data in this Section are based on a survey conducted by the National Research Council for NSF. They are the results of the responses of individuals who received their doctorate degrees in the school years ending from 1930 to 1972 The survey of doctorates undertaken by NRC for NSF also revealed that some 7,900 persons who had received degrees in fields other than science or engineering indicated employment in a science or engineering field in 1972. NRC. *Doctoral Scientists and Engineers in the United States A 1973 Profile*. 1974 (in press).

[14] U.S Council of Economic Advisors, *Economic Report of the President*. February 1974. Washington, D.C.: U.S Government Printing Office, 1974, Table C-24, and U.S Bureau of Labor Statistics, *Employment and Earnings*, Nov. 1973, Table A-35.

related activities, while less than 20 percent of the social scientists were similarly occupied. Those primarily engaged in teaching accounted for over 35 percent of all doctorates, 60 percent of the mathematicians, and 50 percent of the social scientists, while claiming a fourth of the engineers.

Table 7.4

Labor Force and Employment Status of Science and Engineering Doctorates, 1972

Labor Force Status/Employment	Total[1]	Physical Sciences	Engineering	Mathematics	Life Sciences	Social Sciences
			Thousands			
Total in population[2]	236.0	69.2	35.1	13.6	61.1	56.8
Not in labor force	7.6	2.4	0.5	0.4	2.4	1.9
Total in labor force	228.6	66.9	34.6	13.2	58.7	55.0
Employed	225.9	65.8	34.3	13.0	58.1	54.4
In science or engineering	213.4	62.1	33.0	12.7	56.0	49.4
In non-science/engineering	12.5	3.7	1.4	0.3	2.1	5.0
Unemployed	2.7	1.0	0.3	0.2	0.6	0.6
			Percent distribution			
Total in labor force	100.0	100.0	100.0	100.0	100.0	100.0
Employed	98.8	98.4	99.2	98.6	99.0	99.0
In science or engineering	93.3	93.0	95.2	96.1	95.4	89.9
In non-science/engineering	5.4	5.5	4.0	2.5	3.5	9.1
Unemployed	1.2	1.6	0.8	1.4	1.0	1.0

[1] Includes those (0.1 percent) with unknown field of degree.
[2] Those not reporting labor force status (3 percent) have been redistributed proportionately among the categories.

Components may not add to totals because of independent rounding
Source: National Science Foundation and National Research Council.

Table 7.5

Field Distribution of Doctorate Employment in Science and Engineering, 1972 (percent)

	Field of Employment				
Field of Degree	Physical Scientists	Mathematicians	Engineers.	Life Scientists	Social Scientists
Total	100.0	100.0	100.0	100.0	100.0
Physical sciences	89.6	6.5	14.6	7.3	0.3
Mathematics	0.3	74.9	1.6	0.4	0.2
Engineering	4.3	8.1	81.2	0.5	0.3
Life sciences	4.5	0.7	1.1	88.3	1.0
Social sciences	0.5	2.9	0.8	2.8	86.9
Subtotal all sciences	99.2	93.1	99.3	99.3	88.7
Non-sciences	0.9	6.9	0.7	0.8	11.3

Note: Components may not add to totals because of independent rounding.
Source: National Science Foundation and National Research Council.

Table 7.6

Estimated Sector and Primary Activity of Employed Doctorate Scientists and Engineers by Field, 1972

	Field of Degree[1]					
Activity/Sector	Total	Physical Sciences	Engineering	Mathematics	Life Sciences	Social Sciences
	Thousands					
Total	225.9	65.8	34.3	13.0	58.1	54.4
	Percent distribution					
Primary Activity - Total[2]	100.0	100.0	100.0	100.0	100.0	100.0
Teaching	36.0	29.7	24.9	60.3	31.2	51.0
R&D	43.2	57.1	58.4	27.8	50.7	19.1
Other[3]	20.7	13.2	16.6	11.9	18.1	29.9
Sector - Total[2]	100.0	100.0	100 0	100.0	100.0	100.0
Academic	58.5	46.4	35.8	79.5	67.6	72.4
Industry	22.1	35.3	48.3	11.9	11.3	4.5
Government	10.3	10.1	9.8	5.3	12.7	7.3
Other[3]	9.1	8.2	6.1	3 3	8.5	15.7

[1] Includes only persons with doctorates in science/engineering fields
[2] Because data on the distribution by sector and activity were not currently available by field of degree, available information on these distributions by field of employment was used. Such distribution by field of degree will be added in a later draft
[3] Includes no report

Components may not add to totals because of independent rounding
Source National Science Foundation and National Research Council

8. Manpower Requirements Analysis and the Skill Composition of the U.S. Work Force

This chapter is based on Dr. Freeman's oral presentation and his paper. The lead discussants were Thomas J. Kennedy, Jr., M.D., National Institutes of Health, and Hugh Folk, University of Illinois.

Richard B. Freeman:
Professor, Department of Economics, Harvard University

This presentation makes use of the formal paper as well as another paper, "Forecasting the Ph.D. Labor Market: Pitfalls for Policy"[1] written with Dr. David Breneman this year, which in some ways even more closely treats the subject of the conference.

Most economists, myself included, have criticized the fixed coefficient models In the Freeman-Breneman piece we cited four problems: absence of wages and prices; failure to link forecasts to policy; neglect of the supply behavior; ignoring interactions and feedback among economic variables. In the paper before you, I take a different tack: in a more positive view, I propose that the fixed coefficient model be reinterpreted as a forecast of *shifts* in the level of demand for a broad disaggregate collection of skills, rather than of actual levels of employment. I believe that, so interpreted and used, the model provides useful information often neglected in the standard price theory model.

The question I raise in the paper is: Does knowing a lot about the changes in industrial mix, which is really the key thing that makes these requirements models go, give us a good notion of the shift in the demand curve? And I might just point out that forecasting shifts is the most difficult part of any forecast.

I tend to believe the supply curves are quite stable and reasonably elastic, and we can indeed learn a lot about the supply behavior. And with that part of the models put out by the BLS or NSF, I am very, very dissatisfied.

The demand side is much more complicated. It is complicated in the science area because there is a squeaky wheel of government which changes its policies left and right. It's complicated also, in some sense, because price theory tells us little about shifts in demand curve.

The paper examines the value of requirements calculations in getting a fix on this shift and compares the importance of the shift in demand with movements along demand curves in determining employment. It is based on highly disaggregate data—occupation/industry matrices from the 1950 and 1960 Censuses which relate employment in 228 occupations to 142 industries giving us two matrices with nearly 26,000 elements. It assumes that we knew, in fact, the 1960

[1] Freeman, R.B and Breneman, D.W., "Forecasting the Ph D. Labor Market Pitfalls for Policy." National Board on Graduate Education (April 1974)

industry totals and examines how well *occupational* employment could be predicted using the 1950 industry/occupation matrix. The model will do a good job if: (a) there is a lot of change in the distribution of employment among industries; and (b) there is relatively little change in manpower coefficients—percentage of workers with different occupational skills—within industries. Put another way, the fixed coefficient model will work if there are large shifts in demand due to changes in industrial mix and reasonably small elasticities of demand.

The first evidence that bears on this empirical issue is given in Table 8.1 (in the accompanying paper), which records the means and standard deviations of log-changes in employment and income from 1950 to 1960. For employment, the large standard deviations reveal enormous changes in the number of persons in various occupations or industries. For income, on the other hand, there are rather small standard deviations, which means that the income structure was more stable than the employment structure. This does not, I must stress, mean that incomes in particular areas—like the sciences—do not change greatly relative to those elsewhere. The Freeman-Breneman paper shows very sizeable changes in the income of Ph.D.'s relative to that of other workers. What it does mean is that in the *broad aggregate* the composition of employment changes a lot while the income structure changes only moderately.

There are two possible explanations. One, which I support, is that the supply structure was very elastic and stable and responds to large shifts in demand. The other explanation is that demand is very elastic, adjusting to large shifts in supply. Either is consistent with great changes in employment and small changes in income.

In support of the former explanation, it is shown in Table 8.2 that logarithmic changes in employment, as forecast by the fixed coefficient model, account for a large share of the actual logarithmic shifts in employment among occupations. By themselves, the forecasted shifts are found to explain 44 percent of the actual logarithmic changes in employment and 55 percent of the absolute change in share of total employment. Addition of other variables, including estimates of changes in supply contributes only 5 or 10 percentage points to the R^2 and does not detract greatly from the impact of the shift variable.

Table 8.3 goes a step further and—with two-stage least squares regressions—estimates directly the extra "oompa" we get by taking account of actual changes in occupational wages in making forecasts. Because the data consist of wages in different occupations in 1950 and 1960, the analysis is forced to assume that there is a single elasticity, which is clearly a gross simplification. It ignores differences in the elasticity among occupations, connections between occupations, and so forth. It's very, very crude. Even so, there is a clear negative coefficient on wages, indicating that there are important substitutions among skills, an estimated elasticity of around -0.6. But, and this is the crux of the matter, because the standard deviation of the wage structure is small relative to that in the employment structure, a much larger elasticity is needed for wage changes and substitutions to have a major effect on employment via changes in manpower skill coefficients. As far as can be told from the disaggregate cross-sectional changes in the Census data, the elasticity is not that big. Knowledge of changes in wages and substitutions matters, but not *that much*. I concluded that as a first approximation, the fixed coefficient model does a tolerably good job in accounting for changes in occupational employment—given, of course, exogenous changes in the industrial mix of jobs.

The fact that the fixed skill coefficients assumption works reasonably well from one perspective does not, however, mean that in fact coefficients are constant. The next part of the paper examines changes in coefficients *within* industries. Why do some industries experience large changes in the mix of skills and others, small or no changes? I hypothesized that these differences were due to: the amount of R&D and concurrent technological change, the amount of investment in plants and equipment, and total growth of sales. The results, which surprised me, were quite good. It turns out, as the evidence in the paper shows, that each of these factors counts a lot—explaining 64 percent of the change in coefficients (defined as the summation of the absolute value of difference in coefficients between 1950 and 1960). It is possible then to identify industries with likely future changes in skill structure.

In this discussion, I will skip the estimates of the supply schedules of young persons to occupations in Table 8.4. I believe that other experiments reported in *The Labor Market for College-Trained Manpower* (Harvard University Press, 1970) and various succeeding papers, cited in the Freeman-Breneman paper, provide superior estimates and tests of supply responsiveness, using better data, measures of variables, etc. The only point is that the supply analysis does hold up in the framework and data of this model also.

Finally, I conclude by examining the value of my demand-shift variant of the fixed coefficient model to explain the "Griliches' relative wage puzzle." Griliches' puzzle was that, despite the enormous increase in the numbers of college graduates in post-war years, their wage was virtually unchanged relative to that of other workers. My explanation is twofold: first, during the 1950's and 1960's when the supply of college workers was increasing, so too was demand, as estimated by the fixed coefficient index. During the period covered by Griliches' data, changes in industrial mix increased demand by roughly as much as supply was increased by the inflow of new college graduates, preserving wage ratios. Second, I present data that shows substantial declines in the ratio of college starting salaries to average earnings after 1969—the dissolution of the puzzling fact—when supplies continue to grow while the relative demand index leveled off. The regression estimates show that the changes in supply and demand account for the bulk of the time path of stability and changes in income ratios. Because I believe these changes to be extremely important, I intend to come back to this answer to the puzzle in future work.

The lesson of the paper is that fixed coefficient models, treated as estimates of shifts in demand schedules, do provide a good fix on shifts, and thus on changes in employment and income. This does *not* mean, however, that if one is interested in particular occupations such as engineering or physics or chemistry the appropriate thing is to use a giant fixed coefficient model of the type analyzed in the paper. Far from it, if one is interested in a specific occupation, one wants to use much more information—about elasticities, which can differ greatly among occupations; about wage changes, which can alter the position of a particular area in the income structure greatly (as in physics in recent years); about possible technological developments; and so forth—than is available in an industry/occupation matrix. Time series data should be employed, along with changed cross-section data, possibly along lines described in the Freeman-Breneman paper. Moreover, to be useful for policy, it is necessary to tie both the demand and supply sides of the market to particular policy control variables, which is absent from the usual projection models and makes them not very useful for many people. As estimates of shifts in occupational demand schedules due to changes in industrial mix, the fixed coefficient models are useful but much more is needed to increase their value in economic and policy analysis.

Thomas J. Kennedy, Jr., M.D.

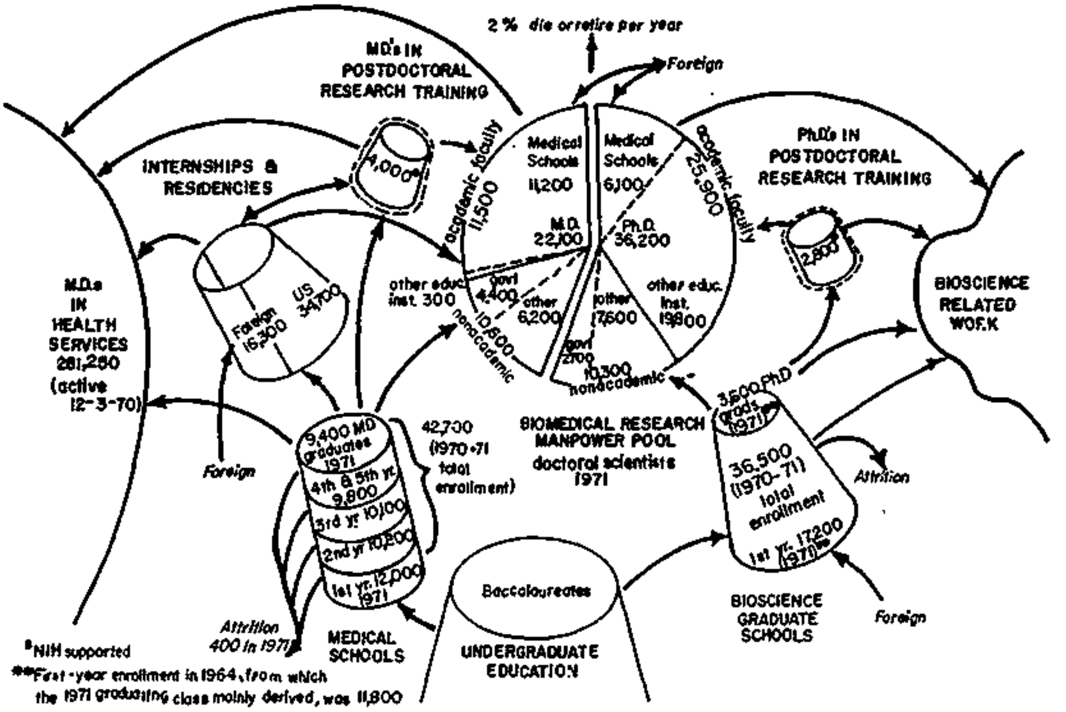
Associate Director, Program Planning and Evaluation, National Institutes of Health*

The NIH was called upon by Office of Management and Budget to justify future expenditures for its biomedical research training programs in 1969. Two lines of argument were developed: demand predictions based on relatively simple mathematical models, and justification based on policy considerations.

Figure 8.1 shows the basic conceptual framework for discussing research training. It attempts to illustrate the flows of individual scientists into and out of the pool of biomedical research manpower. This pool is expanded by the entry of scientists and research-trained physicians from graduate schools and medical schools. For physicians, there is a substantial "leak" from the pool into medical practice—with or without part-time teaching—of probably no less than 6 percent per year; by the age of forty or so, after ten to fifteen years of research and often after an individual's creative research peak has passed, many physicians shift into an alternative socially productive and economically rewarding career. In this sense, medical research for physicians has not been professionalized and the social problem of maintaining them in research, when their research productivity begins to wane, does not exist. No comparable alternative career path outside academe could be identified for academic doctorates.

Figure 8.1

Training Pipelines into Biomedical Research, 1971



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Future demand based on the dynamics of turnover of this pool was calculated under a variety of assumptions and the predictions were used as a basis for justifying research training expenditures. There is no evidence that the demonstrated continuing demand for research scientists, reflecting a predicted steadying but small increase in Federal obligations for biomedical research, was convincing to higher level policy-makers.

In terms of the policy aspects of this question, our analyses led us to conclude that:

- NIH, since its contributions to the total cost of graduate training in the biomedical sciences was relatively small, could not control or probably even critically modulate the number of doctoral degrees awarded.
- The NIH would have to take an unacceptable risk if it were to attempt to fine-tune the distribution of doctoral candidates and doctoral awards by sub-field, sub-discipline, or sub-specialty. The rapid pace of research, combined with the long period required to complete training, accounts for the difficulty in forecasting the need for scientists by discipline or field of science.
- Prevailing policies and practices of the NIH with respect to its training program exerted their major effect with the provision of assistance to high quality training sites, enabling such departments and institutions to offer a thoughtfully organized training experience to graduate post-doctoral students.

The position that emerged from this line of analysis was to assign to Federal support the role of sustaining and improving the quality of the training experience in institutions which awarded doctoral degrees and provided postdoctoral training. Thus, the nature of the competition for training grants should be on the excellence of the training experience provided. Again, this argument did not win enough votes to recommend continuation of the NIH's biomedical research training programs.

The several years during which I was preoccupied with this problem of training led me to some personal conclusions—emphasize the personal; I would not wish to have these views considered the official views of the NIH:

- Federal support for training and the magnitude thereof is more a value question of appropriate Federal role than a number question based on supply-demand considerations. Quantitative predictions about need may vary over a wide range and yet have complete intellectual respectability. This is because the system is complex, the rate processes are difficult to quantify, and the parameters to which estimates of demand are sensitive (e.g., Federal research expenditures) are highly unpredictable, etc. If the battle for Federal support of training is waged on the ground of supply-demand predictions, equally credible numbers justifying high or low investments can be derived by advocates of any predetermined position.
- Another objection to the use of demand forecasts relates to operational consequences. Even if future demands could forecast with a high degree of precision, how could supply be matched to it in practice? How, for example, would the 200-odd universities which award doctoral degrees in physics mesh their efforts to produce 1,347 (or any other precise number) doctoral awards in 1979?

I would wonder if Federal support of training *qua* training should not disappear as a line item in the budget. If there are important Federal objectives to be achieved—and I, for one, believe that improvement in the quality of the training opportunities offered graduate students is a most important one—a mechanism that does not rely on head counting should be employed. One device might be to provide funds for such purposes coupled somehow or another to the success of a department or institution in competitively securing Federal research support in a given discipline or field of science, on the assumption that the most meritorious research environments are the best for training graduate students.

Hugh Folk
Director, Center for Advanced Computation
University of Illinois

First, some brief comments on Dr. Freeman's paper. The special occupational groups that we are concerned with may have different supply characteristics, and these may not be as elastic as low-skill occupations. But the principal conclusion is correct, and it is extremely important: occupational structures are more variable than wage structures. That makes the task of predicting demand easier in the sense that we don't have much information on wage changes or the elasticities of demand with respect to wages. Therefore, the very limited help that we do get from the fixed skill coefficients can permit us to make some rough predictions of future demands of various occupations and industries.

In regard to Dr. Falk's paper, I with to disagree on a number of points. His paper attempts to answer an exceedingly important question, "Is the outlook for Ph.D.'s in science and engineering a catastrophe, as shown by the basic model, or is it merely to be a disaster?" Falk's basic model is the good old mixed integral finite difference model which tries to deal with a dozen or more variables and a number of trends.

Specifically, I disagree with several procedures. The use of double-weighting for the last five years in a study that covers the last ten years, emphasizes the market situation, and explicit market adjustments elsewhere in the model might then constitute double counting. I hope that we have seen the last of these basic models and that henceforth we will be concerned with market models.

In the supply side of the market model, my first objection to making the entry rate of baccalaureates into graduate school dependent on the utilization rate is a fairly narrow mathematical one. The limit of the entrance rate in the market model approaches minus infinity as utilization goes to zero. This would be unfortunate; we can't reverse the process and make Ph.D.'s into bachelors.

The definition of underutilization is a problem area also. If the utilization rate is utilization divided by the supply of the entire stock of people, and if utilization excludes those who are working in some nonscientific field, then the rate is likely to be too high. A better measure of under utilization would be the proportion of Ph.D.'s earning less than, say, the average manufacturing wage, or the average wage of bachelor's degree holders in a particular field. If you actually have, as you do in education, a negative rate of return on investment in graduate school, that is a real measure of economically significant underutilization; in other words, an advanced degree is not necessary to teach in primary school or in high school.

Market models need to include an attrition rate which reflects the balance of supply and demand. In the academically-dominated professions such as physics (where people are forced out or encouraged to leave as a reflection of the balance of supply and demand), the attrition is going to be greater than it will be in computer science where there is an excess demand.

On the utilization side there seem to be inconsistencies in the NSF models. For example, the four-year institutions are assumed to have increasing student-faculty ratios. The junior colleges are assumed to have decreasing student-faculty ratios. This seems unlikely to occur since both kinds of institutions are facing the same kinds of economic pressure.

The assumption that openings due to growth and replacement in science and engineering facilities and industrial staffs will be increasingly filled by Ph.D.'s is perhaps not correct. In order to achieve their affirmative action goals, institutions will be required to hire non-Ph.D.'s because the pool of doctorate-holding women and minority candidates is so small. For example, in *Griggs v. Duke Power Company* it was established that you cannot impose an educational requirement for a job unless you prove that that education is necessary to perform the job. Now if anyone cares to prove that you have to have a Ph.D. to teach in a university, then they'd better not have any non-Ph.D.'s teaching in that university. When the chips are down, universities will be required to hire non-Ph.D. teachers to meet their affirmative action goals. This means that enrichment is not likely to be the case.

General Discussion

During the discussion that followed the presentations of Drs. Freeman, Kennedy and Folk, these points, some of which are at variance with each other, were made:

- Students use wage figures as indicators of the state of the labor market rather than as concrete future earnings. The average wage is less significant than the student's conception of where his abilities and knowlege will place him with respect to that average.
- The National Merit Scholarship Corporation asked essentially that question (of dispersal around the average wage) of college juniors and seniors and received a wide range of occupational choices with a very accurate distribution of incomes for them. Those students chose a wide range of expected average salaries in a way that suggested that their occupation choice did not depend essentially on future expected income.
- Students would have more use for projected annual or career earnings, for various jobs, instead of projected manpower needs in those occupations. What students are interested in is the lifetime profile of income.
- Science students who expect to enter industry perceive their future quite differently than those who will enter academic life, so the two groups must not be lumped together. Also, because wages are often not the main driving force in leading students to enter a field, projections of supply must reflect this fact.
- It is simply not socially acceptable in answering questionnaires to say, "I am motivated by money." But, money factors should not be un-

derplayed; it is a factor in choice, an obvious driving factor. People speak of alienation, but settle for dollars.

- Professionals do not accurately perceive where their career will lead them, in terms of eventual income. They perceive the first five years or so accurately, but not the years beyond.
- Dr. Freeman's conclusion that supply is very sensitive to small changes in wage is in disagreement with the views of some persons. The discussion included opinions, without citations to results, and the point was not resolved.

The formal paper prepared by Richard B. Freeman for this session appears below.

Manpower Requirements and the Skill Composition of the U.S. Work Force

Fixed coefficient manpower requirement models, which are the basic tool of manpower forecasting, have been severely criticized. The absence of substitution between various types of labor skills is often cited as a fatal flaw, especially since econometric evidence suggests that elasticities are quite high.[1] The neglect of labor supply behavior is another well known weakness of the approach, which has led many analysts into simplistic forecasts of impending shortage or surplus crises.[2] Yet another problem has been the close link between requirements methodology and rigid educational planning.[3] As a result of these problems, requirements models and, more generally, the demand-side determinants of the composition of skills and income have been overshadowed by human capital models of individual investments in skill.

This paper seeks to redress this imbalance and reconcile the requirements and price-theoretic approaches to the analysis of labor skills. Section one argues that the fixed coefficient model is best interpreted as a tool for analyzing *shifts* in demand schedules in the context of a simple supply-demand model, rather than as a device for forecasting manpower 'needs' or employment. The validity of the model depends not on the elasticity or inelasticity of demand for labor, but rather on its ability to track shifts in demand over time. Section two presents empirical evidence that a detailed requirements model of the U.S. work force does, in fact, a reasonably good job in accounting for differential shifts in the demand for labor in 228 disaggregated occupations, given changes in industrial employment. Paradoxically in view of the tie between the requirements methodology and rigid planning models, the requirements analysis also provides a good fix on actual changes in employment, not because demands for labor are inelastic, but because supplies are elastic. This section also examines intra-industrial changes in skill composition, using revealed preference index numbers to show that changes in

[1] See, in particular Bowles, *Planning Education for Economic Growth* (Harvard University Press) 1969, Dougherty, "Substitution and the Structure of the Labor Force," *Economic Journal*, 82, 170-182. Blaug, "Approaches to Educational Planning," *Economic Journal*, 74, 262-287. Blitzer, "Employment and Human Capital Formation in L. Taylor, P. Clark and C. Blitzer, eds. *Economy Wide Models and Development Planning* (Oxford).

[2] Neglect of supply behavior is criticized in Freeman, R and Breneman, D. "Forecasting the Ph.D Labor Market: Pitfalls for Policy" (National Board of Graduate Education, 1974)

[3] See M J Bowman, "Education and Manpower Planning Revisited." OECD (DAS/EID/69 16).

the structure of employment within industries are affected by substitutions due to rising wages as well as by exogeneous changes in the technological coefficients. The final section turns to the puzzling constancy of relative income differentials by level of education in the U.S.[4] In the context of the requirements model this wage pattern is explicable by changes in industrial mix that raised the demand for high-level labor by enough to counterbalance the increases in supply of post-World War II years. As the relative demand for the highly educated has begun to slacken at the outset of the 1970's, the analysis predicts a narrowing of income differentials in the future, and some preliminary evidence of such a development is also given.

1. Supply-demand framework for requirements calculations

Standard manpower requirements analysis applies the fixed coefficient input-output model to the labor market, under the assumption that labor skill coefficients within industries are fixed and can thus be estimated by past levels. The model directs attention to the role of autonomous changes in industrial mix in altering the demand for various types of labor skills. Formally, if D_i is the number of workers in occupation i, N_j, the number in industry j and a_{ij} the proportion employed in j having skill i in the base period, the model can be represented as:

$$(1)\quad D_i = \sum_j \alpha_{ij} N_j = \sum_j \alpha_{ij} (N_j/O_j)\, O_j$$

where O_j is the output in the jth industry and N_j/O_j total labor requirements. In logarithmic change form, this becomes:

$$(2)\quad \dot{D}_i = \sum_j \gamma_{ij}\dot{N}_j = \sum_j \left[\gamma_{ij}\,(\dot{\widehat{N_j/O_j}}) + \gamma_{ij}\,(\dot{O}_j)\right]$$

where dots refer to percentage changes and γ_{ij} is the proportion of workers in occupation i employed in the jth industry.[5]

In this paper equation (2) is treated as a conditional predictor of shifts in the demand for skill i in a three equation model, with demand schedule (in log change form):

$$(3)\quad \dot{L}_i = \dot{D}_i \cdot \eta_i \dot{W}_i$$

and supply schedule

$$(4)\quad \dot{L}_i^s = \dot{S}_i + \epsilon_i \dot{W}_i$$

where $\dot{L}_i$ = log-change in number demanded

η_i = average elasticity of demand for ith occupation

$\dot{W}_i$ = change in wages

$\dot{L}_i^s$ = log-change in number supplied

ϵ_i = elasticity of supply

$\dot{S}_i$ = exogenous changes in supply, due, say, to demographic developments

[4] This puzzle is stressed by Griliches in, "Notes on the Role of Education in Production Functions and Growth Accounting," in W. Lee Hansen, ed., *Education, Income and Human Capital*. National Bureau of Economic Research, 1970.

[5] Since $\alpha_{ij} = N_{ij}/N_j$ where N_{ij} = number of workers in ith occupation and jth industry, when we take percentage changes $\Delta D_i/D_i = \sum_j \frac{\alpha_{ij}\Delta N_j}{D_i}$ =

$$\sum_j \frac{N_j \alpha_{ij} \Delta N_j}{D_i N_j} = \sum_j \frac{N_{ij}}{D_i} \dot{N}_j = \sum_j \gamma_{ij} \dot{N}_j$$

It is important to note that whereas the α_{ij} give the distribution of workers in the jth industry among occupations, the γ_{ij} gives the distribution of workers in the ith occupation among industries.

For simplicity, the analysis focuses solely on developments in a single occupatio though extension to the case where wages change in other occupations, includii supply and demand cross-effects, is direct.

The solution of (2)-(4) is a relation between the forecasted change in mai power requirements (and supply) and employment or wages in the ith occup. tion:

$$(5)\ \dot{L}_i = (\epsilon_i \sum_j \gamma_{ij}\dot{N}_j + \eta_i \dot{S}_i) \,/\, (\epsilon_i + \eta_i)$$

$$(6)\ \dot{W}_i = (\sum_j \gamma_{ij}\dot{N}_j - \dot{S}_i)/(\epsilon_i + \eta_i)$$

Equation (5) shows that holding supply fixed ($S_j = 0$), the fixed coefficient mode will forecast employment perfectly for any given shift in demand for labor wher either the elasticity of demand is zero or the elasticity of supply is infinite. With finite non-zero values of both parameters, D will exaggerate the effect of shifts in demand on employment due to the neglect of economizing behavior. Given outside information about relative elasticities, however, it would be relatively simple to correct for this effect.

Empirical application

This study applies versions of the augmented requirements model (2)-(4) to two types of data: Changed cross-section comparisons of over 200 3-digit occupations in the U.S.; and time series evidence on the relative position of college graduates. Since the changed cross-section data measure the relative positions of various occupations in two time periods, strong simplifying assumptions are needed to apply the model. First, to estimate elasticities from these data, it is assumed that all occupations have the same elasticity of demand and that the elasticity is unaffected by the industrial structure of employment. Second, in the absence of data on which occupations are especially good or poor substitutes for other, the calculations contrast wage changes in each to the average change in the entire sample, implicitly assuming that there are no particular interconnections among them.[6] Third, since the purpose of this paper is to examine the fixed skill structure model, the factors that determine industrial output and employment, including feedback from wage and related labor market developments, are also ignored. Industrial employment is taken, as is usual in requirements work, as given from other parts of a larger economic model. All of these assumptions are restrictive and, given additional information, should be relaxed. In one sense, they are the price that is paid for the large number of detailed occupations covered in the analysis.

2. Changes in the U.S. skill structure

The augmented requirements model (2)-(4) is applied in this section to changes in occupational employment in the U.S. in the 1950-1960 decade, using data on 228 detailed 3-digit occupations from the U.S. Census of Population. To calculate the requirements shift in demand, an industry-occupation matrix was estimated from Census data for the base year 1950, using 142 detailed industries. Skill coefficients were computed by dividing occupational employment by total employment in each industry. Following equation (1) the coefficients were then multiplied by the number of employees in the industry in 1960 and summed across industries to yield a 'manpower requirements' prediction for 1960. The logarithmic difference between this figure and actual 1950 employment is the

[6] This is a first-order approximation which will be improved in later work

measure of predicted change in employment. A similar computation for 1940 is made by 'backwards projection' with the 1950 industry-occupation matrix, producing a statistic which is used to indicate gradual changes in average skill coefficients in years past. This statistic (T, for technical coefficients) will positively affect demand in the fifties if the same patterns of change in coefficients continue in a positive autoregression manner.

Changes in the supply of workers to each occupation ($\dot{S}i$) are estimated by applying the 1950 sex and education distribution of workers by occupation to the 1960 number of workers in the relevant category. Additional data on income, unemployment, and related statistics were also obtained and used to estimate equations (3)-(6).

Changes in the occupational structure

The overall pattern of change in the occupational and industrial structure of the U.S. work force in the decade under study is examined first in Table 8.1, which reocrds the logarithmic changes and standard deviation of changes in employment and income.

Table 8.1
Logarithmic Changes in Employmement and Income in the U.S., by Detailed Occupation and Industry, 1950-60

	Logarithmic Changes in					
	Employment			Income		
	Mean (1)	Standard Deviation (2)	Coefficient of Variation (3)	Mean (4)	Standard Deviation (5)	Coefficient of Variation (6)
Occupational Changes						
Average, 228 occupations ..	.095	.412	4.35	.46	.086	.18
Ten fastest growing	1.250	-	-	.58	-	-
Ten slowest growing	-.868	-	-	.46	-	-
Industrial Changes						
Average, 142 industries	.140	.290	2.07	.52	.082	.16
Ten fastest growing	.77	-	-	.61	-	-
Ten slowest growing	-.45	-	-	.51	-	-

Source Data calculated from U S Census of Population 1950
Industrial Characteristics PE-No 1D
Occupational Characteristics PE-No 1B
Occupation by Industry PE-No 1C

U S Census of Population 1960
Industrial Characteristics PC(2) - 7F
Occupational Characteristics PC(2) - 7A
Occupation by Industry PC(2) - 7C

What stands out in the table is the enormous variation in the change of employment. The ratio of the standard deviation of the change in employment to its mean value is over 4 in the case of occupations and over 3 for industries. In the ten fastest growing occupations, employment increased by roughly 125 percent compared to a decline of 87 percent in the slowest growing; among industries, the differential is similar, +77 percent versus -45 percent. By contrast, the coefficient of variation for the change in incomes is relatively modest, on the order of one-fifth, and while income increased less rapidly in slow-growing than in fast-growing occupations or industries, the difference is only about 10-15 percentage points. The occupational and industrial structure of the work force is, it is evident, much more variable than the wage structure—a pattern which could be due either to: substantial changes in demand for labor along elastic supply schedules; or, alternatively, substantial shifts in supply along an elastic demand schedule. Ensuing empirical work strongly supports the elastic supply interpretation and suggests, in general, that the supply of workers to occupations is relatively elastic and stable, while the demand for labor skills is more dynamic or unstable and less elastic with respect to wage changes.

Regression estimates

Regression analyses of the reduced form relation between shifts in demand for labor skills, estimated by the requirements methodology, and actual changes in employment in the 228 occupations under study are contained in Table 8.2. Panel A deals with logarithmic changes in employment, with observations weighted by the number of workers in the coccupations in 1950; panel B presents results with absolute changes in shares of employment as the dependent variable. In addition to the demand ($\dot{D}$) and supply shift ($\dot{S}$) variables, the difference between 1940 actual and predicted employment ($\dot{T}$) and the 1950 level of employment (Lo) are entered as explanatory variables. Lines 1 and 4 of the table show that, by itself, the requirements calculations give a reasonably good explanation of changes in employment, accounting for 44 percent of the log changes and 55 percent of the share changes in employment. The other variables introduced in lines 2 and 4 also affect employment in the expected manner, with $\dot{T}$ and $\dot{S}$ raising employment and the larger occupations having a modestly smaller log growth than the smaller occupations. When, moreover, the sample of occupations is reduced to focus on those for which occupational definitions change least between the Censuses (line 3) or increased to include agricultural occupations, where the industrial-occupation link is virtually one to one (line 6), the explanatory power of the model is enhanced. Finally, additional experiments with other specifications—involving unemployment, weeks worked, and the like—yield similar results As a first approximation the requirements and augmented requirements model do a tolerable job in accouting for changes in occupational employment.

Table 8.3 pursues the analysis of demand a step further with two stage least squares regression estimates of the structural demand equation of the model, using the average full-time wage and salary income of men and women as the first stage measure of wages. The mean years of schooling in each occupation and the inverse unemployment rate are entered as additional explanatory variables to see whether or not, even with inter-industrial shifts in demand fixed, there was a bias toward more educated occupations in the fifties and whether employers altered their demand for skills toward those with excess supply, wage incentives held fixed.

Table 8.2
Growth of Employment, By Occupations

Equation Number	Constant	*Regression Coefficients and t-Statistics* $\dot{D}$	$\dot{T}$	$\dot{S}$	Lo	R^2
		Panel A: Logarithmic Equations				
1	-.064	1.15				.44
		(13.0)				
2	.088	1.00	.11	.37	-.013	.49
		(9.86)	(3.50)	(2.72)	(1.70)	
3a	.077	0.94	0.13	0.18	-.017	.68
		(7.26)	(2.55)	(0.66)	(0.94)	
		Panel B: Share of Employment Equations				
4	.077	0.80				.55
		(16.43)				
5a	0.15	1.38	0.08	0.12		.65
		(14.04)	(4.29)	(5.52)		
6b	0.16	0.97	0.08	0.04		.78
		(28.25)	(3.76)	(3.63)		

Numbers in parentheses are t-statistics.
a) sample restricted to occupations whose definition did not change from 1940 to 1950.
b) sample including agricultural occupations.
Source: Basic data from U.S. Census of Population 1940, 1950, and 1960, as in Table 8.1.

Table 8.3
Structural Demand Equations

Equation Number	Constant	$\dot{W}$	$\dot{D}$	$\dot{T}$	YRS a	1/(UNE) b	R^2
1	0.12	-0.64	0.97	0.11	0.02		.48
	(1.06)	(3.00)	(8.90)	(3.38)	(2.19)		
2	0.04	-0.61	0.93	0.10	0.03	-0.26	.49
	(0.31)	(2.81)	(8.44)	(3.09)	(2.97)	(1.99)	

Dependent variable is log-change in employment; equation estimated by two-stage least squares. Numbers in parentheses are t-statistics. Wages are obtained as a weighted average of the wages of men and women, using the sex composition of the occupation as weights.
a) Mean Years of schooling in occupation
b) Inverse of rate of unemployment in occupation in 1950
Source: See Table 8.2

The principal finding of the regressions is that both the requirements shift and wage variables have their expected effect on changes in employment, with $\dot{D}$ obtaining an approximately unity coefficient, and $\dot{W}$ an elasticity on the order of -.6. In addition, the past 'change in technical coefficient' ($\dot{T}$) has a significant positive effect, indicating that despite the peculiarities of the 1940-1950 decade, occupations that had greater than predicted increases in demand then also experienced greater increases in the fifties. Finally, years of schooling obtains a positive regression coefficient, revealing a shift in demand toward more educated occupations, all else held fixed, while the inverse unemployment has a negative impact on growth of employment, suggesting some independent effect of the unemployed pool on demand.

The relative importance of shifts in demand and movements along the demand schedule due to changes in wages in the differential growth of occupational employment can also be estimated from the regression results. Multiplying the wage and $\dot{D}$ coefficients by their standard deviations to obtain the relevant B-weights yields .03 and .23, respectively—indicating that requirements shifts are more important explanations of differential expansion of demand for labor-skills than movements along a demand curve, though the latter are also at work.

In sum, Tables 8.2 and 8.3 show that skill coefficients are sufficiently stable for requirement calculations to provide a good measuring of decadal shifts in the demand for disaggregated labor skills. Even so, however, there were significant nonrandom changes in the coefficients within industries, to which we turn next.

Intra-industrial skill changes

To begin with, the amount of change in occupational structures varies greatly by industry. Measured by the sum of absolute values of differences between the 1950 and 1960 proportion of workers in each occupation ($\sum_i |\Delta a_{ij}|$ for all j), the data reveal substantial change in some industries (transportation services (.39) office machinery (.29) and aircraft (.30) and little change in others, such as apparel (.03) or furniture (.07). Analogously, the direction of change also turns out to vary greatly among industries, with, for example, office machinery experiencing a sizeable increase in professional employment (from 7.7 percent to 17.8 percent of the work force) at the expense of craftsmen while craft employment increased in the telegraph industry, and so forth. More interestingly, despite the complexities of technological developments, the amount of change in skill structures varies in a comprehensible manner. Industries that do a lot of R&D work or have made considerable investment in new plant and equipment or have been growing rapidly tend to experience the greatest amount of structural change. In manufacturing, as the following regression shows, over half of the variation in structural change by industry is explicable by differences in R&D per dollar of sales and in the ratio of investment to capital:

$$CSC = .06 + \underset{(2.40)}{.08\ I/K} + \underset{(4.71)}{.12\ RD/S} \qquad R^2 = .53$$

where CSC = change in skill coefficient, 1950-1960: $\sum_i |\Delta a_{ij}|$

I/K = ratio of new investment, 1947-1958 to capital stock, 1947[7]

RD/S = ratio of R&D spending to sales, 1957[8]

numbers in parentheses are t-statistics

Addition of the growth sales ($\dot{S}$) also contributes to the amount of change in the job structure, as would be expected if rapid growth requires changes in production methods.

$$CSC = .05 + \underset{(2.48)}{.07\ I/K} + \underset{(2.44)}{.12\ RD/S} + \underset{(2.41)}{.05\ \dot{S}} \qquad R^2 = .64$$

[7] Investment data are taken from U S Department of Commerce *Annual Survey of Manufacturers*, capital stock, from Harvard Economic Research Project, 1947 capital stock data

[8] R&D to sales data taken from National Science Foundation (NSF 64-9), with adjustments for difference between NSF and Census industry definitions The adjustments of allocated expenditures to industries on the basis of their relative employment of scientists and engineers, are reported in the Census

While these data are not available for the entire 142 industry sample, a comparable measure of R&D activity—the 1950 ratio of scientists and engineers to total employees in each industry—is highly correlated (r = .60) with the ensuing decadal change in skill structures. We conclude that structural change within industries can be viewed as the outcome of research and scientific-technical work, and other economic factors, which makes identification of industries with likely future changes in skill structures possible.

The extent of substitution due to rising wages in altering skill structures can also be estimated from the industry-occupation matrices. To do this, the change in industrial wage is decomposed into three parts, due to: changes in the wages of occupations employed in the industry $(\Sigma_i S_i \dot{W}_i)$, where S_i is the cost share of occupation i in the industry's wage bill in the base period); 'autonomous changes' in skill coefficients, at previous wage levels $(\Sigma_i S_i \dot{a}_{ij})$, and an interaction term $(\Sigma S_i \dot{W}_i \dot{a}_{ij})$. If each industry takes occupational wages as given and substitutes against those with the most rapid increases, the interaction term will be negative. In fact, between 1950 and 1960, 103 of the 1942 industries had negative interaction terms, suggesting a general pattern of substitution against skills whose wages rise rapidly.

Supply of young workers

The supply side of the occupational labor market is examined next in Table 8.4, which records the results of regressing changes in the number of 20-29 year old men, who were likely to have made career decisions in the fifties, on: $\hat{W}_i$ the

Table 8.4
Changed Supply of 20-29 Year Old Men to Occupations, 1950-1960

	Regression Coefficients and t-Statistics[a]						
Dependent Variable	Constant	W	L_o	W_o	S^b	Est. tech.	R^2
1. Men, 20-29	-2.36	1.18	-.04	0.30	0.90	OLS	.21
		(2.40)	(2.57)	(1.66)	(2.83)		
2. Men, 20-29	-2.25	3.69	-.07	0.12	0.80	TSLS[c]	.11
		(3.64)	(3.54)	(0.72)	(2.39)		
3. Men 20-29, t or more years of college	-6.02	3.00	-.06	0.60		TSLS	.10
		(3.14)	(3.18)	(4.87)			
4. Men, 20-29, less than 2 years of high school	-3.07	3.65	-.08	0.23		TSLS	.12
		(3.77)	(4.69)	(1.54)			

a) All dependent and independent variables in logarithmic or log difference form

b) $\hat{S}$ measured by taking a weighted average of the log changes in the number of a 20-29 year olds with varying levels of education, with weights set by the 1950 educational distribution of men by occupation

c) OLS = ordinary least squares
TSLS = two stage least squares

changes in income in each occupation; L_o the number of 20-29 year olds in 1950; and the base year (1949) income W_o. The latter term is designed to capture supply responses to post-World War II disequilibria in the wage structure. Regressions 1 and 2, dealing with the entire 20-29 year old group, include a measure of 'autonomous changes' in supply, based on the educational distribution of the occupation; regressions 3 and 4 focus more narrowly on men with selected levels of education. The key result of the calculations is that changes in wages were important in directing young men to various occupations, with an elasticity above unity in OLS computations and ranging from 3.5 to 4.0 in TSLS regressions where W is endogenous. The other estimated coefficients show only a small effect for the lagged number of persons in the occupation and a moderate response to initial wage differentials. Changes in the relative supply of young men to occupations—the ultimate determinants of the long-run supply of workers—this appears to be quite elastic with respect to wages, making requirements calculations applicable to cross-sectional changes of the type under study.

2. Changes in relative incomes, 1949-1973

This section applies the fixed coefficient model of shifts in labor demand to the Griliches' 'puzzle' of relatively constant or rising educational income differentials in the U.S. It shows that the relative income of highly educated workers was maintained in post-World War II years by an increase in relative demand due to changes in the industrial structure of employment. At the outset of the 1970's, demand began to level off while the supply of educated manpower continued to increase, causing previously stable income ratios to decline.

Salaries, supply and demand

Table 8.5 presents the basic time series evidence on changes in skill differences, relative supplies, and demand for highly educated workers in the U.S. Column (1) records the ratio of the income of college graduates to high school graduates; column (2) gives the ratio of the more volatile starting salaries of college men to average wages; columns (3) and (4) show the relative supply of old and new college graduates; and finally, columns (5) and (6) give the ratio of a requirements index of demand for college graduates, obtained by weighting employment in 46 industries by 1960 proportions of college workers, to the comparable index for high school graduates and all workers. The table shows that the relative income for all and starting college graduates rose in the 1950's-early sixties, despite increases in relative supply—the puzzle requiring explanation. It also shows, however, that relative demands increased (columns 5 and 6) and that both relative salaries and demands began to level off or decline at the end of the decade, with the ratio of starting salaries to average wages (column 2) falling sharply at the outset of the 1970's.

Taking the supply of college workers and the requirements demand as given, the role of supply and demand shifts in the educational income differential can be evaluated by least squares regressions of the differential on the relevant supply and demand variables. When the ratio of college to high school graduates income is used, the sample is limited to 14 data points; with ratio of starting salaries, every year from 1948 to 1973 can be used. The results of the regressions, summarized in Table 8.6, suggest that shifts in labor demand due to the changing mix of industrial employment were, as asserted, critical in raising or maintaining the college-high school differential in the face of rising supplies. In line 1, the demand index has a significant positive effect and the relative supply variable a modest negative impact on salaries. In line 2, where the more sensitive starting salary variable is used and the number of observations increased, the results are stronger. Even here, however, the coefficient on the demand shift and supply variables are not equal in magnitude, as would be the case in a perfectly specified model. This proviso notwithstanding, the puzzling pattern of college-high school income ratios appears to be resolved by taking account of shifts in demand in the augmented requirements model. Analysis of the factors underlying the shifts in industrial employment and output, which range from changes in the demographic composition of the population to Federal R&D spending to differential income and price elasticities, lies beyond the scope of this paper.

Conclusions

The findings of this paper can be summarized briefly: (1) fixed coefficient manpower requirements calculations are best interpreted as conditional estimates of shifts in labor demand schedules in the context of standard supply-

Table 8.5
Relative Incomes, Supplies and Requirements Indices of Demand, by Level of Education

	Ratio of College Grad. to H.S. Grad. Income	Ratio of College Starting Salary to Ave. Earnings[a]	Ratios of Employment		Ratios of Demand Indices	
			College Grad. to H.S. Grad.	B.A. to Total Employ-ment	College to' H.S.	College to Total
1950	——	.99	——	0.75	.86	.87
1952	——	1.00	——	0.53	.90	.86
1954	——	1.10	——	0.43	.91	.90
1956	1.37	1.14	.37	0.44	.93	.92
1958	1.35	1.19	38	0.53	.98	.97
1961	1.39	1 17	40	0.54	1 02	1.02
1963	1.33	1.19	44	0.58	1.05	1.05
1965	1.41	1.18	.45	0.67	1.08	1.08
1967	1.45	1 24	46	0.72	1.12	1.13
1969	1.45	1.24	.47	0.87	1.13	1.14
1970	1.45	1.22	48	0.95	1.15	1.17
1971	1.44	1.16	.49	0.99	1.17	1.18
1972	1.43	1.13	50	1.00	1.18	1 19
1973	1 36	1.09	52	1.01	1.19	1 21

a) calculated as weighted averages of starting salaries of engineering accountant sales and general business trainees

Incomes in column 1 are ratios of median incomes of men with 4 or more years of college to men with 4 years of high school

Sources U S Bureau of Census *Current Population Reports* Series P-60 various editions U S Department of Commerce *Survey of Current Business* for average earnings F Endicott *Trends in the Employment of College and University Graduates in Business and Industry* Weights for indices from U S Census of Population 1960 *Industrial Characteristics* demand analysis. Requirements do a reasonably good job of estimating decadal demand shifts for disaggregated occupations and, because the supply of labor is relatively elastic, of employment as well. (2) While skill coefficients are sufficiently stable for the requirements model to work, there is a discernable pattern of change in coefficients among industries. In the 1950-60 decade, industries that did considerable research and development, made substantial investment, or expanded rapidly had the greatest change in skill coefficients. In general, industries also tended to reduce employment of occupations with rising wages. (3) The postwar pattern of change in educational income differentials can be explained in terms of requirements shifts in demand and changes in the relative supply of highly educated workers. As supplies increased rapidly at the outset of the 1970's and relative dr nd for college workers levelled off, the relative starting salaries of graduates began to fall rapidly and the relative income of all college men dropped modestly. The implication for the future is that, unless the number of students going to college falls or demand begins to increase at the rapid rates of the 1960's, the college-high school premium will fall.

Table 8.6
Regression Estimates of the Effect of Shifts in Manpower Requirements and Supply on the Relative Income of College Graduates[a]

Dependent Variable[b]	Constant	Relative Demand Index	Relative Supply	R^2
1. Income, college to high school men, 1956-1972[c]	-2.69	.87 (.60)	-.41 (.45)	.63
2. Starting salary, college men to average hourly earnings, 1948-1972	-9.35	.81 (.08)	-.16 (.04)	.84

a) Numbers in parentheses are standard errors of estimate
b) All dependent variables are in logarithmic form
c) Excludes 1957 1960 due to absence of data

Source See Table 8 5

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9. Scientific Manpower Forecasts From the Viewpoint of a Dismal Scientist

This chapter is based on the oral presentation of Dr. Oi and on his paper. The lead discussants were Herman Travis, U.S. Department of Labor, and Lewis C. Solmon, National Research Council.

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As the title of the paper suggests, these remarks follow in the tracks of Malthus, Ricardo, and Adam Smith. In reviewing the literature, the whole demand, market response to the demand, and other issues were considered in the context of an economist viewing a commodity, that commodity being forecasts.

Societies have always sought information about the future. Important public and private decisions about the allocation of our resources are based on forecasts, and presumably better information about the future can lead to a better allocation of resources provided that the information is reasonably accurate. If the information is not correct at least 70 percent of the time, the actions that will be taken in light of the predictions will tend to destabilize rather than stabilize the system under consideration.

The forecasting industry has indeed been one of our growth industries over the course of the last two or three decades. However, the products are heterogeneous. The forecasts are very different in quality. Professor Folk has pointed out one common attribute of projections, predictions, and conditional forecasts, and that is they are used as forecasts. Despite the label, policy-makers will use them as predictions.

Scientific manpower forecasts are not only part of the many forecasts demanded by the public sector. Why does the public sector demand forecasts? There are at least three reasons that help to explain this public demand. First, benefit-cost analyses of capital investment projects with long pay-out periods must rely on forecasts to measure the present value of beneifts. Second, evaluation of a government agency is typically accomplished by compiling massive quantities of data. The availability of these data greatly reduce the costs, and when the "price" of a forecast is lowered, there is a rise in the quantity of forecasts demanded. Third, it has been emphasized by Kenneth Arrow[1] that information is

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1 Arrow, K J "The Organization of Economic Activity Issues Pertinent to the Choice of Market vs Nonmarket Allocation," in *The Analysis and Evaluation of Public Expenditures The PPB System*, Joint Economic Committee, Vol 1 (U S Government Printing Office, Washington, D C , 1969) pp 47-64

a commodity unlike other commodities in the sense that once produced the cost of disseminating the information to another party is virtually zero. Therefore, once produced, information should be widely disseminated. If left to private markets, not enough information will be produced. Thus, according to Arrow, it is the role of government to provide information about future states of the world.

When it comes to manpower forecasts, a number of other rationalizations have been developed on why we need more and better forecasts. Some of these are:

1. Forecasts are needed as a part of a manpower planning system to balance supplies and demand.
2. Forecasts are needed to help us formulate public policy.
3. Forecasts are needed to provide information to students.

Implicit in these many reasons for needing scientific manpower forecasts are a number of hypotheses which do not appear to have been empirically validated. For example, in the absence of publicly supplied manpower forecasts and policies, the labor markets for trained scientists will be inherently unstable with recurring cycles of manpower surpluses and shortages. This is the so-called "cobweb" that Professor Freeman talks about.

It appears that the evidence which Freeman cites is contradicted by the data supplied by Professor Folk. It seems that the question of whether or not labor markets are inherently unstable has yet to be resolved. Yet instability of labor markets is one of the rationalizations for more forecasts.

Three Kinds of Forecasts

We are interested in the information content of three kinds of scientific manpower forecasts: (1) the academic requirements for new doctorates, (2) the manpower requirements for specific occupations, and (3) the supplies of college-educated workers.

Academic requirements for new doctorates. Professor Allan Cartter[2] was the first to dramatically illustrate the possible numerical magnitudes of the imbalance between projected requirements and supplies of new doctorates. More recently Balderston and Radner[3] have developed a more complicated model. Some comments on these models follow, but a more complete treatment is given in my formal paper.

The model that is implicit in these projections is a form of a fixed coefficient model. Although Balderston and Radner disaggregate the system into six sectors of higher education—public versus private, university, four-year and two-year colleges—the essential features of the model are described by a system of three equations. In the first equation, the new doctorate requirements are assumed to

[2] Cartter, A M "Scientific Manpower for 1970-1985" *Science* (April 9, 1971) Vol 172, pp 132-140

[3] Balderson, F E, and R Radner "Academic Demand for New Ph D's, 1970-1990. Its Sensitivity to Alternative Policies." University of California paper, p 26, 1971

be some proportion P of the demand for new faculty with and without degree: The second equation says that demand for new faculty arises from two considerations: (1) replacement demand for those incumbent faculty members wh retire or withdraw from academia, and (2) the net change, which is determined b student-faculty ratios. The third equation states that the number of faculty i proportional to the number of students.

If one solves these equations, a very simple reduced form is obtained which can be approximated by equation 2.3(b) in the paper. One can then disaggregate the forecasts or projections of the academic demand for new doctorates into several components. This disaggregation shows that in all these models the new doctorate requirement depends critically upon three parameters—the marginal doctorates/student ratio, projected student enrollment, and student/faculty ratio. Hidden in this is the enrichment factor in the proportion of new doctorates.

If one asks what information is obtained from these projections, it becomes quite clear that the information we obtain is determined by what is assumed about the three parameters described above. The reduced form equation shows how the model is driven, and it appears that the so-called sensitivity tests become rather trivial exercises. Thus, the information obtained is really what someone else has projected about student enrollments together with what is assumed about the marginal doctorate/student ratio.

The BLS projections of occupational requirements. Projections of manpower requirements for specific occupations have been developed by the Bureau of Labor Statistics for many years. The equations that are used to project industry employment cannot be interpreted as labor demand equations. They are naive, reduced-form equations that totally ignore the fact that observed employment in prior years was determined by the market forces of demand and supply. If short-run supply is extremely elastic (implying that workers can easily shift from one occupation to another), there is little to be gained from projecting manpower requirements for that occupation. Why worry about producing a requirement projection for an occupation where supplies can adjust to demand requirements very, very quickly? The need is to get projections which can be potentially useful for public policy.

The supply of college graduates. The implicit model in all of the supply projections of college graduates is simply a distributed lag function of population. It is claimed that the intent of projections is to tell us the implications of trends. However, current methodology does not make a serious attempt to explain temporal fluctuations in trends. These trends are changing. Thus the information contained in these projections does not appear to be very useful from a policy viewpoint.

Production and Employment of Doctorates

I will discuss a preliminary theoretical model describing the production and employment of doctorates. The complete model is presented in Section III of the formal paper As Professor Breneman has pointed out, the decision to invest in a doctorate degree can be viewed, in part, as an investment in human capital. This decision can be broken into two parts. (1) the supply of applicants for graduate study, and (2) the demand for graduate students by universities.

What determines the supply of students who are going to seek Ph.D. degrees? Previous studies have looked at data on the continuation rate from bachelor to first enrollment in graduate school. If that ratio has remained stable, the assumption was it will remain stable into the future. If it has dropped, some ad hoc explanation such as the draft is offered.

If we view the supply of doctorate students from the context of an optimizing decision model on the part of the students, then there are at least four considerations which must be included in the model:

1. The earnings differential that can be expected from the investment in a doctorate.
2. Costs—both outlays and opportunity costs.
3. The probability of success.
4. The search for a career.

What is the earnings differential that one can expect from the investment in a doctorate? In terms of 1960 dollars, for both academic and nonacademic doctorates combined, the difference in earning streams between the ages of 26 and 64 years at different discount rates is roughly as follows: (a) at zero interest rate the Ph.D. will earn approximately $36,000 more than a bachelor's degree; (b) at a 5 percent interest rate a Ph.D. will earn approximately $10,000 more than a bachelor's degree; and (c) at a 10 percent interest rate a Ph.D. will earn approximately $4,000 more than a bachelor's degree.

If one considers the costs of education, two concepts are pertinent. The first is called *outlays*. The student who chooses to pursue a Ph.D. degree has the expenses of tuition plus room and board. In 1960 these costs were approximately $1,700. Currently these costs are approximately $4,200 for a private school and $2,400 for a public university. These outlays do not include stipends or tuition waivers. They are the out-of-pocket costs of choosing to enter graduate school rather than to enter the labor market. The second cost is the *opportunity cost* of income which one would forego if one enrolled as a graduate student rather than earning income as a bachelor. If one combines opportunity cost with outlays, the costs of a Ph.D. degree for a period of four years at 5 percent interest is in the order of magnitude of about $43,000 today and was about $22,000 in 1960.

A comparison of costs to earnings for all doctorates shows that the rate of return on investment is very low. It is roughly a 3 to 4 percent return. However, if the individual goes into non-academic employment, then the rate of return is in the neighborhood of 8 to 8.5 percent—a quite profitable investment.

The third consideration is the propability of success. It can be argued, however, that the probability of success is not a very important consideration at the initial decision point. The student is faced with uncertainty and lack of information at the time the initial decision is made.

Robert Hall,[4] Banfield[5] and a number of others have pointed out that a characteristic of youth is uncertainty. They are *searching*. They do not know what they want, and there is virtually no way to get information about a career choice in academia other than by trying it. There are two implications that seem perti-

[4] Hall, R E "Turnover in the Labor Force," *Brookings Papers on Economic Activity*, 3 (1972) pp 709-704

[5] Banfield, E C *The Unheavenly City*, (Little, Brown and Co., Boston, Mass 1970)

nent to the present discussion. First, if the cost of the search is lowered, more search will be demanded. The number of searchers and the duration of time spent in the search activity will increase. The offer of stipends, tuition waivers, etc., will greatly reduce the cost of search. Thus, if the person wants to gain more information about career choice, it pays to enroll in graduate school. Second, wealthier individuals typically demand more leisure, and for them the nonpecuniary attributes are usually more important than the pecuniary ones. Nonpecuniary attributes are harder to discover without search. Given the wealth of parents today, significant numbers of students are enrolling in graduate school to search out additional options. There is a value to the search. Further, casual evidence suggests that the wealthier the individual, the more likely they are to enter graduate school in search of a suitable and desirable career. There are other nonpecuniary attributes. The lifestyle of the Ph.D. is very different, and people do seek it for the prestige, recognition, and other values.

The National Science Board and others will claim that the doctorate represents a high level of training that prepares persons for jobs that could not otherwise be performed. Although this is correct, one must recognize the nonpecuniary attributes, of having that degree so the straight equating of monetary returns to monetary costs will not yield the whole story on what determines the supply of graduate students.

Professor Ashenfelter[6] surveyed college seniors, mainly in northeastern colleges, to ascertain their intentions of attending graduate school, and show how sensitive these decisions are. If one plots the series of first-time graduate enrollment, they rise steadily between 1961 and 1966-67, then there is a sharp turnaround in professional sch ls, in the sciences, and in the humanities. If one then plots Federal fellowship assistance in constant dollars per graduate student enrolled, the peak in this series also hits right around 1966 or 1967. There is not a clear cause and effect relationship, but the relationship between Federal and State funding and the first enrollment rate must be considered. Funds are fungible, as Breneman and others pointed out earlier at this meeting. If an increase in Federal support frees funds to be given for fellowships to humanities majors, then one sees a distorted picture. What is needed is the total amount of stipend and tuition aid that is being granted.

Let me close with some implications derived from possible university response to changing conditions and some thoughts on how one ought to validate the supply and demand projections that NSF, Professor Cartter, and others have made. The trends that have been observed are clearly the results of private and public decisions to enter graduate school and pursue a Ph.D. degree. Of those who begin, the percentage who complete their degrees varies widely across fields, and there seems to be some indication that these percentages vary over time. One in every nine Ph.D. degrees requires at least fifteen years beyond the bachelor to complete. Thus at any point in time there is a huge inventory of Ph.D.'s in process with all but dissertation completed.

A trend extrapolation simply tells what is likely to happen if the variables which influence the public and private decisions follow the same trends as they have been doing over the period which these trends have been tracked (essential-

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[6]Ashenfelter, O. "Some Evidence on the Response of the Students' Graduate Career Plans to Market Forces" (unpublished paper, Princeton, Nov., 1971)

ly five years in the NSF model). If forecasts are to be useful, they should provide a basis for policy decisions. What will NSF do, given the forecasts which show that at worst one in five doctorates and at best one in twenty will be underutilized? What actions will be taken? Will they cut research grants to private institutions? If so, how will this affect the market for Ph.D.'s? How does this fit into their objectives to provide the nation with an adequate supply of highly trained people?

If the policy-makers are going to utilize projections in formulating a rational public policy toward higher education, they must begin to study the factors which generate the trends. To focus on the numbers themselves, on the projections, is insufficient.

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Usually, a projection should not be made if it does not rely on assumptions that are reasonably probable. This, in effect, makes it a forecast. Projections essentially forecast what should be expected under stated probable conditions, but they do not ordinarily include a second order of estimation which attempts to show what would happen if users of those projections, believing them, take some other than projected action to profit from or mitigate the consequences of the original projection. Thus the distinction between projection and forecast takes on some meaning. If a projection is used as a basis for policy decision or individual decision, the projection may well be defeated, although it might have turned out to be accurate had there been no reaction to the projection.

In a complex society and in the course of nature, there are unforeseen events that can change outcomes. Therefore, one needs stated assumputions to allow some assessment of the reasons a projection did or did not achieve its outcome. By the same token, a range of projections should ordinarily be prepared, although there are problems here too, as we can tell from the progressive widening of Census Bureau population projection options which nevertheless failed to bracket reality.

There is no defense for either the errors or deficiencies of past projections that have been made, but an adeuqate case has not been made that a more accurate or more useful kind of projection can be constructed based on market models which provide for some reaction to the conditions and outcomes projected by the simpler models. Market models should be tried even though it also seems likely that, in the light of the wide degree of error prevailing in the basic data, neither the added variables required for market and econometric models, nor any extensive refinement in the degree of detail, would necessarily improve the accuracy or the usefulness of the projections resulting from such additional sophistication in technique.

There is merit in both what Dr. Oi says and what he criticizes. There is a need for explaining variations between projections and actualities in terms of measurable influences that affected the outcomes. Rather than using events as alibis, we ought to be looking for relationships between events and their effects on projected results. We should attempt to identify casual events which affect and are not merely coincidental with outcomes. However, immense caution is needed when tracking events and assuming there is a cause and effect relationship, even though the investigations should be made.

There is not really much difference between the econometric model and previous forms of projections. If carried out at a level of detail that is fine enough, the previous forms of projection perform the same function as equilibrium models when they introduce qualifiers to charted trends based on changing factors in the market.

We should consider also the problem of gross flows as the perspective within which to consider any realistic attempt to improve the accuracy of projected net changes. There are entries into categories, exits out of categories, and shifts between categories that are several orders of magnitude greater than the net changes we are basically interested in. If we rely on models that deal only with net balance changes, we are not only *not* going to reduce errors, but there is a great danger of coming up with grossly incorrect information.

Net change is the payoff that we must find when we can, but in addition I would suggest that more attention be paid to the immense flows in and out.

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National Research Council*

Dr. Oi presented some statements in his paper about evaluating the accuracy of demand or supply projections by looking at employment that actually occurs in the year for which the projection was made. This is because observed employment is a result of both the demand side and the supply side. Dr. Falk has estimates of 2.3 or 2.7 percent underutilization per year, but this underutilization will only be observed if the markets do not work and if prices (wages) do not change so that demand equals supply. What we will observe in employment in the years between now and 1985 will be the result of the interaction between demand and supply, and this will result in a certain level of employment and a certain wage level.

Rather than point projections which assume no change in variables like wages or non-monetary satisfaction, it might be more useful to project curves (demand curves or supply curves) based on different sets of wage assumptions or on different sets of estimates of non-monetary returns to certain kinds of jobs. Projections which ignore demand and supply are either assuming a particular wage structure or are assuming completely inelastic demand or supply curves. Simply ignoring markets, by not mentioning them, does not mean that one is making assumptions that markets have no effect.

In regard to another problem, it seems that with existing data we should be able to estimate the effect of wage levels on career decisions of scientists, and the

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effect of wage levels on demand and supply. This is particularly true if we believe in survey data. There is voluminous data available on surveys in which people have been asked the importance of various factors in career choice. Even though it is not fashionable to admit to selecting a job because of salary, the analyst can get some feeling for the power of wages in job determination. For instance, in the follow-ups to the American Council on Education Freshman Surveys, we could look at the employment decisions, and then compare these decisions with the responses on the survey regarding important factors in determining career choice. There are other studies of this kind, and I think it should be possible to test the validity of responses in terms of the state of the markets for various types of skilled employers, and hence to understand the relative impact of wages and markets on career decisions.

On another matter, this conference confirms my belief that the Freeman school should not be considered an alternative to the so-called extrapolation school or the Goldstein school. Insights from the work of those oriented toward the markets should be incorporated into the NSF-type projections. It doesn't appear to me that the new NSF projections have taken sufficient account of markets, despite claims by Dr. Falk and others to the contrary.

There are other types of studies which can be helpful in refining projections. If the data collected by the different professional societies could be coordinated, and if societies and social scientists with longitudinal data sets could begin collecting comparable data, we might be able to begin to understand why peoples' careers develop the way they do. We might obtain coefficients from analyses of past career patterns rather than make the kind of assumptions which are necessary in some of the current predictions. We can learn from the past, and one main reason for doing history is to improve the next round of projections.

One cannot neglect the fact that the United States economy does not work in a purely market sense. There are so many restrictions, rigidities, controls, regulations, etc., that reliance on market forces ends up with a reliance on a set of unrealistic assumptions. In the manpower business, government intervention has been very disjointed, more countercyclical than helpful.

Free markets and continuous curves are just not happening. There are tremendous shifts in supply and demand curves, and that is one reason the markets do not appear to work when the shifting curves are ignored. However, it is not only government that fouls up free markets. Private industry, professional societies, universities, and others, all introduce controls and rigidities into the system.

Let me give emphasis to the National Research Council's survey of doctoral scientists, *Doctoral Scientists and Engineers in the United States. 1973 Profile*[1], as it relates underutilization of talent and underemployment. Some summary numbers used in Dr Falk's presentation are just becoming available from this study. The unemployment rate for all doctorate scientists and engineers is roughly 1.2 percent. He adds that if doctorates who are working in non-science areas are considered to be underemployed, then the total figure goes to 2.2 percent.

[1] A report by the Commission on Human Resources Based on the 1973 Survey of Doctoral Scientists and Engineers. National Academy of Sciences, Washington, D.C., March 1977

Private and social rates of underemployment, however, can be differentiated. An individual can be underemployed from his own viewpoint, or he can be underemployed from society's point of view. A bank president earning $200,000 a year is probably not underemployed from his own point of view. Yet if it is assumed that this person has been trained as a scientist and his education was subsidized with the understanding that he would be using his science, then perhaps from society's point of view he is underemployed. By utilizing NRC's unpublished data together with the set of assumptions that those who are working part-time but seeking full-time employment, postdoctorates who took jobs because other jobs were not available, and Ph.D.'s teaching in the elementary schools are all underemployed, we can obtain a private underemployment rate in 1973 of 3.7 percent. Adding the number of those who from society's point of view might be underemployed the underemployment rate jumps to 13.2 percent. By some definitions, then, there is a substantial amount of underemployment. We hope that NRC's data will throw some light on how future projections will be affected by this underutilization of talent.

General Discussion

During the discussion which follows the presentations of Dr. Oi, Mr. Travis, and Dr. Solmon, comments and concerns were expressed as follows:

- There are market models which give drastically different forecasts of supplies than those being given under extrapolation models. It isn't a question of there being only one game in town. For example, Freeman and Breneman report on an econometric model of physics doctorates which forecasts drastically different supplies than some of the extrapolation models. It isn't a question of market people not having a workable model.
- Putting it another way, it is evident that there are not single parameters which control either the demand or supply for doctorates, but rather a complicated interaction of many parameters takes place. Professor Freeman's market model deals primarily with one parameter, wages. Dr. Oi and others speak of additional parameters, but the question is: Is it possible to disentangle the effects of these parameters so that coefficients or weighting factors can be established? Further, to what extent will the various parameters affect supply and demand?
- Unless an attempt is made to get an estimate of the elasticity of demand for doctoral faculty on the part of universities, and to get a better idea of the production function for Ph.D.'s, one is not in a position to utilize the information recieved by simply extrapolating trends. Once the extrapolation is made, what action do we take? Too much is being invested in projections, and not enough is being invested in understanding how markets are functioning.
- Basically, no one does a simple extrapolation. There are a number of parameters to be considered and these parameters are weighted during the extrapolation in the pragmatic way and sometimes the extrapolations are altered radically on the basis of anticipated new events or changes in trend, but it is in these steps that simplicity becomes fatal.

The trouble with judgmental weighting is that it produces uniform judge factors. We cannot tell if we are studying the behavior we are trying to study. Further, we cannot pin down the errors in our model, and we end up in a situation where there are no improvements.

- Although some have defended the current projection methodology of extrapolating trends, this paper seriously questions the wisdom of continuing this line of research which neglects the structure of labor markets for scientists.

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The formal paper prepared by Walter Y. Oi for this session appears below.*

Scientific Manpower Forecasts from the Viewpoint of a Dismal Scientist

Societies have always sought information about the future, and in earlier times, the task for foretelling future events was left to journalists, gypsies, and clergymen. Advances in the physical sciences greatly increased the accuracy of forecasts with respect to physical phenomena such as the movements of the stars and tides, and the location of oil deposits. More recently, the social sciences have achieved modest successes in forecasting the outcomes of elections, patterns of consumer expenditures, etc. Over the course of the last two or three decades, the forecasting industry has been one of our growth industries. Important public and private decisions about the allocation of our scarce resources have been based on forecasts. In this paper, I have three objectives.

First, I try to explain the reasons for the growth in the demand for scientific manpower forecasts. Second, the methodology which characterizes the available scientific manpower forecasts is critically examined in Part II. Finally, in Part III, attention is directed to the market for Ph.D.'s. Past and future levels of doctorate employment and earnings, as well as the production rate of new doctorates, are jointly determined by the market forces of demand and supply. The public funds that have been allocated to higher education in the past and that are likely to be in the future, are clearly important determinants of both the demand and supply of doctoral scientists. The extrapolation of recent trends of enrollment rates, of ratios of non-academic doctorates to R and D spending, etc., presupposes a very rigid structure of demand and supply that is incapable of explaining the historical data for the same variables. It is placing the cart before the horse. The formulation of rational policies toward higher education must begin with an understanding of the labor market for highly trained manpower, and the extrapolation of trends, however sophisticated, simply does not provide us with the necessary empirical information about the structure and functioning of these labor markets.

I—The Public Demand for Scientific Manpower Forecasts

Uncertainty is an unavoidable, and for many, a highly undesirable reality. Individuals and firms allocate part of their resources to protect themselves against the contingent costs of certain risks.[1] In addition, the private sector is

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prepared to pay for information about future uncertain states of the world. A complex structure of institutions has indeed evolved to provide such information. Firms like Value-Line, totally ignoring the random walk hypothesis, purport to be able to predict the stock market. Corporations hire economists and statisticians to forecast sales and market conditions. Although it is less obvious and informal, when students and consumers demand the services of psychologists, clergymen, vocational and educational counselors, they are to some extent, demanding information about future uncertain states of the world. No census classification exists, but there is clearly a "forecasting" industry whose product is forecasts, information about future uncertain states.

Whatever is demanded by the private sector will almost surely be demanded by the public sector, and forecasts are no exception. Scientific manpower forecasts (SMF) constitute only part of the forecasts demanded by the public sector. At least three reasons can be offered to explain this public demand. First, benefit-cost analyses of public projects with long payout periods must rely on forecasts.[2] The production of highly trained scientific manpower surely involves an investment whose payout period extends over the lifetime of the trained scientist, but this does not explain why forecasts of the returns ought to be made by the government. Second, the evaluation of a government agency is typically accomplished by compiling massive quantities of data because the performance of an agency is not subjected to the same market tests of profitability and survival which apply to the private sector. The availability of large amounts of data greatly reduces the cost of developing forecasts, and when the "price" of a forecast is lowered, more of them will be demanded. Third, information differs from other economic goods because the seller of information (especially about the future) is unable to appropriate *all* of the returns to his information. Arrow (1969) has argued that the marginal cost of distributing information which has already been produced, is zero, and hence, optimality calls for making such information freely available to all. If the production, sale, and distribution of information were left to the free market, the inability to appropriate all of the returns might easily result in an equilibrium in which "too few" resources were being allocated to the forecasting industry. In the light of this argument, it is not surprising to find that the collection and distribution of many kinds of information, including forecasts, have fallen into the domain of the public sector.

More specific rationalizations have been proposed to justify the public demand for SMF's. Six possible justifications were considered and discussed by Freeman and Breneman; these are paraphrased below:[3]

1. Forecasts are needed as a part of a manpower planning system to balance supplies and demands because individual decisions do not reflect economic reality.
2. Forecasts provide important information to guidance counselors enabling them to aid students in career planning.
3. Forecasts can serve as an "early warning system" directing attention to the unforeseen consequences of current market responses and developments.
4. Forecasts are needed to advise educators on the number of slots to be offered in college courses and thus determine the supply of new specialists.

5. Forecasts are needed to evaluate the potential effect of large scale governmental programs on the market.

6. Forecasts are a useful device for organizing and analyzing information about market phenomena that are taken as given by individual decision makers.

Freeman and Breneman conclude that in the setting of a free labor market, only three of these reasons, [3, 5, and 6 above], are valid ones justifying the public demand for SMF's.

An articulation of these reasons tells us something about the objective functions of the public agencies that demand these forecasts. Reasons 1 and 4 suggest that private sources will not provide reliable information about future employment opportunities and student demands for college courses.[4] Public agencies must thus assume the responsibility of supplying the requisite (and hopefully accurate) information. Reasons 1 and 3 tacitly assume that in the absence of publicly supplied manpower forecasts and policies, labor markets for trained scientists will be inherently unstable with recurring cycles of manpower shortages and surpluses. Freeman and Breneman reject the thesis that imperfect student information could generate these cycles, but later in their essay, they strongly support the proposition of inherent market instability. Implicit in these reasons is the theme that public agencies must assume the responsibility of stabilizing the employment and incomes of scientists via their controls over the production and employment of scientists. Finally, reasons 5 and 6 arg e that there is a positive value that can be realized from sound economic analyses on the functioning of labor markets, and on this score, I am in complete agreement with Freeman and Breneman.

Whatever the reason, we have observed a substantial growth in the demand for scientific manpower forecasts. The prior availability of data which lowers the price of a forecast is surely responsible for part of this increased demand. If the Bureau of the Census and the Dept. of Labor had not already compiled detailed statistics on employment by industry and occupation, it is unlikely that a public agency like NSF would have demanded more projections of manpower requirements for specific occupations. What is less clear to an external observer like myself, is, "How does the agency and its policymakers utilize the information conveyed by these manpower forecasts?"

II—The Market Response to the Public Demand

An individual or firm that demands a new good or service can either purchase it from an outside supplier or produce it himself thereby becoming a vertically integrated firm. In the case of SMF's, the public agency buyers have done both. The Bureau of Labor Statistics (BLS) initially began by employing its own staff of analysts who produced the first BLS manpower projections. Later BLS collaborated with NSF thus becoming both a supplier as well as a demander of SMF's. Other agencies like NSF, various national commissions and task forces have typically turned to what I have called the forecasting industry which, in these instances, usually consisted of non-profit research organizations and academic consultants. None of the principal investigators who produced these manpower forecasts in response to the public demands, possessed the audacity, chutzpah, or reliance on a competitive market for their services that was apparently exhibited by Prof. Niblo.[5]

> "Six (professional clairvoyants) advertised in the *San Francisco Chronicle*, the day before the 1906 earthquake, and of these, the boldest was a Prof. Niblo whose academic affiliation was not given: His generous one dollar offer concluded with:
>
> '411A Ellis Street, permanently located at his own home'
>
> In the issue of the Chronicle for May 24, 1906, the first available after the earthquake, he was the only member of his craft to advertise:
>
> 'Prof. Niblo, clairvoyant has warned the public of San Francisco for years of the earthquake of 1906. Permanently located at 1220 Broadway'."

The forecasts that have been produced are quite heterogeneous, but they do share one common attribute that has been perceptively described by Hugh Folk as follows:

> "Despite attempts to shield forecasts from criticism by labelling them 'projections', they are used as forecasts, therefore must be treated as such. . . . Policy-makers must be continually cautioned on the appropriate use of these numbers, but one might as well put a loaded pistol in the hands of a child and caution him that it is not a toy. as place a conditional projection in the hands of a decision-maker and warn him that it is not a forecast. 'Toys' are what children play with, and they play with what they have. 'Forecasts' are what policy-makers use to foretell the future, and they use anything that comes to hand."
>
> [Folk (1970) p. 240]

Many manpower forecasts[6] have been produced in the last thirty years, and these have presumably influenced public policy and individual ecisions. The usefulness of these forecasts as guides to policy-makers has been questioned by among others, Folk (1970), Ahamad and Blaug (1973), and Freeman and Breneman (1973). There is a substantial literature which critically discusses the methodology and accuracy of previous manpower forecasts. I shall not try to summarize that literature but propose instead to direct attention to two related issues:

1. What information do these forecasts convey to policy-makers and other users?

2. How do policy-makers and other users utilize this information in their decision processes?

In this Part of the paper, I try to determine the information content of three kinds of forecasts: (1) the academic requirements for new doctorates, (2) the manpower requirements for specific occupations, and (3) the supplies of college-educated workers.

2.1 The Academic Requirements for New Doctorates

The employment outlook in higher education for the decade of the 1980's is bleak. Anyone who had thought about the implications of the historical data on U.S. birth rates would have reallzed that the population of college-age youths will decline sharply in the 1980's.[7] It seems, however, that the gravity of the problem was not fully appreciated by policy-makers until Allan Cartter dramatically illustrated the possible numerical magnitudes of the imbalances between projected requirements and supplies. More recently, Balderston and Radner (1971) developed a slightly more complicated model which Wolfle and Kidd (1971) described as "a test of the sensitivity of Cartter's projections to some of the underlying assumptions."[8] The Balderston-Radner (BR) model is, however, simply an exercise in simulation which translates alternative data inputs into numerical descriptions of the time path of a dependent variable (new doctorate requirements in academia). It is not a *test* in the scientific sense of that term. The BR projections convey little additional information to the policy-maker other than what he could have inferred for himself from the underlying projections of college student enrollments. This conclusion becomes apparent when one writes out the reduced-form equation implied by the BR model.

BR begin by disaggregating higher education into six sectors according to control (public vs. private) and type of institution (university, four, and two year colleges). The model specifies a system of four structural equations for each sector which can be solved for a reduced-form equation in which the requirement for new doctorates in year t by schools in the j-th sector, $D_j(t)$ is a function of five exogenous variables: P_j = the proportion of new faculty appointments with doctorate degrees, R_j = the student/faculty ratio, k_j = the fraction of all students enrolling in the j-th sector, $S(t)$ = projected student enrollment in all six sectors, and $\sigma = 1-\delta$ = the continuation rate of incumbent faculty members (i.e. the fraction of last year's faculty who do not retire or withdraw).[9]

(2.1) $$D_j(t) = \left[\frac{P_j(t)k_j(t)}{R_j(t)}\right]S(t) - \sigma\left[\frac{P_j(t)k_j(t-1)}{R_j(t-1)}\right]S(t-1)$$

By summing over the six sectors, the academic requirements for new doctorates in all six sectors of higher education, D(t), is described by a first-order difference equation.

(2.2a) $$D(t) = W(t)S(t) - \sigma V(t-1)S(t-1), \qquad [t = 0,1,2,\ldots 20]$$

where t = 0 corresponds to the starting point of the projections, 1970. The parameter W(t) can be interpreted as the marginal doctorate/student ratio for the entire academic sector, while V(t-1) is akin to a LesPeyres index being equal to the marginal doctorate/student ratio in the preceding year multiplied by the assumed increment in the doctorate share of new hires. More precisely,

(2.2b) $$W(t) = \sum_{j=1}^{6}\left[\frac{P_j(t)k_j(t)}{R_j(t)}\right]$$

(2.2c) $$V_j(t-1) = \sum_{j=1}^{6}\left[\frac{P_j(t)k_j(t-1)}{R_j(t-1)}\right] \simeq \left[\frac{P(t)}{P(t-1)}\right]W(t-1)$$

Finally, $\sigma = 1-\delta$ is the survival rate of incumbent faculty which is assumed to be equal to .98 over the entire projection period. The parameters (P_j, R_j, k_j) were initially equated to their observed values in 1967, while the time path of aggregate student enrollment, S(t) was taken from two earlier projections, one by Cartter and the other by G. Haggstrom. BR then invoked judgemental assumptions about the time paths of the parameters to generate six different projections of new doctorate requirements.

We can get a simpler picture of the information content of the BR projections by adopting the following notation:

$$W(t) = W(t\text{-}1) + dW = W + dW, \quad S(t) = S(t\text{-}1) + dS = S + dS$$

$$V(t\text{-}1) = [1 + (\frac{dP}{P})]W$$

Upon substitution into (2.2a), we get,

$$\text{(2.3a)} \qquad D(t) = (W+dW)(S+dS) - \sigma[1+(\frac{dP}{P})]WS$$

Recalling that $\sigma = 1\text{-}\delta$ and ignoring the second-order term in dWdS, the academic requirements for new doctorates in year t can be written,

$$\text{(2.3b)} \qquad D(t) = W(t\text{-}1)S(t\text{-}1)\,[\delta + (\frac{dS}{S}) - (\frac{dR}{R}) + \delta(\frac{dP}{P})].$$

where we make use of the identity; W = P/R so that,

$$\text{(2.3c)} \qquad \frac{dW}{W} = \frac{dP}{P} - \frac{dR}{R}.$$

Thus, in the BR model, the academic requirements, D(t), can be decomposed into a scale parameter, WS = W(t-1)S(t-1), times the bracketed term describing the relative time rates of change in student enrollment, (dS/S), student/faculty ratio (dR/R), and the doctorate share of new appointments (dP/P).

In their "no change" projections, BR assumed that the doctorate share of new appointments P_j and student/faculty ratios R_j would remain unchanged at their 1967 values. Using their judgements (presumably supported by a perusal of some time series data), they assumed that the public four and two year colleges would increase their total shares of total student enrollments over the projection period, 1970-90. The parameter values for all six sectors applicable to the "no change" projections can be found in Table 9.2-1 by looking at the entries for 1970.

Table 9. 2-1
Assumed Parameter Values for the
Balderston-Radner Model

	University		Four Year College		Two Year College	
	Public	Private	Public	Private	Public	Private
k = allocative share of students						
1. $k_j = k_j$ (70) ...	.242	.082	.255	.163	.239	.020
2. f_j	-.0017	-.0015	.0012	-.0011	.0031	0
3. k_j (90)	.208	.052	.279	.141	.301	.019
R = student/faculty ratio						
4. $R_j = R_j$ (70) ...	16.64	11.26	17.86	14.54	21.64	17.72
5. G_j	.132	.063	.143	.077	.132	.236
6. R_j (90)	14.00	10.00	15.00	13.00	19.00	13.00
P = doctorate share of new appointments						
7. $P_j = P_j$ (70) ...	.543	.543	.389	.389	.059	.059
8. H_j	.01785	.01785	.01805	.01805	.01205	.01205
9. P_j (90)	.900	.900	.750	.750	.300	.300

In the "no change" projections, the marginal doctorate/student ratio for public universities is $X_1 = P_1/R_1 = .0326$ meaning a student to new doctorate ratio of $1/X_1 = 30.6$; the corresponding parameters for two year public colleges were $X_5 =$ .0027 and $1/X_5 = 367$ students per doctorate hired. This ratio for all six sectors, W(t), declines linearly over the projection period because by assumption, the two public sectors that are assumed to increase their shares of aggregate student enrollment had marginal doctorate/student ratios below the mean ratio.[10] However, the secular fall in W(t) is slight, and for all intents, the projected requirements in the "no change" case can be expressed as follows:

$$(2.4) \qquad D(t) = W^0 S(t-1)\left[\delta + \left(\frac{dS}{S}\right)\right]$$

where $W^0 = .0225$ is the marginal doctorate/student ratio in 1970. It is evident from (2.4) that the sign of D(t) is entirely determined by projected student enrollments S(t) which is exogenous in the BR model. If projected enrollment declines by more than the assumed attrition rate of $\delta = .02$, the new doctorate requirement, D(t) will be negative irrespective of the value assigned to W^0. A larger value for W^0 [which could have been obtained by assuming either a higher doctorate share of new hires P or a lower student/faculty ratio R] simply magnifies the temporal fluctuations in D(t) and expands the accumulated sum of new doctorate demands. The BR "no change" projection reveals a negative requirement, $D(t) < 0$, in 1984 when the projected student enrollment falls by more than 2 percent.

For each projection of student enrollments, BR generated two additional projections which they labeled "intermediate" and "adequate finance". The authors arbitrarily assumed that the student/faculty ratios R_j would fall, and the doctorate shares of new appointments P_j would climb according to linear trend equations which are shown below. The numerical equations on the right pertain to the first sector, public universities; the parameters for the remaining sectors are given in Table 9.2-1.[11]

$$(2.5a) \qquad P_j(t) = P_j + H_j t \qquad\qquad P_1(t) = .543 + .01785t.$$

$$(2.5b) \qquad R_j(t) = R_j - G_j t \qquad\qquad R_1(t) = 16.64 - .132t$$

$$(2.5c) \qquad k_j(t) = k_j \pm f_j t \qquad\qquad k_1(t) = .242 - .0017t.$$

where $t = 0,1,\ldots,20$. BR arbitrarily assume that over the twenty year period, 1970-90, the student to faculty ratio R (which is a proxy for class size) will decline from 16.64 to 15.00 for public universities and that the proportion of new appointments with doctorate degrees, P_1, will climb from 54.3 percent to 90 percent. The two reinforce one another so that the marginal doctorate/student ratio W(t) rises at an increasing rate. For public universities, the ratio climbs from .0326 to .0643, and for two year public colleges, from .0027 to .0158. In the "adequate finance" projections, an exact functional form for W(t) involves a ratio of two polynomials in t, and this non-linearity suggests that in this case, there may be a need for the simulations. However, equation (2.3b) gives us nearly all of the information conveyed by the "adequate finance" projections.

The relative rate of change in projected student enrollment, (dS/S), is exogenous in the BR model and comes from another study that presumably was available to the policy-maker. One could insert his own assumption about the relative change in the student/faculty ratio, (dR/R). The driving force in the "adequate finance" projections is the time path of the marginal doctorate/

student ratio W(t) which determines the size of the scale parameter, WS = W(t−1)S(t−1), in (2.3b). By using the approximation of (2.3c) based on the identity, W = P/R, [which ignores the aggregation of the six sectors], a policy-maker can substitute his own judgments about the doctorate share of new appointments P and the student/faculty ratio; the requisite calculations could be done on the back of an envelope.

An excerpt from the BR simulations of the academic requirements for new doctorates is presented in Table 2.2A. A decomposition of the projected requirements for selected years, using the approximation of (2.3b), is shown in Table 2.2B. It will be noticed that in this decomposition for the "adequate finance" projections, the growth in the scale parameter, WS, dominates the projection. Balderston and Radner pointed out that their projections for D(t) were "more sensitive" to assumptions about P than they were to assumptions about R. Their conclusion should have been obvious from (2.3c) which divides the growth in the marginal doctorate/student ratio W between changes in P and R. Reference to Table 9.2-1 reveals that in their simulations for the "adequate finance" case, the assumed values for the doctorate shares of new appoint-

Table 9. 2-2A
The Balderston-Radner Projections of New Doctorate Requirements*

Year	Population 18-21 years	Student Enrollment	Faculty	*New Doctorate Requirement* No Change	Adequate Finance
1970	14540	6303	374.6	7.16	8.82
1971	14870	6755	403.6	11.90	14.69
1975	16307	8197	500.4	10.12	15.32
1980	16790	9537	599.8	6.95	13.90
1985	14992	9228	597.2	−2.73	−2.21
1990	14351	8674	579.5	5.29	15.33

Notes: The population figures (in thousands) is a four year moving sum of the 18 year-old age class and are thus. unadjusted for death and immigration. Student enrollment, S(t) was taken from BR (1971). Table 3-1. Faculty figures were computed by multiplying the weighted mean faculty/student ratio, 1/R, times S(t). The projected annual requirements for new doctorates were taken from BR (1971). Table 3-3.

Table 9. 2-2B
Decomposition of the "Adequate Finance" Projections

Component	1971	1980	1985	1990
1. Separation rate δ	.02	.02	.02	.02
2. Student Enrollment dS/S	.0717	.0228	−.0301	.0151
3. Student/Faculty ratio dR/R	−.0053	−.0071	−.0061	−.0065
4. Doctorate share. δ(dP/P)	.0008	.0007	.0006	.0004
5. Sum lines 1-4	.0978	.0506	−.0034	.0420
6. WS	141.7	302.1	361.0	376.5
7. New Doc. Req. D(t)	13.9	15.3	−1.2	15.8

ments P_j nearly double over the projection period, while student/faculty ratios R_1 fall by only around 15 percent.

A systematic critique of the Balderston-Radner model (and those like it) is deferred to Part III. Several remarks can, however, be made at this point:

1. An examination of the reduced-form equation (2.2a) reveals that the projected academic requirement in year t, D(t), is determined by three data inputs: (a) the projected student enrollment S(t), (b) the marginal doctorate/student ratio W(t) which in turn depends on the assumptions about the doctorate share of new appointments P and the student/faculty ratio R, and (c) the attrition rate of incumbent faculty, $\delta = 1\text{-}\sigma$.

2. The projected student enrollment, S(t), in all sectors is exogenous and is assumed to be unaffected by the assumed demands for new faculty. The BR model implicitly assumes that future levels of student enrollment in higher education will be invariant to the way in which students are distributed to the six sectors or to the quality of higher education as measured by student/faculty ratios or the proportion of college faculties who hold doctorate degrees.[12] Further, optimistic or pessimistic projections of the demands for new doctora' .s presumably have no effect on graduate student enrollments.

3. A variation of 1 percentage point in the assumed attrition rate of $\delta = 2$ percent, changes the projected requirement for new doctorates by roughly 3,000. The NSF model, [NSF 71-20] derived the attrition rate δ from the incumbent faculty; the deviations from the assumed constant rate of $\delta = .02$ were small over the 1970-90 period.

4. Although the disaggregation into six sectors unduly complicates the arithmetic of the BR model,[13] the reduced-form equation reveals that the variables driving the projected requirements are (a) projected student enrollments, S(t) which BR take as given, and (b) the marginal doctorate/student ratio, W(t) which is judgmentally determined.

5. The so-called sensitivity of the BR projections to the underlying assumptions could have been easily calculated by using the approximation to the reduced-form equation given by (2.3b). The policy-maker could have substituted his own assumptions about the marginal doctorate/student ratio W, the rate of change in student enrollments (dS/S), and the change in student/faculty ratios (dR/R).

6. The BR model is essentially a variant of the "fixed coefficients" approach to manpower forecasting, and all of the criticisms that have been lodged against that methodology are equally applicable here.

7. Finally and most serious, no attempt is made in the study to place the projected academic requirements for new doctorates into an equilibrium model for the higher education sector as a whole. The "adequate finance" projections presuppose that funds from somewhere, will become available to finance lower class sizes and larger fractions of Ph.D.'s on college faculties. If these funds are raised through higher tuition, is the student enrollment projection plausible? What is the magnitude of the "adequate finance" needed to attain the assumed time tracks for P_j and R_j? What are the implications of nearly doubling the fraction of new appointments with doctorate degrees with respect to salaries of doctorate and non-doctorate faculty members and with respect to the conformance of higher education to the affirmative action policies of H.E.W.? None of these issues is addressed, in the BR study, and the study

must, in my opinion, be regarded as an exercise in the simulation of a wholly hypothetical world.

2.2 BLS Projections of Occupational Requirements

Projections of manpower requirements for specific occupations have been developed by the Bureau of Labor Statistics for many years.[14] These projections are intended to represent estimates of future "demands" or requirements for particular occupations without regard to the availability of supplies to meet those "demands". When these projected requirements are *juxtaposed* to supply projections, they are supposed to indicate possible future imbalances in specific labor markets. Since at least one other paper at this Conference deals with these projections, the discussion here is limited to a brief review of the BLS methodology.

The methodology essentially involves three steps. First, projections of employment by industry $\hat{E}_{i.}$, are developed for the projection year. Second, projections of occupational ratios, $\hat{r}_{ij}$, [the proportion of total employment in industry i that falls into occupation j] are generated for the projection year. Third, the two projections are multiplied and summed over industries to arrive at the manpower requirement for the j-th occupation in the projection year.

(2.6) $$\hat{E}_{.j} = \sum_{i} \hat{E}_{i.} \hat{r}_{ij}.$$

The BLS methods and their underlying assumptions for estimating $\hat{E}_{i.}$ and $\hat{r}_{ij}$ are more fully discussed in Appendix A to this paper. The lack of adequate time series data on employment by detailed occupations largely dominates the BLS methodology. If such data were available, one could avoid the two step procedure of projecting both $\hat{E}_{i.}$ and $\hat{r}_{ij}$.[15]

What can we learn from these BLS projections? The equations that are used to project industry employment cannot, by any stretch of the imagination, be interpreted as labor *demand* equations. They are naive reduced-form equations that totally ignore the fact that observed employment in prior years was jointly determined by the intersection of market demand and supply functions. When this fact is acknowledged, industry employment projections *cannot* be interpreted as manpower requirements or "demands"; they represent BLS estimates of what they think will be the *equilibrium* industry employments in the projection year.

That occupational ratios are likely to vary over time, is acknowledged in the following excerpt:

> "The relative importance of particular occupations changes over time, however, in response to technical advancement and changes in the scale of production, product mix, and organization of industries among other factors." [BLS Bulletin 1606, Vol. IV, p. 9]

Of the reasons enumerated here, the substitution of factors in response to changing factor prices is conspicuous by its absence unless it is included in the "other factors". Hollister (1966), Folk (1970), and others have roundly criticized the BLS for neglecting the substitutability of factors in production. But despite these criticisms, the BLS has never attempted to rationalize their projections of occupational ratios by developing companion projections of occupational wage differentials. In passing, the opportunities for factor substitutions through product substitutions have received little attention in the critical literature. Even if *every* production function involved *fixed* technical coefficients, a rise in the price of a factor will lead to a decrease in the demand for that factor because consumers will reduce their demands for products using this factor.[16] A defender of the BLS methodology might contend that there is, in principle, some structure of occupational wage rates and product prices such that the projected occupational ratios (and industry employments) would have been optimal, cost-minimizing combinations. This is surely correct, but what are these shadow wage rates and product prices?

Several researchers have assessed the accuracy of the BLS projections by retrospectively comparing the projected requirement to the realized employment in each occupation for the projection year. Two conclusions can be drawn from these retrospective comparisons. First, the magnitudes of the relative forecast errors are quite large, especially for detailed occupational specialties. When detailed occupations are aggregated into larger groups, [the upper limit being all occupations or economy-wide employment], the size of the forecast errors typically gets smaller and can sometimes be traced to discrepancies between assumed and actual values for some of the exogenous variables such as real GNP, the size of the Armed Forces, etc. Second, if the relative forecast errors are decomposed into errors in industry employment projections vs. errors in occupational ratios, the latter accounts for the largest part of the forecast errors.[17] In the light of these findings, I agree with earlier writers that the BLS projections of occupational requirements do *not* provide policy-makers and other users with accurate predictions of future labor demands when judged by conventional criteria for good statistical predictions..

The impossibility of the BLS methodology is articulated in the concluding remarks by Gannicott and Blaug (1973):

> "It is not enough to assume, as seems to be implied by the latest works from the BLS, that forecasting errors will be reduced if only the data and statistics can be refined. What is needed is what the BLS has not carried out in the ten years we have reviewed, a fundamental assessment of the relevance and objectives of the manpower requirements approach itself." [p. 76]

The BLS methodology still does not adequately cope with the obvious facts that the occupational employment patterns which were observed in the past and which are likely to prevail in the future are jointly determined by the market forces of demand and supply. If the short-run supply for a specific occupation is extremely elastic, [meaning workers can easily shift from this occupation to another and vice versa], there is little to be gained by projecting the manpower requirements for that occupation. Until the BLS methodology embraces a theoretically sound model of labor markets, their projections only convey to us, information about the extrapolation of trends in occupational employment patterns based on the guesstimates of the BLS analysts.

2.3 The Supply of College Graduates

The basic methodology for projecting the future supply of college graduates [or for that matter, supplies of persons with various levels of educational attainment] has apparently changed little in spite of the criticisms voiced by Alice Rivlin (1961) over a decade ago. The methodology can be described in a nutshell as follows: the projected supply in year t is obtained as the product of the Census projection for an age-specific population (say 18 or 22 year-olds) times a trend projection for the appropriate continuation rate (or rates). Since nearly all of the children who will be entering the higher education sector during the next eighteen years are already born, the Census projections of the pertinent age-specific populations will be extremely accurate. The issues thus come down to an evaluation of the methods that have been used to devise the appropriate continuation rates and to project them into the future.

Various aspects of the current supply projection methodology could be critically analyzed, but in this paper, I shall limit the discussion to three topics: (a) extrapolations via weighted trend lines, (b) compounding of several linear trends, and (c) the economic determinants of continuation rates.

(a) *Extrapolations via weighted trend lines:* This technique which has been employed in the NSF supply projections can best be analyzed with the aid of an illustrative example. The projected supply of high school graduates in year p, $\hat{Y}_p$, is usually obtained by multiplying the Census projection of an age-specific age class X_p, (usually 17 year-olds, but sometimes a moving average of 17 and 18 year-olds) and the projected proportion $\hat{H}_p$ of the future age class that is predicted to complete high school.

(2.7a) $\hat{Y}_p = X_p\hat{H}_p$.

As I argued earlier, X_p is likely to be quite accurate so that attention can be directed to the method used to project $\hat{H}_p$. It is typically assumed that H_t will follow a trend, and in the NSF model, a linear trend.[18]

(2.7b) $H_t = \alpha + \beta T_t + e_t$

where T_t is the trend variable, and e_t is a random error term. If $(\hat{\alpha}, \hat{\beta})$ denote the estimates for the parameters of (2.7b), then $\hat{H}_p = \hat{\alpha} + \hat{\beta}T_p$, and the projected supply of high school graduates $\hat{Y}_p$ is seen to be a non-linear trend extrapolation of the specific age-class X_p.

(2.7c) $\hat{Y}_p = X_p\hat{H}_p = \hat{\alpha}X_p + \hat{\beta}X_pT_p$.

The novel feature of the NSF procedure lies in the estimation of (α,β). Ordinary least squares which attaches equal weight to all observations yields one set of parameter estimates $(\hat{\alpha}_0, \hat{\beta}_0)$. The NSF procedure contends, however, that the most recent observations should be given more weight. More precisely, the estimation is based on data only for the last ten years with double weights given to observations for the most recent five years. The parameter estimates $(\hat{\alpha}_1, \hat{\beta}_1)$ in the NSF procedure describe a weighted trend line estimated by generalized least squares, GLS.[19] No attempt is made to provide either a statistical or theoretical justification for ignoring sample data from the preceding decade or for attaching double weights to the most recent five years of experience. One could, as well, have assigned triple weights to the most recent three years, double weights for the next three years, and unit weights for four years of observations of H_t; let me call this last set of parameter estimates $(\hat{\alpha}_2,\hat{\beta}_2)$.

The historical data on high school graduates as a percentage of the 17 year-old age class H_t, are presented in Table 9.2-3 for the period 1948-67. The data for the last ten years, 1958-67, were used to estimate the parameters of a linear trend line, (2.7b), assuming equal weights, double weights for 1963-67, triple weights for 1965-67 and double weights for 1962-64. The results are shown below:

(2.8a) $\hat{Y}_t = \hat{\alpha}_0 + \hat{\beta}_0 T_t = 62.33 + 1.541T_t$, [equal weights, OLS]

Table 9. 2-3
Continuation Rates from High School Graduation to Bachelor's Degree

Year of HS Grad.	H	ϵ	Year of B degree	(1-α)	β=Hϵ (1-α)
1948	54.0	47.67	1952	58.52	15.1
1949	56.5i	45.19i	1953	54.97	14.0i
1950	59.0	42.71	1954	57.16	14.4
1951	58.8i	43.60i	1955	61.41	15.7i
1952	58.6	44.49	1956	58.48	15.2
1953	59.3i	46.73i	1957	60.14	16.7i
1954	60.0	48.97	1958	58.53	17.2
1955	60.4	49.45	1959	57.65	17.2
1956	62.3	50.53	1960	55.23	17.4
1957	63.0	49.90	1961	55.68	17.5
1958	64.8	51.28	1962	54.10	18.0
1959	63.4	49.93	1963	55.07	17.4
1960	65.1	49.52	1964	54.02	17.4
1961	71.3	51.67	1965	52.92	19.5
1962	69.5	53.54	1966	53.47	19.9
1963	70.5	53.66	1967	56.85	21.5
1964	76.3	53.49	1968	54.43	22.2
1965	75.6	54.10	1969	53.38	21.8
1966	74.9	51.57	1970	60.03	23.2
1967	76.5	53.69	1971	60.99	25.1
Mean	64.99	49.585		56.651	18.32
S.D.	7.11	3.536		2.696	3.08

Symbols:
H = percentage of the 17 year age class graduating from high school.
ϵ = percentage of the high school graduating class who enroll for the first time in college.
1-α = the survival rate defined as bachelors in year t expressed as a percentage of first time enrollments in year t-4.
β = the percentage of the 17 year age class t-4 years earlier who earn a bachelor's degree.

(2.8b) $\hat{Y}_t = \hat{\alpha}_1 + \hat{\beta}_1 T_t = 62.57 + 1.507T_t$ [double weights, GLS]

(2.8c) $\hat{Y}_t = \hat{\alpha}_2 + \hat{\beta}_2 T_t = 62.67 + 1.475T_t$ [triple weights, GLS]

The three fitted trend lines were used to predict the percentage of the 17-year age class that would complete high school in 1967-71. The results are tabulated below where the first line gives the actual observed percentage H_t.

Predicted Values of Percentage of High School Graduates $\hat{H}_p$

	1967	1968	1969	1970	1971
Actual, H_t	76.5	76.7	76.0	75.7	75.9
Projected, $\hat{H}_p$					
(2.8a) equal weights	77.73	79.27	80.81	82.25	83.89
(2.8b) double weights	77.64	79.15	80.66	82.16	83.67
(2.8c) triple weights	77.43	78.90	80.38	81.86	83.33

The relative forecast error, $(\hat{H}_t/H_t)$ is less than 1.6 percent in 1967 and is smaller for the weighted regressions (2.8b) and (2.8c). All of the trend lines overestimate H so that by 1971, there is nearly a 10 percent discrepancy.

I cannot logically explain the reasons for the NSF procedure. It seems to assume that the parameters (α,β) of the linear trend equation (2.7b) are not stable over time. By attaching more weight to the most recent observations, the resulting weighted parameter estimates will presumably give us a better linear approximation to an unknown non-linear trend relationship. If the NSF procedure was intended to capture non-linear trend relationships, the estimation of a weighted *linear* trend line will unavoidably lead to biased projections.[20] Finally, there is *no* reason to suppose that the *variance* of the error term e_t should be smaller for the more recent observations. In short, the NSF method for projecting future values of $\hat{H}_p$ or any other continuation rate [by extrapolating a weighted *linear* trend line] has *no* logical foundation.

(b) *Compounding of Several Trend Lines:* The methodology for projecting the supply of college graduates differs from that for high school graduates in three respects. First, the projected supply of high school graduates, Y_p, is often assumed to be an exogenous data input. Second, a projection must be developed for the percentage of each high school graduating class who will enroll for the first time in college, ϵ_p. Third, one must estimate the fraction of each freshman class who will complete the four years of college and earn a bachelor's degree, $c_t = 1\text{-}\alpha_t$, where α_t is the attrition rate in college. If we let Z_p denote the projected supply of bachelor degrees in year P, we have,[21]

(2.9a) $Z_p = c_{p-4}\, \epsilon_{p-4}\, Y_{p-4}$.

where c_{p-4} is the completion rate applicable to the cohort entering in year p-4. Again time series data are used to estimate the parameters of *two* trend equations.

(2.9b) $\epsilon_t = a + bT_t + u_t$.

(2.9c) $c_t = A + BT_t + v_t$.

where u_t and v_t are random error terms. The parameters of these trend lines can again be estimated by using the historical series for ϵ_t and $c_t = 1\text{-}\alpha_t$.

If the high school completion rate H, the first-time enrollment rate ϵ, and the college completion rate $c=1\text{-}\alpha$, are multiplied together, we can compute the percentage of each age class that completes college; this is denoted by β_t.

(2.10) $\beta t = H_t \epsilon_t (1-\alpha_t)$.

These completion and continuation rates for the period, 1948-67, are presented in Table 9.2-3[22] A few descriptive remarks about these data may be in order. The fraction of each 17 year-old age class completing high school climbed from 54.0 percent in 1948 to 76.7 percent in 1968; since then, H_t has declined slightly. The first-time enrollment rate ϵ_t also exhibited a positive trend rising from 47.7 to 64.0 percent. The percentage of each freshman class who earned bachelor degrees, $1\text{-}\alpha_t$, followed a flat U-shaped curve being slightly higher in the early and late years of this twenty year period, 1948-67. Finally, 15.1 percent of all youths who were 17 in 1948 ultimately went on to earn a bachelor's degree, and this figure rose to 25.1 percent for those reaching 17 in 1967; see the series for β_t in Table 9.2-3.

The current methodology fits separate trend lines to each completion and continuation rate. The final supply projection for college graduates Z_p is, however, simply a compounding of these trend lines. Thus, when the three trend lines from (2.7b), (2.9b) and (2.9c) are substituted into (2.10), we get,

$$\beta_t = (\alpha+\beta T_t)(a+bT_t)(A+BT_t) = \psi_0 + \psi_1 T_t + \psi_2 T_t^2 + \psi_3 T_t^3$$

where $\psi_0 = \alpha aA$, $\psi_1 = [\alpha aB + abA + \beta aA]$, etc. Thus, when the projected supply of high school graduates Y_p is endogenous, [as it is in the NSF model], the projected supply of college graduates Z_p is linked to the population of 17 year-olds four years earlier, via a cubic trend equation. There is no a priori reason to suppose that fitting three separate trend lines and multiplying them together improves the predictive accuracy of a forecast. Indeed, one might do even better by directly fitting a polynomial trend equation to the historical data for β_t, and project bachelor supplies from the size of the 17 year age class as follows:

$$Z_p = \hat{\beta}_{p-4} X_{p-4}, \qquad \hat{\beta}_p = \psi_0 + \psi_1 T_p + \psi_2 T_p^2 + \ldots$$

A drawback to this latter approach is that the analyst cannot intuitively interpret the ψ parameters, but he can use his judgment about the plausibility of the parameters of separate trend lines. From the viewpoint of predictive accuracy, one cannot judge in advance, which is the preferred approach.

The methodology for projecting the supplies of advanced degrees, (masters and doctorates) is qualitatively similar. In some instances, the supplies of bachelor degrees in specific fields are taken to be exogenous. Some forecasts assume fixed time lags between the baccalaureate and doctorate degrees; I shall comment on this lag in Part III below. The data in Table 9.2-4 show the number of degrees awarded and the implicit completion rates which assume fixed two and five year lags between bachelor and either master or doctorate degrees.[23] The proportions of each college graduating class who continued on to earn masters and doctorate degrees have climbed dramatically. For the classes graduating in the 1960's, nearly 30 percent went on to earn masters degrees and around 6 percent received doctorate degrees. The naive extrapolations of these trends accounts for earlier projections of 55 to 80 thousand doctorate degrees supplied in 1980. The NSF method which attaches more weight to the most recent data must, by its very nature, generate volatile supply projections; i.e. the forecast of the doctorate supply in 1980 that was developed in 1969, [before the recent levelling off of first-year graduate enrollments] will be very different from the projected 1980 supply utilizing the historical data through 1973.

To sum up, a model that projects supplies at all levels of educational attainment, [high school, baccalaurate, masters, etc.] can almost always be reduced to a trend projection of some multiplicative combination of trend lines times the Census projection for the size of age specific populations. Further, the existing models [like NSF 71-20]utilize simple linear trend equations. By appealing to logistic or logarithmic functional forms, I suspect that one could get far better fits to the historical time series.

(c) *The Economic Determinants of Completion and Continuation Rates:* My principal criticism of the current methodology is that no serious attempts are made to explain the temporal fluctuations in the historical data on completion and continuation rates. The strong upward trend in the percentage of each age class completing high school must surely be due, in part, to the declining opportunity costs of attending high school as more and more of the U.S. population is residing in urban areas, the growth in real family incomes, and the secular rise in teen-age unemployment rates. If we could establish stable empirical

Table 9. 2-4
Bachelor and Advanced Degrees Awarded by All Institutions, 1948-71

	No. of Degrees			Continuation Rates*		
Year	Bachelor B_t	Master M_t	Doctorate D_t	M_t/B_{t-2}	D_t/B_{t-5}	D_t/B_{t-5}
1948 ..	272311	42449	3989			
1949 ..	366698	50763	5050			
1950 ..	433734	58219	6420	0.214		
1951 ..	384352	65132	7338	0.176		
1952 ..	331924	63587	7683	0.147		
1953 ..	304857	61023	8309	0.159	0.0305	
1954 ...	292880	56832	8996	0.171	0.0245	0.0252
1955 ..	287401	58204	8840	0.191	0.0204	0.024
1956 ..	311298	59294	8903	0.202	0.0232	0.0232
1957 ..	340347	61955	8756	0.216	0.0264	0.0257
1958 ..	365748	65614	8942	0.211	0.0293	0.0289
1959 ..	385151	69584	9360	0.204	0.0320	0.0317
1960 ..	394889	74497	9829	0.204	0.0342	0.0331
1961 ..	401784	78269	10575	0.203	0.0340	0.0338
1962 ..	417846	84855	11622	0.215	0.0341	0.0343
1963 ..	450592	91418	12822	0.228	0.0351	0.0352
1964 ..	498654	101050	14490	0.242	0.0376	0.0379
1965 ..	538930	112195	16467	0.249	0.0417	0.0418
1966 ..	551040	140555	18237	0.282	0.0454	0.0450
1967 ..	594862	157892	20621	0.293	0.0494	0.0487
1968 ..	666710	176749	23089	0.321	0.0512	0.0507
1969 ..	769683	194414	26189	0.327	0.0525	0.0528
1970 ..	827234	208291	29866	0.312	0.0554	0.0564
1971 ..	877676	230509	32107	0.299	0.0583	0.0527
Sum ...				5.0680	0.71520	0.68400
Mean ..				0.2304	0.03764	0.03800
S.D. ...				0.0534	0.01146	0.01145

* The base for the last column is defined as:
$B_{t-5} = (1/3)\,[B_{t-4} + B_{t-5} + B_{t-6}]$

relationships between H_t and these variables, it would provide us with a far sounder basis for projecting H_t into the future. The first-time enrollment rate as freshmen ϵ_t, depends on, among other things, the cost of a college education, the impact of military conscription, and again, family incomes.[24] Although the temporal variations in the college completion rate, $c_t = 1-\alpha_t$, are smaller, they are still substantial. My observations suggest that the completion rate, $1-\alpha$, is systematically related to the size and control of the institution being higher in smaller and private institutions. Further, to the extent that college education represents an investment in human capital, the earnings differential between college and high school graduates should affect both ϵ_t and $1-\alpha_t$.

The naive extrapolations of trends in these rates will yield accurate forecasts of future supplies if and only if the causal variables which generated the historical time paths for these continuation rates just happen to be correlated with the same continuation rates in the future as they were in the past. Such a fortuitious outcome is highly improbable. Instead of devoting more research funds and resources into collecting more reliable and current data to develop better trend equations, it is my considered opinion that far more can be learned by developing sound economic models to identify the causal variables which are responsible for the temporal variations in the pertinent completion and continuation rates.

III—On the Production and Employment of Doctorates

The public sector at both Federal and state levels has clearly assumed the responsibility for promoting the growth of higher education. Increasingly larger shares of general tax revenues have been appropriated to finance the expansion of both public and private colleges and universities. The allocation of these public funds has been uneven, understandably favoring public institutions and to a lesser extent, graduate as opposed to undergraduate study.[25] Further, the NSF and NDEA fellowship and traineeship programs were expressly intended to expand the supply of one kind of highly trained manpower, namely science doctorates. Expanded support for state universities and the research grants to academia from public agencies and foundations also contributed to the financial aid that was needed to subsidize a growing population of graduate students. As Wolfle and Kidd (1971) pointed out, our decentralized higher education system responded admirably by nearly tripling the annual production of doctorates between 1961 and 1972. The predictions in the late 1950's of a severe shortage of doctorates never came to pass, but predictions and fears, like bad pennies, keep turning up, and the latest vintages foretell of a glut in the market for Ph.D.'s. According to Balderston and Radner, *if* public policies do not provide the "adequate finance" that is needed to finance an enrichment in the doctorate shares of faculties and reductions in student/faculty ratios, the nation may have to suffer the consequences of a "hole" in the flow to academia of new doctorates in the mid 1980's. Cartter (1971) and others generally agree that we need not worry about unemployed Ph.D.'s, but the danger is what might be called "underemployment". Indeed, Cartter voices the fear that new doctorates in the 1980's will be forced to accept employment in positions well below what they had aspired to as Ph.D. candidates. On this point, I agree with Gannicott and Blaug (1973) who wrote, ". . . that the concept of an *appropriate* job for a given level of education is meaningless." [p. 76]. Others, however, disagree with this view. One thing is, however, clear; more public resources are being devoted to refine the projections of doctorate supplies and requirements even though it is unclear how policy-makers, students, university administrators, etc. utilize the information conveyed by these projections.

To place the problem in perspective, I first review the NSF projections of doctorate supplies and requirements in 1980. The NSF projections and others like them are mainly extrapolations of recent trends, modified occasionally by judgments about certain parameters which describe the links between inputs of doctorate faculty (or R and D scientists) and the outputs of student enrollments (or R and D outlays). They do not come to grips with the factors that determine the prior observed equilibria of Ph.D. labor markets or that are likely to determine equilibrium rates of production and employment in the future. In my admittedly non-comprehensive review of the literature, I have come across only three studies, [Breneman (1970A), and (1970B), Freeman and Breneman (1973)] that seriously view the Ph.D. labor market from this latter perspective. In sections 3.2 and 3.3, I sketch the outlines of a model describing the production and employment of doctorates.[26] In developing this crude model, it became apparent to me that many facets of the Ph.D. labor market have not been analyzed in any systematic fashion. Finally, it is hoped that the model may help us in evaluating the plausibility of the current projections for a glut in the Ph.D. labor market.

3.1 The Projected 1980 Surplus of Doctorates

Several recent articles and studies have apparently reached a concensus that the Ph.D. labor market in the 1980's will be characterized by substantial excess supplies of Ph.D. scientists seeking appropriate jobs.[27] In order to illustrate the magnitude of the projected surpluses, I have selected the most recent published doctorate supply and utilization projections developed by the National Science Foundation [NSF 71-20].[28] Although the NSF study identified five broad fields, I have combined the physical sciences, life sciences, engineering, and mathematics into one category which I call the "hard sciences".

I shall not, at this point, criticize the NSF methodology but direct attention to the numerical results of the NSF projections for 1980 which are shown in Table 9.3-1. Line 1 presents the utilization [employment which is also equal to the 1969 stock supply] of doctorate scientists as of Jan. 1, 1969. The high

Table 9. 3-1
Supply and Utilization of Science and Engineering Doctorates (actual, Jan. 1969 and projected 1980)

Item	Total	Hard Sciences*	Social Sciences
1. Actual 1969 Utilization	158.0	123.0	35.0
1.a Academic	94.3	68.8	25.5
1.b Non-academic	63.7	54.2	9.5
2. High Projected 1980 Utilization	297.4	226.9	70.5
2.a Academic	165.1	116.6	48.5
2.b Non-academic	132.3	110.3	22.0
3. Low Projected 1980 Utilization	269.7	203.7	66.0
3.a Academic	163.5	115.1	48.4
3.b Non-academic	106.2	88.6	17.6
4. Supply Projections			
4.a Hogh	335.6	248.3	87.3
4.b Low	314.8	233.5	81.3
5. Maximum Surplus			
(line 4-a minus line 3)	65.9	44.6	21.3
	(19.6)	(18.0)	(24.4)
6. Minimum Surplus			
(line 4-b minus line 2)	17.4	6.6	10.8
	(5.5)	(2.8)	(13.3)

Source: NSF 71-20, p. 6 and p. 24.

* The hard sciences include physical sciences, life sciences, mathematics, and engineering

and low projections of 1980 utilization, shown in lines 2 and 3, invoke different assumptions about Federal R and D spending, faculty/student ratios, etc. The high and low projected 1980 supplies (lines 4-a and 4-b) were derived by taking the initial 1969 supply, adding the projected production of new doctorates, and deducting losses due to death, retirement, and emigration. An estimate of the maximum surplus is obtained as the difference between the high supply and low utilization projections; this is shown on line 5. Similarly, the difference between the low supply and high utilization give us the minimum surplus shown on line 6.

For all sciences combined, the projected 1980 surplus of doctorates, [the excess of projected supply over demand] varies between 55.9 and 17.4 thousand. If these surpluses are expressed as percentages of their corresponding projected supplies, [indicated by the figures in parentheses on lines 5 and 6 of Table 9.3-1], they are 19.6 and 5.5 percent. The NSF projections thus imply that at worst, one in every five Ph.D. scientists will be unable to find suitable employment in 1980 that "requires" the training and skills of a Ph.D. The optimistic picture implies that one in every twenty will be "under-employed". The employment outlook is considerably bleaker for the social scientists according to these forecasts.

The historical data on the actual number of doctorate degrees conferred in the academic years ending in 1961-72, as well as the NSF projections of doctorate production rates through 1980, are presented in Table 9.3-2. First, it will be noticed that there are some discrepancies between actual and projected flows in 1970-72. The NRC doctorate record file indicated a drop of −2.2 percent in the output of Ph.D's in the hard sciences, while NSF projected a modest growth of +3.4 percent. Since the actual data for 1970-72 were not available at the time that the NSF projections were made, the discrepancies represent forecast errors. Second, it will be noted that the growth rate of hard science Ph.D.'s in the period 1970-75 is considerably below the projected growth rate of social science Ph.D.'s. This outcome follows from the NSF methodology of linking doctorate production in year t to first-year graduate enrollments some five to eight years earlier. The data for the period 1967-69 exhibited sharp declines in first enrollments in chemistry and physics, while no such break in the trend was observed in the soft sciences.[29] Since the NSF projection methods place more weight on the most recent experience, (without really trying to explain that experience), we get the results reported in Tables 9.3-2 and 9.3-1, namely a much larger increase in the projected supply of social scientists accompanied by a larger estimate for the 1980 surplus. Finally, selected data on doctorate production rates by field are shown in Table 9.3-3 mainly to show the wide variance in growth rates across fields.

3.2 Investment in a Doctorate Degree

In order to explain previous historical trends and to gain insights into possible future developments, we need a market model for that part of our higher education system which produces Ph.D.'s. A convenient point of departure is an analysis of the individual student's decision on whether or not he should enroll for graduate study. In his excellent paper, Breneman (1970A) initially considered the possibility that the quest for a Ph.D. might involve elements of both consumption and investment. However, given the sizeable costs and a commitment to a particular field, the decision to seek a doctorate should, in Breneman's view, be analyzed as an investment in human capital. In the context of a human capital model, the student's decision should depend

Table 9. 3-2
Doctors Degrees Conferred by Field
(actual 1961-72, projected 1970-80)

Year	All Fields No.	All Fields change	Hard Science No.	Hard Science change	Social Science No.	Social Science change	Non-Science No.	Non-Science change
Actual								
1961	10.411	—	5.047	—	1.829	—	3,535	—
1962	11.507	10.5	5.675	12.4	1.944	6.3	3 888	10.0
1963	12.720	10.5	6.345	11.8	2,082	7.1	4.293	10.4
1964	14.324	12.6	7,142	12.6	2.329	11.9	4.853	13.0
1965	16,302	13.8	8,290	16.1	2.411	3.5	5,601	15.4
1966	17.865	9.6	8,946	7.9	2.708	12.3	6,211	10.9
1967	20,295	13.6	10,003	11.8	3.187	17.7	7.105	14.4
1968	22,834	12.5	11.126	11.2	3.579	12.3	8.129	14.4
1969	25,734	12.7	12,314	10.7	4,051	13.2	9.369	15.3
1970	29,436	14.4	13,603	10.5	4,700	16.0	11.133	18.8
1971	31,772	7.9	14.276	4.9	5.316	13.1	12.180	9.4
1972	33,001	3.9	13.966	-2.2	5.574	4.9	13.461	10.5
Projected (NSF)*								
1970	28.4	8.4	12.82	5.3	4.06	10.9	11.54	11.0
1971	31.4	10.6	13.82	7.8	4.53	11.6	13.09	13.4
1972	33.7	7.3	14.29	3.4	4.94	9.1	14.49	10.7
1973	35.9	6.5	14.73	3.1	5.25	6.3	15.90	9.7
1974	38.4	7.0	15.74	6.9	5.65	7.6	16.94	6.5
1975	39.1	1.8	15.90	1.0	6.05	7.1	17.12	1.1
1976	40.4	3.3	16.32	2.6	6.46	6.8	17.56	2.6
1977	41.4	2.5	16.61	1.8	6.86	6.2	17.86	1.7
1978	42.6	2.9	16 97	2.2	7.26	5.8	18.42	3.1
1979	43.9	3.1	17.33	2.1	7.67	5.6	18.87	2.4
1980	45.2	3.0	17.77	2.5	8.06	5.1	19.42	2.9

Source: Actual degrees conferred taken from National Research Council. Doctorate Record File. Projections are from NSF 71-20. Table B-1, p. 26.

* The NSF projections were based on Office of Education data on earned doctorate degrees, and not on the NRC estimates shown in the upper panel of this table. The two series (NRC and Office of Education) are, however, quite similar.

on the expected costs and returns from his investment in a doctorate degree. However, to the extent that the working conditions for a doctorate recipient differ from those in alternative employments, [in terms of the prestige, recognition, hours, places of work, etc.], the "returns" cannot be mechanically equated to estimates of monetary earnings differentials. There are also compelling reasons to suspect that for many, graduate study may be part of the search for a career as well as elements of consumption—the sheer joy of learning. A correct calculation of *the* rate of return to the investment in a doctorate must somehow allocate the costs [of foregone income, tuition, incremental living expenses, etc.] to these joint products of human capital, consumption, and search. Breneman cogently argues that a key variable in this investment decision is the student's subjective estimate for his probability of success meaning the successful attainment of the Ph.D. degree. If one also believes that the prestige of a doctorate degree is an important element of the "returns", and if

Table 9. 3-3
Doctorate Degrees Conferred for Selected Fields

Field	1961	1966	1970	1971	1972	Growth rate* 1961-72
Physics	597	1,049	1,657	1,740	1,635	9.59
Chemistry	1,150	1,580	2,223	2,204	2,011	5.21
Engineering	940	2,283	3,432	3,495	3,475	12.62
Mathematics	332	766	1,218	1,236	1,281	13.06
Health Fields	101	175	300	349	318	10.99
Zoology	265	395	519	572	551	6.88
Psychology	820	1,133	1,883	2,116	2,262	9.66
Anthropology	60	109	225	258	278	14.96
Economics	413	622	971	951	980	8.17
Sociology	167	258	506	583	634	12.96
Geography	50	55	137	158	177	12.16

Source: National Research Council, Doctorate Record File.
* Figures represent the annual compound growth rate between 1961 and 1972.

an academic post provides more prestige, then the chances of securing an academic position will be another important variable. In this section, I try to combine these considerations into a model of the supply of applicants to graduate schools. The *juxtaposition* of this supply function and the Universities' demand for graduate students determines the equilibrium flow of first-year graduate students. The supply of Ph.D.'s is then linked to these first-year equilibrium enrollments via a theory of attritions from doctoral programs.

A. *The Monetary Earnings Differential:* A standard procedure in measuring the returns to education is to calculate the present value of earnings differentials over the working life. Let Y_{Bt} and Y_{Dt} respectively denote the wage earnings of bachelors and doctorates t years after completing the bachelor degree. If the successful completion of a Ph.D. degree entails k years of full-time graduate study, the present value of the earnings differential which accrues to the doctorate is given by,

$$(3.1) \qquad E = \sum_{t=k}^{T} (1+r)^{-1} (Y_{Dt} - Y_{Bt})$$

where r is the discount rate at which future income streams are discounted, and the individual is assumed to retire T years beyond his AB degree. Given the age-earnings profiles, (Y_{Dt}, Y_{Bt}), it is apparent that E will be larger, the lower is the discount rate r, or the shorter is the period of full-time study k.

Estimates of the age-earnings profiles of all doctorates, non-academic doctorates, and male college graduates (bachelor degree holders) for 1960 are presented in the top panel of Table 9.3-4.[30] If I assume that all workers retire at age 65, the undiscounted lifetime earnings are given by the sums shown in panel 1. [This also assumes that the Ph.D. earns nothing during his period of grad-

Table 9. 3-4
Annual Earnings of Bachelors and Doctorates, 1959-60*

Item	Bachelors	All Doctorates	Non-academic Doctorates
1. Annual Earnings at Age:			
22	3.032	0	0
26	5.224	6.197	7.588
30	7,099	7,614	9,290
35	8,863	9,235	11,220
40	10,318	11,240	13,634
45	11,199	11,492	13,061
50	10,534	12,519	14,701
55	11.626	12,755	15.802
60	11,435	12.942[a]	16.735[a]
64	11,181	13,183[a]	17,984[a]
Sum 22-64	407,155	426,421	522,926
2. Present Value of Earnings Y.			
2.a at 5 percent	148.914	143,967	174.759
2.b at 10 percent	74,693	64,909	78,634
3. Annual Equivalent Income Y.			
3.a at 5 percent	8,083	9,794	11,889
3.b at 10 percent	6.905	8,855	10,727
4. Differential in Present Value of Earnings[b]			
4.a at 5 percent		-4.947	25,845
4.b at 10 percent		-9.784	3,941

* Source: The bachelor figures are the 1959 incomes of White males with 16 years of education from the 0.1 percent sample. The doctorate figures are the geometric means of six cohorts in 1960 taken from: "Careers of Ph.D.'s. Academic vs. Non-academic". A Second Report on follow-up of doctorate cohorts, 1935-1960. (National Academy of Sciences, Publication 1577, Washington. D.C. 1968), see especially Tables 5 and 7, pp. 26 and 31.

a. Calculated by extrapolating the annual compound growth rate between ages 50 and 55 to ages 60 and 64.

b. Calculated from lines 2.a and 2.b.

uate study, ages 22-25.] The present values of earnings [where bachelors have a longer working life of 43 years vs. 39 for doctorates] at interest rates of 5 and 10 percent are shown on lines 2-a and 2-b.[31]

The earnings of all doctorates exceed the earnings of bachelors, but the difference in accumulated lifetime earnings (at a zero interest rate) is small, +19.3 thousand dollars in 1960. At a 10 percent interest rate, this difference in the present values of lifetime earnings becomes negative, −9.8 thousand, due to the loss of income during the assumed four years of graduate school. If, however, doctorate salaries are measured by the earnings of non-academic doctorates, the differences become sizeable, 115.8 thousand at a zero interest rate and 13.9 thousand at 10 percent.[32]

The differences shown on lines 4-a and 4-b of Table 9.3-4 are not the same as the differential in monetary earnings E [defined in (3.1) above] that accrues to the Ph.D. holder. To get E, we must add to the differences in Table 9.3-4, the present values of the incomes of bachelors over the first four years evaluated at interest rates of 0, 5, and 10 percent; these were 16.3, 15.0, and 14.0

thousand in 1960. Using both the all doctorate and nonacademic doctorate income profiles for Y_{Dt}, I calculated the following earnings differential to the Ph.D. degree:

Earnings Differential E for Alternative Interest Rates*

	r=0	r=.05	r=.10
All doctorates	35,577	10,093	4,175
Nonacademic doctorates	132,082	40,885	17,898

*derived from Table 9.3-4 using equation (3.1)

These figures indicate the rough orders of magnitude of the monetary returns to the Ph.D. degree. The earnings data, (Y_{Dt},Y_{Bt}) were geometric or arithmetic mean earnings that mask the wide variations of incomes across fields, individuals, and types of employment. An able engineer with a BS degree might easily earn more over his lifetime than a Ph.D. in agronomy. Further, these calculations were based on the earnings differentials (by education and age) that were observed at one point in time, 1960. The measured monetary return E for any given interest rate r [e.g. E = 10,093 for r = .05] will understate the *realized* differential in monetary returns E^* *if* all money incomes rise over time due to inflation and economic growth. More precisely, if (Y_{Dt},Y_{Bt}) describe the cross-sectional age-earnings profiles, and we want to calculate the present value of the monetary returns to a Ph.D. at an interest rate of r = .05, the appropriate formula is given by,

$$(3.1') \qquad E^* = \sum_{t=k}^{T} (1+r^*)^{-t} \; (Y_{Dt}-Y_{Bt}), \text{ where } r^* = \frac{r-g}{1+g}$$

In this equation, g is the annual compound growth rate of money incomes due to inflation and secular growth in labor productivity. Over the period, 1959-73, the Endicott series on the starting salaries of college graduates in business exhibited an annual compound growth rate of g = 4.75 percent per year, and it is probable that this will continue into the future.[33] Some writers like Banfield (1970) have asserted that youths attach a high discount rate to future income streams. If so, the use of adjusted interest rates r^* of 5 and 10 percent give us the right measure for the earnings differential E^* that correspond to personal time preference rates r of 10 and 15 percent.[34]

The question of whether salary differentials have widened or narrowed is of considerable importance in an analysis of the Ph.D. labor market. The starting salaries of Ph.D.'s who received their degrees in 1950, 1955, and 1960 [as well as an interpolated value for 1963] can be obtained from the NRC Survey.[35] The NSF Roster of Doctoral Scientists also gives us estimates of the median annual salaries of all Ph.D.'s of all ages. The NSF medians are considerably higher than starting Ph.D. salaries due to the older age of the NSF sample. These Ph.D. earnings data are shown in the first four lines of Table 9.3-5. The starting monthly salaries for business placements of college graduates, [the Endicott series] were converted to annual salaries and appear in line 3 of Table 9.3-5. The ratios of bachelor to doctorate salaries for selected dates are presented in lines 4 and 5. Over the period 1955-63, all doctorates earned nearly 50 percent more than bachelors (line 4-a). Line 5 suggests that the relative

Table 9. 3-5
Comparison of Annual Earnings of Doctorates and Bachelors, 1950-73

	1950	1955	1960	1963	1966	1968	1970	1973
1. NRC Cohort Data								
1-a All Doctorates	4,975	6,062	7,614	8,644[a]				
1-b Academic	4,525	5,316	6,976	7,983[a]				
1-c Non-academic	5,957	7,324	9,290	10,182[a]				
2. NSF Median Ph.D. Salaries			10,000	11,500	13,200	15,000	16,500	20,890
3. Starting Bachelor Salaries (Endicott, Business)	2,936	4,060	5,256	5,912	6,816	7,868	9,004	9,696
Relative Earnings of Doctorates								
4-a = (1-a)/3	1,694	1.493	1.449	1.462				
4-b = (1-b)/3	1.541	1.309	1.327	1.350				
4-c = (1-c)/3	2.029	1.804	1.768	1.722				
5 = 2/3			1.903	1.945	1.937	1.906	1.833	2.154

Sources: "Careers of Ph.D.'s" NRC (1968 and NSF Roster of Doctoral Scientists and Engineers).
a. Obtained by extrapolating the 1963 salaries back by three years assuming that doctorate earnings increase at 4 percent per additional year of experience.

salary differential has not changed much over time.

B. *The Costs:* In defining the appropriate concept for the cost of a Ph.D it is useful to distinguish between "outlays" and "economic" costs. The full economic costs of the investment in a Ph.D. include tuition, fees, travel, extraordinary living expenses[36] and the opportunity cost of foregone income during the period of graduate study. From the student's viewpoint, his *private* economic costs may be less than the full social economic costs by the amount of any scholarships, fellowship stipends, or income from part-time employment (such as through research and teaching assistantships) that he earns during his period of "full-time" study. Educators and graduate deans are often concerned about the out-of-pocket outlays that are needed to sustain a full-time graduate student. These "outlays" include tuition, fees, travel, and all living expenses.

All of the cost items that enter into both outlays and economic costs vary across fields of study, institutions, and individuals. In panel A of Table 9.3-6, I have assembled some of the background data on tuition and room and board costs.[37] In deriving the data appearing in panel B, I invoked the following assumptions:

1. Tuition is the arithmetic average for public and private universities. This is in rough conformance with the ratio of graduate student enrollments in the two types of institutions.

2. Living expenses for graduate students, (who are older and more likely to be married), are assumed to be 50 percent higher than the room and board expenses shown in panel A.

3. Roughly 20 percent of living expenses are extraordinary expenses that

would not have been incurred if the individual had not elected to attend graduate school.

4. The calculations for both outlays and economic costs assume that the student receives *no* financial aid and earns *no* part-time income.

The last two columns of Table 9.3-6 were included for the curious who might want to conjecture about the reasons for different growth rates in these cost components.

Table 9. 3-6
University Tuition and Living Expenses
(selected years)

Item	1959	1963	1968	1973	Growth Rate 1963-68	Growth Rate 1968-73
A. Background Data[a]						
1. Tuition						
Public		281	377	522	6.05	8.08
Private		1,216	1,638	2,412	6.14	8.05
2. Room and Board						
Public		745	868	1,147	3.10	5.73
Private		899	1,035	1,376	3.09	5.86
3. Foregone Income[b]	5.064	5,912	7,868	9,696	5.89	4.27
B. Constructed Data						
1. Tuition	590	749	1,008	1,482	6.12	8.02
2. Living Expense	1,084	1,225	1,427	1,812	3.10	4.89
3. "Outlays"	1,674	1,947	2,435	3,374	4.69	6.75
4. "Private Econ. Cost"	5,871	6,906	9,161	11,620	5.81	4.87
5. Present Value of "private cost" at r = .05 (000)	21.86	22.70	34.11	43.28	—	—

a Source: *Digest of Education Statistics*, Table 128 p. 113.
b Source: Endicott Series on Starting College Salaries for Business Positions.

According to my constructed estimates, the annual "outlays" that must be incurred in the quest for a Ph.D. have roughly doubled between 1959 and 1973. Tuition now accounts for 40 percent of the outlays. The private economic cost [which equal the full economic costs given no financial aid] are dominated by the opportunity cost of foregone income accounting for around 87 percent of the economic cost in 1973.[38] At a 5 percent interest rate, the present value of the economic costs for a student contemplating four years of full-time, unsubsidized graduate study, would have been 21.9 thousand dollars in 1959 and 43.3 thousand in 1973. These economic costs can be compared to the monetary returns in 1960 of 10.1 thousand for all doctorates [at r = .05] and 40.9 thousand for nonacademic doctorates. It is evident from these illustrative figures that the return to the investment in a Ph.D. for an unsubsidized student whose representative earnings stream is that of all doctorates, is below 5 percent. However, if he elects to enter nonacademic employment with its 20 percent higher salaries, the rate of return is just below 10 percent.[39] These "representative" calculations again conceal the wide variance across individuals. Tuition at private universities is three times that at public although the differential seems to be narrowing.

A comparison of the *private* economic costs to the monetary returns yields very different rates of return. A survey of graduate student finances in Spring 1965 revealed that 43 percent of the 477,535 graduate students received some stipends.[40] Weiss (1971) found that the *net* earnings of graduate students [defined as stipends and income from spouse or part-time employment less tuition] were positive and varied between 39 and 64 percent of the full-time earnings of comparable bachelor degree holders who did not pursue a graduate degree. He found that the median income of graduate students in 1966 was $5,900. When Weiss deducted the net student earnings from economic costs, the rate of return to the investment in a Ph.D. climbed from 6.67 to 12 percent. It is evident from these results that the size and availability of fellowships and part-time income have substantial effects on the profitability of an investment in the Ph.D. in terms of monetary rewards.

C. *The Probability of Success*: Not all who embark on the quest for a Ph.D. succeed. Our casual observations tell us something about the magnitude of the proportion π of each entering graduate class that ultimately completes all of the requirements for the degree. Rodney Stark (1966) compiled the records of several cohorts of graduate students at Berkeley. The completion rates of these cohorts from the Stark data are shown below:

Percentage Distribution of Degree Earned by 1966: Berkeley*
(for cohorts entering in 1951, 1954, 1957)

Department	No. in Sample	Percentage who earned: Ph.D.	Master	No Degree
Political Science	82	7.3	31.7	61.0
English	81	11.1	33.3	55.6
Chemistry	125	75.2	11.2	13.6
History	74	21.6	21.6	56.8

*taken from Breneman (1970A), Table 2, p. 9

What surprised me about the Stark data, was not the proportion π who earned the Ph.D. but the fact that aside from Chemistry, over half of each entering class went away without even a Masters degree which in many departments that I have observed is awarded in lieu of a certificate of attendance. A study of 3,450 Woodrow Wilson Fellows by Mooney (1968) is even more startling. Only 34.4 percent of these presumably able and adequately financed students completed the requirements for a Ph.D. degree.[41] A discussion of the determinants of the completion rate π [across fields and institutions] is deferred to section 3.3 below. The issue here is, "How does the student's estimate of π affect his decision to enroll in graduate school?".

Let γ denote the private net economic cost for k years of graduate study.

(3.2) $\gamma = \Sigma (1+r) (C_t - S_t)$,

where C_t is the full economic cost including the opportunity cost of foregone income, and S_t is the sum of stipends, tuition waivers, and part-time income. If we ignore the attrition risk, the expected net present value of the investment is simply,

(3.3a) $V = E - \gamma$,

where E is defined in (3.1). The model proposed by Breneman (1970A) tacitly assumes risk neutral students who maximize the expected net value, V', adjusted for the probability of completing the degree requirements π.

(3.3b) $V' = \pi E - \gamma$.

Clearly V' will vary across students depending on, among other things, ability and the chosen field of study which will affect π, the monetary returns if successful E, and the net economic cost γ. In this model, a student will apply for graduate school if $V' > 0$; i.e., if the net present value of returns is positive implying a profitable investment in human capital. The data in panel B of Table 9.3-6 provide some illustrative comparisons. A student who received a fellowship covering tuition and living expenses would have incurred a net economic cost of $\gamma = \$15.6$ thousand in 1960. Since the monetary return to all doctorates was only $E = \$10.1$, the Investment in a Ph.D. was *not* a profitable one at a 5 percent interest rate, even if $\pi = 1$. If, however, we compare γ to the income stream of a nonacademic doctorate, $E = 40.9$, the net present value V' will exceed zero when $\pi > .381$. It should be emphasized that these comparisons (which are based on admittedly crude data) describe the net returns to the "representative" student. The values of (π, E, γ) obviously vary across students. Although V' may be negative for the "representative" individual, it will be positive for some able students who are confident of their ability to earn the Ph.D. or who perceive high monetary return E which exceeds the average return.

D. *Non-Pecuniary Returns and Search:* The attainment of a Ph.D. degree is generally accepted as evidence of scholarly excellence and bestows upon its holder, preference in securing certain kinds of employment as university professors, heads of prestigious research organizations, or jobs involving original, independent research. If prestige, research, and teaching (especially at the graduate level) are desirable attributes (for which most individuals would be willing to forego some monetary [pecuniary] compensation),[42] competitive labor markets can be expected to establish equalizing wage differentials. The equilibrium wage rates for jobs with more prestige and better working conditions, will be lower by the equalizing differential R which represents the implicit monetary value which the marginal employee attaches to the attributes of the job or occupation. Introspection suggests that for many, academic salaries contain elements of economic rent; i.e., if all universities were cartelized and salaries reduced by X percent, many of us would still choose to remain in academia. This is *not* implying that the supply of Ph.D.'s to academia is completely inelastic, but rather that in measuring the pertinent supply *price* (the compensation needed to attract the last Ph.D. into academia), we must include the size of the equalizing differential R for the marginal worker. The difference between the earnings of academic and nonacademic doctorates (the latter earn about 20 to 30 percent more) gives us a rough indication of the nonpecuniary returns to academic employment.

The hiring and salary policies of universities and the heterogeneity of Ph.D.'s and jobs are two of the factors that may impede the attainment of a Pareto optimum equilibrium in the Ph.D. labor markets.[43] Virtually all universities have adhered to a policy of never cutting the nominal salary of an incumbent faculty member. Since roughly two-thirds of all faculty members are tenured, the burden of adjusting to changing market conditions must largely be borne by new doctorates. Further, the matching of individuals and jobs often entails substantial hiring and training costs because of the wide diversity in the traits of Ph.D.'s and the varying demands imposed by specific jobs. High labor turnover in an academic faculty or in a research organization greatly reduces the productivity of the organization. Given existing tenure arrangements and salary policies, new Ph.D.'s may be unable to obtain preferred jobs even though the employing institution (and the new Ph.D.) would be willing to exchange the new Ph.D. at a lower salary for an incumbent. As of Jan. 1, 1969, 59.7 percent of all science doctorates were employed in academia [confer Table 3.1]. If the potential supply of new Ph.D.'s prefer, on average, academic to nonacademic employment, the future availability of academic posts, [measured by the probability of securing such posts] must affect the non-pecuniary returns. More precisely, if the likelihood of getting an academic position is reduced, (as it is likely to be in the years ahead), it lowers the "returns" to the Ph.D. degree (including both monetary and non-pecuniary returns) thereby reducing the supply of students who will apply for graduate study.

The decision to continue beyond the AB degree may be prompted by a search motive. The inherent instability and uncertainty that surround the transition from school to work, manifest themselves in high labor turnover with frequent job changes and intervening spells of unemployment. Hall (1972) found, for example, that teen-agers typically hold three or four different jobs in a single year. For the non-college bound, the period following high school is characterized by the search for a suitable job. The situation is not qualitatively different tor the college graduate. For some individuals, the search for a career may be most economically carried out by enrolling in graduate school. Breneman (1970A) argues that most first-year students are ignorant about the objective chances π of earning a Ph.D. degree. I suspect that even fewer know how they would value the non-pecuniary attributes of the kinds of jobs which Ph.D.'s hold. Such information can only be obtained by enrolling in graduate schools. Others who do not find "suitable" employment in their senior year may apply for graduate school either as a way of staying in a "holding pattern" or as a means of switching fields of study. We have only limited empirical evidence on the returns to an investment in graduate education that does *not* culminate in an earned Ph.D. degree.[44] The cost of a graduate education, (at least for some individuals) should not be treated solely as an investment in human capital, but a part of the cost may be properly viewed as a cost of search.

The economic literature on job search yields two pertinent implications. First, a decrease in the cost of search increases the demand both in terms of the number of searchers and the duration of search. Second, wealthier individuals demand more leisure and attach higher implicit values to non-pecuniary attributes of employment which can only be determined by search. The availability of fellowships, TA's, and RA's greatly lowers the cost of search and should thus expand the supply of first-year graduate students. Further, students who do not have to migrate to universities confront lower search costs thereby implying higher first-year graduate student supplies (in relation to bachelor degrees) at the large urban universities. With the secular growth in the real wealth of our economy, I get the impression that more and more students are extending the time between formal schooling and full-time employment. The Vista volunteers, travel to Europe, or a stint in graduate school may all be reflections of an increase in the demand for a more leisurely search for a lifetime career. The wealth hypothesis [i.e. that the value of search is larger for wealthier persons] further implies that at a point in time, the family wealth of graduate students should be larger than that of undergraduates. The search motive thus suggests that other things equal, [specifically the monetary returns E and the cost γ], the projected growth in real incomes should lead to an expansion in the supply of first-year graduate students.

The expected net present value, V″, of an investment in graduate education can now be defined to incorporate these considerations. Let H denote the implicit value of search, while Q represents the implicit value of the non-pecuniary attributes of doctorate employments.

(3.4) $V'' = \pi(E+Q) + H - \gamma.$

All of the variables determining V″ can vary across individuals. The private cost γ, for example, is to a considerable extent determined by Federal, state, and private university policies concerning the amount and allocation of fellowship, TA, and RA funds; moreover, γ is likely to be smaller, the more able the student. Each graduating senior can, conceptually, be imagined to formulate subjective estimates about the value of search H, the probability of earning a Ph.D. π, the gross returns to the Ph.D. (E+Q), and the costs, γ — his estimate for γ is likely to be the most accurate. Hence, for each student, there is, in principle some V″, and we could conceptualize a frequency distribution of net present values, f(V″). The population of graduating seniors B who form the potential population of first-year graduate students, and the supply of first-year students, G_a, will then be given by,

(3.5) $G_a = \int_0^{\infty} f(V'')dV''. \qquad B = \int_{-\infty}^{+\infty} f(V'')dV''.$

In this abstract model, only individuals who perceive a net positive value for the investment in graduate education are presumed to enter graduate schools. The effect on G_a of changes in H, π, E, Q, and γ are obvious. There is some evidence corroborating these obvious anticipated signs. An unpublished study by Ashenfelter (1971) revealed, for example, a close positive correlation between the percentage of college seniors who intended to go on to graduate school, and the real (deflated) Federal outlays per graduate student for fellowships and traineeships; this result is consistent with $dG_a/d\gamma < 0$. The tighter labor markets for new Ph.D.'s, (especially in academia) in recent years, 1970-73, indicate a decline in both the monetary and non-pecuniary returns, (E+Q), to the Ph.D. degree. A fall in (E+Q) should be accompanied by a decline in G_a, and the recent data do, indeed, show a drop in the ratio of first-year enrollments to bachelor supplies, (G_a/B).

The aggregation implicit in the supply model outlined above conceals the ways in which market forces can influence the allocation of graduate students across fields. In the NSF supply model, the supplies of first-year graduate students in each science field are linked to the output of bachelor degrees in the corresponding fields.[45] An important omission in the model is the impact of the professional schools, [law, medicine, optometry, dentistry, business, etc.] on the supply of applicants to the science fields. There seems to be ample room for more empirical research on how the monetary returns, the psychic value of non-pecuniary returns, and the costs of the Ph.D. influence the supply of graduate students, both in the aggregate and to particular fields.

3.3 The University Demand for Graduate Students

A university can be imagined to be a firm that produces several joint products—bachelor degrees B, masters degrees M, doctorates D, and research X. Some might want to add another "output", service to the community. These "outputs" are produced by combining inputs of undergraduate students U, graduate students G, faculty F, and other resources—buildings, facilities, administration, and support personnel. The specification of a model describing the behavior of a university is beset by two difficult problems that have not been satisfactorily resolved in the literature. The first, (and simpler of the two), is the identification and estimation of a joint production function which describes how input flows of faculty and students, (F,U,G), are technically transformed into output flows of completed degrees and research, (B,M,D,X). In short, we want to know more about the properties of what Nerlove (1972) called the joint production function of an educational institution.

$$(3.6) \quad f(B,M,D,X) = g(F,U,G)$$

The second and more formidable problem is the specification of the university's objective function. Advancing the frontiers of knowledge, training tomorrow's leaders, solving pressing national and social problems, are but some of the phrases that appear in alumni magazines to describe the goals of a university. At a more disaggregative, partial level, Breneman hypothesizes a departmental objective function whose arguments include a prestige index for the reputation of the faculty, and the quality of its Ph.D.'s as measured by their placement in quality institutions. If degree recipients and research are properly adjusted for quality,[46] the arguments of a university's objective function should only include "outputs" and be something like,

$$(3.7) \quad W = \psi(B, M, D, X)$$

where increases in any of the arguments enhance the measure of achievement of the university which is denoted by some index W.

In striving to maximize achievement W, the university is constrained not only by the properties of the joint production function (3.6), but also by a budget constraint which might be written as:

$$(3.8) \quad FP_f + ZP_z = R + E. \qquad [R = R(U,G,X)]$$

where FP_f = the compensation of faculty, ZP_z = the cost of other resources, R = net revenue from tuition and research, and E = endowment income including the "fixed" components of Federal and State grants.[47] The model is complicated by the fact that each university is a slightly differentiated firm. The "price" of comparable faculty inputs can vary within narrow limits depending on the quality of the institution, of colleagues, of research facilities, and of graduate student inputs. Likewise, the "prices" that can be charged to comparable undergraduates U, may vary, but competition among institutions for these students limits the range of these price (tuition) variations. It is beyond the scope of this paper to attempt to derive the properties of the equilibrium for the university as a whole. I propose, instead, to direct attention to two special cases dealing with the demand for graduate students.

A. *The Short-run Trade-off Between Undergraduate and Graduate Degrees:* Consider a case in which research output X, other resources and their costs ZP_z, and endowment income E are fixed in the short run. The budget constraint facing the university can be simplified to:

$$(3.8') \quad FP_f = R^*(U,G) + K,$$

where K is the net revenue from endowments and research contracts less ZP_z, the costs of other resources. The "fixed coefficient" models that are used to project supplies, imply strong separability of the joint production function (3.6), namely, undergraduate inputs U do not affect the output of graduate degrees, and vice versa. The production functions implied by these models are of the form:

(3.6a) $B = (1-\alpha) U_1,$

(3.6b) $D = (1-\delta)G_1,$

where for simplicity, I assume only one kind of graduate degree, doctorates D. Thus, in (3.6a), the output of *equivalent* bachelor degrees B is linked to the lagged input of first-year undergraduates U_1 via the attrition rate α in undergraduate education. Similarly, D is linked to the lagged input of first-year graduate students G_1 via a different doctoral attrition rate δ. This is surely an over-simplification,[48] but it enables us to see how the budget and production function constraints limit a university's demand for graduate students.

Consider a university that increases its demand for graduate students in an attempt to expand its output of doctorates. It can do this in two ways; (a) offer more stipends to applicants of a given quality or (b) lower the minimum qualifications for admission to the doctoral program. If G and G_1 are measured in *equivalent* quality units, the revenue function, $R = R^*(U,G)$, will exhibit rapidly diminishing returns.[49] Further, an enlarged doctoral program must be accompanied by an increase in the size of the graduate faculty, F_g, in order to prevent an unwanted rise in the doctoral attrition rate δ. We can define a net marginal revenue, NMR_g, as the difference between the marginal revenue generated by the student, (dR/dG_1), and the incremental cost of the added faculty needed to maintain a constant attrition rate δ.

$$NMR_g = (\frac{dR}{dG_1}) - (\frac{dF_g}{dG_1})P_f.$$

It is probable that NMR_g becomes negative rather quickly when the university hires new faculty to staff the doctoral program.[50] When this happens, the budget constraint is violated, and the university must adopt another means of financing its increased demand for graduate students. The requisite graduate faculty could be obtained by reallocating the incumbent faculty from undergraduate to graduate programs. Such a reallocation must, however, be accompanied by curtailing undergraduate student enrollments U. If this is not done, a lower faculty to student ratio in undergraduate courses must lead either to a higher undergraduate attrition rate α or a lower quality of bachelor degrees; both result in fewer *equivalent* bachelor degrees.

In the absence of more external funds from endowments, research grants, or public funds, a university's short run demand for graduate students is effectively limited by its budget. The net marginal revenue of a graduate student, NMR_g, eventually becomes negative as (a) larger stipends are offered to attract students, (b) lower quality students are admitted, and (c) more faculty are hired to staff the graduate program. The enlarged doctoral program can only be financed within the university's budget constraint by cutting back on the production of undergraduate degrees.

B. *A Digression on the Incubation Period from Bachelor to Doctorate*: The NSF model for projecting future supplies of Ph.D.'s is qualitatively similar to the "fixed coefficient" model of equation (3.6b) above. The assumption in (3.6b) of a fixed ratio, $(1-\delta)$, of the output of Ph.D. degrees to the lagged input of first-year graduate students is an over-simplification. The "incubation period" from AB to Ph.D. degree clearly varies across individuals and fields. Let G_t denote the number of first-time enrollments to a graduate program in year t. Some fraction π_2 of them will complete all of the requirements for the degre in two years, another fraction π_3 in three years, etc. The doctorate yield from this cohort will then be the sum of these proportions where J is the upper limit, $(\pi_2 + \pi_3 + \ldots + \pi_J)$. If these completion probabilities are stable over time, the actual number of Ph.D. degrees conferred in year t, D_t, will be a distributed lag of prior first-year graduate enrollments, G_{t-j}.

$$(3.9) \qquad D_t = \sum_{j=2}^{J} \pi_j G_{t-j} = \pi_2 G_{t-2} + \pi_3 G_{t-3} + \ldots + \pi_J G_{t-J}.$$

The NSF Roster or the NRC Doctorate Record File could be used to estimate the profile of these completion probabilities π_j. In the time available for this paper, I was unable to gain access to these files. If, however, one assumes that nearly all students enter graduate school immediately after receipt of their bachelor degrees, the biographical data in *American Men and Women of Science* allow us to infer the length of the incubation period from AB to Ph.D. degree. A sample of 368 individuals was selected from this source, and data on the time interval between AB and Ph.D. degrees were cross-tabulated by major field and the year in which the Ph.D. degree was conferred. The results are presented in Tables 9.3-7A and 9.3-7B.

For the entire sample, the mean length of time from the bachelor to the Ph.D. degree was 8.48 years. One of every nine degrees was awarded to an individual who required fifteen or more calendar years beyond the AB before he completed his dissertation. In this sample of 368 degree recipients, the interval ranged from two years, [one of which was a Ph.D. in forestry awarded to an Indonesian whose previous degree was not easily translated into U.S. terms] to thirty years [for an undergraduate from McAllister who eventually earned his Ph.D. in inorganic chemistry].[51] The data of Table 9.3-7A reveal different frequency distributions for the physical and biological sciences vs. the social sciences. Fully 45 percent of the Ph.D.'s in the hard sciences were completed in four to six years. The social science distribution was essentially flat between four to nine years.

The incubation period as well as the probability of eventual completion [i.e. the sum of completion probabilities π_j] should be affected by the same market forces that influence the supply of graduate students. The analysis of section 3.2 suggests the hypothesis that the probability of completion should increase during periods of rapidly rising demands for Ph.D.'s. The percentage of late finishers [ten or more years to earn a Ph.D.] seems to have increased in the 1955-59 and 1965-73 periods, but the sample sizes in Table 9.3-7B are too small to show statistically significant differences. Aside from the Stark (1966) study, [reported in Breneman (1970A)], I was unable to get reliable estimates on the probability of ultimate completion, $\pi = \Sigma\pi_j$. I have the impression that π is around .2 to .4 in the social sciences and around .5 to .7 in the physical sciences.[52] If these guesses are near the mark, the long tails in the frequency distributions of incubation periods, suggest that at any point in time, there is a substantial reserve of "all but dissertation" Ph.D. candidates who could be induced to finish their degrees thereby augmenting the supply of new Ph.D.'s in a period of rising demands. Conversely, in a period of falling demands for

Table 9. 3-7A
Distribution of Incubation Period from Bachelor to Doctorate Degrees

Years from Ab/BS to Ph.D	Total Sample Freq.	Total Sample Percent	Total Sample Cumulative Percent	Degree Granted Since 1960 Freq.	Degree Granted Since 1960 Percent	Degree Granted Since 1960 Cumulative Percent
Physical and Biological Sciences						
2-3	9	4.95	4.95	3	3.95	3.95
4	29	15.93	20.88	11	14.47	18.42
5	28	15.33	36.26	11	14.47	32.89
6	25	13.74	50.00	12	15.76	48.68
7	17	9.34	59.34	8	10.53	59.21
8	15	8.24	67.58	6	7.89	67.11
9	10	5.49	73.08	1	1.32	68.42
10	11	6.04	79.12	6	7.89	76.32
11	4	2.20	81.32	2	2.63	78.93
12-14	14	7.69	83.01	8	10.53	89.47
15 or more	20	10.99	100.00	8	10.53	100.00
Social and Behavioral Sciences						
2-3	11	5.91	5.91	3	3.26	3.26
4	21	11.29	17.20	5	5.43	8.70
5	17	9.14	26.34	9	9.78	18.48
6	22	11.83	38.17	12	13.04	31.52
7	20	10.75	48.92	15	16.30	47.83
8	28	9.68	58.60	11	11.96	59.78
9	18	9.68	68.28	9	9.78	69.57
10	11	5.91	74.19	4	4.35	73.91
11	11	5.91	80.17	4	4.35	78.26
12-14	14	7.44	87.63	3	3.26	81.52
15 or more	23	12.37	100.00	17	18.48	100.00
All Sciences						
2-3	20	5.43	5.43	6	3.57	3.57
4	50	13.59	19.02	16	9.52	13.10
5	45	12.23	31.25	20	11.90	25.00
6	47	12.77	44.02	24	14.29	39.29
7	37	10.05	54.08	23	13.69	52.98
8	33	8.97	63.04	17	10.12	63.10
9	28	7.61	70.65	10	5.95	69.05
10	22	5.98	76.63	10	5.95	75.00
11	15	4.08	80.71	6	3.57	78.57
12-14	28	7.61	88.32	11	6.55	85.12
15 or more	43	11.68	100.00	25	14.88	100.00

Ph.D.'s, we should expect to observe a fall in the ultimate completion probability π (implying a rise in the doctoral attrition rate δ). The vast quantities of data in the NRC Doctorate Record File, and the diversity across fields in the market demands for new Ph.D.'s can be used to develop economic models that can be empirically implemented to test some of these hypotheses. Aside from Breneman (1970B),[53] the research to date has largely been addressed to projecting future supplies and *not* to further our understanding about the underlying production function for Ph.D.'s.

C. *The Longer Run Determinants of the University Demand:* In the long run, a university's demand for graduate students will clearly be influenced by its fi-

Table 9. 3-7B
Percentage Distribution of the Incubation Period from Bachelor to Doctorate
(classified by broad field and year of doctorate degree)

Year	Years from AB to Ph.D 2-7	8-14	15 or more	No.	Mean	Standard Deviation
Physical and Biological Sciences						
before 1939	91.7	0.0	8.3	12	6.00	2.98
1940-49	57.1	33.3	9.5	21	7.62	4.43
1950-54	65.7	34.3	0.0	35	6.69	3.01
1955-59	44.7	31.6	23.7	38	9.89	5.97
1960-64	58.8	35.3	5.9	34	8.32	5.83
1965-73	59.5	26.2	14.3	42	8.67	5.10
Total	59.3	29.7	11.0	182	8.18	5.03
Social and Behavioral Sciences						
before 1939	47.1	52.9	0.0	17	7.71	3.41
1940-49	65.0	30.0	5.0	20	6.60	3.07
1950-54	40.0	60.0	0.0	25	8.52	3.66
1955-59	50.0	34.4	15.6	32	8.66	5.13
1960-64	33.3	41.7	25.0	24	10.75	5.63
1965-73	52.9	30.9	16.2	68	9.13	5.40
Total	48.9	38.7	12.4	186	8.77	4.88
Combined Sciences						
before 1939	65.5	31.0	3.4	29	7.00	3.30
1940-49	61.0	31.7	7.3	41	7.12	3.82
1950-54	55.0	45.0	0.0	60	7.45	3.39
1955-59	47.1	32.9	20.0	70	9.33	5.60
1960-64	48.3	37.9	13.8	58	9.33	5.83
1965-73	55.5	29.1	15.5	110	8.95	5.27
Total	54.1	34.2	11.7	368	8.48	4.95

nancial (budgetary) resources and by the market demand for new Ph.D.'s. Very few universities admit *all* applicants for their doctoral programs because tuition simply does not cover all of the incremental costs. These costs include not only the direct costs for the higher faculty/student ratios in graduate courses,[54] but also the indirect costs of diverting faculty time away from contributing to the research output and undergraduate teaching of the university. In determining the size of its entering class which together with attrition rates fixes the size of the graduate program, [in terms of graduate enrollment and degree production], each department also considers the hidden costs deriving from the implicit, quasi-contractual, [and sometimes even paternal] relationships that often develop between graduate students and faculties. The process of dropping students from a graduate program is distasteful to many faculty members, and they would rather not admit marginal students even when the student is prepared to pay for the incremental costs.[55]

A university demands graduate students to produce Ph.D.'s who will hopefully contribute to the university's reputation and achievement. The value of more Ph.D.'s, in terms of the university's objective function (3.7), depends critically on the market demand for new doctorates. Breneman (1970A) assumed, for example, that each department behaves as if it had a "perceived demand" for its Ph.D.'s. In his model, a Ph.D. who can only be placed at a two-year community college, detracts from the department's reputation; i.e. he has a negative marginal value. If these are the only kinds of jobs available, the department will simply limit its output of Ph.D.'s either by reducing its demand for new graduate students or by increasing attrition rates.[56]

Information about the job market is often imperfect. Students seek the advice, guidance, and assistance of their principal advisors in finding suitable employment. These faculty advisors are often the channels through which information about the market is funneled back to the admissions committee. Graduate deans are continually surveying degree recipients and compiling data on their employment. Several writers have asserted that these information channels are imperfect, and they call for a national employment service for new Ph.D.'s. The Ph.D.'s and the institutions that employ them are very heterogeneous, and organized national exchanges like the wheat pit do not function well when buyer and seller must determine for themselves, the precise attributes of the other. My impressions are that the existing information channels, at least in the older established doctoral programs, function quite well. The newer programs with little prior experience in producing and placing students, seem to have more difficulty in perceiving current market conditions. For roughly comparable budget conditions, these impressions imply that in response to the recent downturn in the employment opportunities for physicists, the older established doctoral programs in physics should have exhibited sharper reductions in graduate enrollments.[57] Employment opportunities for new Ph.D.'s in academia and research are thus likely to affect both the university demand for graduate students as well as the supply of qualified applicants. Given current tuition rates and stipend policies for graduate students, the production of advanced degrees, (especially Ph.D.'s), constitutes a drain on the university's financial resources. With a declining market demand for new doctorates, universities will, in all likelihood, contract the size of their doctoral programs because Ph.D.'s in non-research and predominantly undergraduate teaching positions contribute little to the institution's reputation and prestige.

3.4 On Market Equilibrium and Projections of the Ph.D. Labor Market

The current NSF projections of the future supply and utilization of science doctorates predict the development of a serious glut in the Ph.D. labor market. By 1980, some 6 to 20 percent of all Ph.D. scientists are projected to be unable to find suitable employment in academia and in nonacademic research positions. The supply projections are mainly predicated on extrapolations of recent trends in the production of new doctorates. Thus, when first-year graduate enrollments dip, [as they did in 1971 and 1972], these supply projections are drastically revised downward without ever really trying to determine the underlying causal factors that produced the dip. Although surveys of the deans of graduate schools contradict these supply projections,[58] the trend projections still seem to command the attention of policy-makers.

On the other side, the utilization or requirements projections invoke rather rigid assumptions about the structure of the market demand. The projected academic requirements for new doctorates are based on arbitrary judgmental assumptions about the future time paths of two critical parameters, (a) the students to faculty ratio and (b) the doctorate share of new faculty appointments. The teaching load of American professors is absurdly low when compared to that of Soviet professors in non-research university positions. University professors, especially those with Ph.D. degrees, are expected to produce some research even when they are not explicitly provided with earmarked research grants; the role of academic research is wholly ignored in the current demand projection methodology. The relative values which a university attaches to the research and teaching outputs of their faculty, will surely influence the equilibrium ratio of students to faculty.[59] The assumptions about the doctorate share of new appointments also largely neglect market considerations except for *ad hoc* rationalizations for the particular assumptions invoked for the projections. Ph.D. and non-doctorate faculty inputs are clearly imperfect substitutes. The rational university can be expected to vary the proportions of doctorate to non-doctorate faculty inputs in response to changing relative prices (salaries) and relative productivities where the latter is measured by their respective contributions to the research and teaching outputs of the university.[60] In fact, these substitutions are also likely to affect the university's demand for graduate students when they are also employed as teaching assistants. I have not come across *any* empirical studies that attempted to estimate the magnitudes of the elasticities of substitution between doctorate, non-doctorate, and teaching assistant faculty inputs; in fact, I know of no theoretical studies on this topic.

The neglect of market equilibrium is also evident in the methodology behind the doctorate supply projections. Expectations about the salaries and employment opportunities for new Ph.D.'s, as well as the private net costs of an investment in the quest for a doctorate are, from a theoretical viewpoint, important determinants of the supplies of first-year graduate students; these factors are totally ignored in the current projection methodology. Moreover, many of these same variables are also likely to affect the ultimate supplies of conferred Ph.D. degrees via their impact not only on the university demands for first-year students, but also in the departmental practices which influence attrition rates from doctoral programs.

I can only conjecture on the ways in which policy-makers might react to the projected 1980 glut in the Ph.D. labor market. They could try to reduce the future supply of science doctorates by cutting back on fellowship and traineeship funds. They might try to augment the demand for Ph.D.'s by expanding the flows of Federal and state funds to finance more research and development. If universities could be assured of a continued exponential growth in their budgets, it is virtually certain that the academic demands for science doctorates would also expand. The simplest economic models, common sense, and intuition are sufficient inputs that enable us to predict the *direction* of change of the policy alternatives before us. We know that more Federal and State funds to subsidize graduate education will expand the supply of Ph.D.'s. What we do *not* know is the empirical magnitudes of the response of the Ph.D. labor market to the various policy alternatives, and the existing information that is conveyed by the scientific manpower forecasts do not tell us these crucial magnitudes.

The available projections of doctorate supplies and utilizations tacitly assume that whatever has happened in the recent past, will continue to prevail into the next decade or two. The projection methodology simply assumes away the fundamental facts of market equilibrium. The past and future supplies and demands for Ph.D.'s represent the equilibrium outcomes of private and public decisions. It is contended that the available projections give policy-makers an indication of the probable state of the Ph.D. labor market *if* the policies that were followed in the recent past were continued into the future.[61] But the rational formulation of public policies toward higher education can only be achieved if we, as analysts, are able to identify and quantify how past and future public policy actions affect the equilibrium in the Ph.D. labor market. In spite of these criticisms which have been voiced by earlier writers, public agencies continue to demand more scientific manpower forecasts that differ only in the refinement of the available statistics and in insignificant alterations in the basic methodology. The pressing need for more manpower projections of essentially the same ilk, [backed by the funding to produce these projections], seems somehow to have gotten the priorities reversed.[62] Forecasts that can be potentially useful in guiding the formulation of public policies, must be based on a sound economic model of the market for Ph.D.'s. Such a model would provide policy-makers with empirical estimates of the relationships describing the behavior of universities and other institutions (mainly research organizations and government) that employ science doctorates, as well as the behavior of college graduates who form the potential supply of new Ph.D.'s. The existing projection models that foretell the future of the Ph.D. labor market, do *not* incorporate these behavioral relationships and thus are incapable of providing us with valuable insights about the functionings of the Ph.D. labor market.

FOOTNOTES

[1] Market insurance and self-insurance via savings offer two ways of spreading the costs of some random events such as fires, illness, death, etc. Other risks and costs can be affected by allocating resources to protection; e.g. installing sprinkler systems, hiring public and private police protection, buying non-flammable fabrics, etc. F.H. Knight (1921) drew a distinction between "risks" and "uncertainties". According to my interpretation of Knight, risks pertain to situations in which the probability distribution of the random event is stable implying that the event is potentially insurable. Uncertainty, on the other hand, refers to a situation in which the probability distribution is unspecifiable or unstable. It would seem that the random events which scientific manpower forecasts purport to predict, are closer to Knight's concept of uncertainty.

[2] This reason applies equally to both public and private demands. An oil company contemplating an investment in another ocean-going tanker must somehow forecast the future returns whether that forecast be explicit or implicit.

[3] The six reasons cited here are direct quotations with only one minor omission. The reader is urged to consult the full text, [Freeman and Breneman (1973), pp. 16-18], which presents the authors' arguments for rejecting reasons 1, 2, and 4 as valid justifications for manpower forecasts.

[4] Freeman and Breneman (1973), pp. 16-18, contend that students distrust guidance counselors and that college administrators are quite responsive to changing demands for study in different fields. In their view, the objectives sought by reasons 1 and 4 are already being accomplished (without forecasts) by the decentralized decision processes which characterize the U.S. higher education system.

[5] This description appeared in G.J. Stigler, *The Theory of Price* (The MacMillan Co., New York: 1952), second edition, pp. 156-7.

[6] Although I appreciate the important distinctions between forecasts, conditional forecasts, and projections, the exposition is facilitated by referring to all of them as "forecasts". I shall, however, distinguish between requirements or demand forecasts vs. supply forecasts.

[7] The magnitude of the decline is evident by examining the data for a specific age class. In the table below, I present the Census data for the actual and projected population of 18 year-olds. The figures are five-year averages for both sexes in thousands:

1950-54	2,120.4
1955-59	2,279.6
1960-64	2,790.8
1965-69	3,620.0
1970-74	3,953.6
1975-79	4,215.2
1980-84	3,936.4
1985-89	3,569.0

It should be remembered that the 18 year-olds in 1989 were already born in 1971 so that these population projections will be extremely accurate.

[8] In their review article, Wolfle and Kidd (1971) p. 789 wrote, "For example, Balderston and Radner's work was, to a considerable extent, a test of the sensitivity of Cartter's projections of faculty employment to changes in some of the underlying assumptions."

[9] The four structural equations are: (1) new doctorate requirements D_j are equal to the doctorate share of new appointments P_j times total new faculty appointments N_j, $D_j = P_jN_j$, (2) total new faculty appointments are equal to the change in the stock demand for faculty plus replacement of faculty who retire. It can be written,

$$N_j(t) = [F_j(t) - F_j(t-1)] + \delta F_j(t-1) = F_j(t) - \sigma F_j(t-1),$$

where $\delta = .02$ is the retirement rate and $\sigma = 1-\delta$. (3) the stock demand for faculty is equal to the projected student enrollment in the j-th sector S_j divided by the student/faculty ratio R_j, $F_j = S/R_j$, and (4) student enrollment in the j-th sector is equal to the allocative proportionality share k_j times total student enrollment.

$$S_j(t) = k_j(t)S(t).$$

[10] If the assumed trends in the allocative shares of students, $k_j(t)$, are substituted into (2.2b), we get,

$$W(t) = W_0 - \beta t = .0225 - .0001227t.$$

Thus, W(t) declines from .0225 in 1970 to .0200 in 1990. In interpreting equation (2.4), it should be remembered that in the "no change" projection, P_j and R_j do not vary.

[11] I have only shown the parameters for the "adequate finance" case. The "intermediate" projections assume target values for the doctorate share of new hires, P_j, which, by 1990, will equal the observed 1967 percentage of associate professors in each sector who held doctorate degrees.

[12] According to the *Digest of Educational Statistics*, [(1972), Table 88, p. 75], resident degree credit enrollment in all institutions of higher education as a percentage of the 18-21 population, climbed from 4.01 percent in 1899-1900 to 51.89 percent in Fall 1970. The *Digest* figures of 7,545 thousand enrolled in Fall 1970 differs from the Cartter projection for 1970 of 6,303 thousand [as reported in Table 3-1 of Balderston and Radner (1971), p. 18]. The discrepancy is probably due to the use of full-time equivalent students in the Cartter projections. The Cartter student enrollment projections imply that college student enrollments as a percentage of the 18-21 population will rise from 43.3 percent in 1970 to 60.4 percent in 1990.

It is my understanding that the current version of the NSF projection model incorporates a feedback effect. Using a Phillips curve type adjustment model, the projection for first-year graduate enrollments is lower, the larger is the excess supply of doctorates. Hence, the projected academic requirements for new doctorates affects projected student enrollments in the "market" version of the NSF model.

[13] Disaggregation serves a useful purpose when the behavior and/or parameter values for the disaggregated sectors are substantially different. The principal difference among the six sectors is in the doctorate share of new appointments P_j. A disaggregation between undergraduate vs. graduate enrollments would, I suspect, have been far more efficient in describing the prior "demands" or requirements for new doctorates.

[14] The most recent BLS projections are reported in, "College Educated Workers, 1968-80" BLS Bulletin 1676. Projections for 1975 appear in "Tomorrow's Manpower Needs", BLS Bulletin 1606. The BLS methodology is described in Appendix A of Bulletin 1606, Vol. IV.

[15] In actuality, the methodology is more complicated. For some occupations such as auto mechanics, dentists, etc. for which time series data are available, occupational requirements are directly estimated by relating employment in the occupation to various explanatory variables such as vehicle registrations, disposable income, frequency of repairs or visits to dentists, etc. I am also skimming over the difficult empirical issues of comparable data and consistent occupational definitions.

[16] With fixed technical coefficients, the prices of products that are more labor intensive will rise faster when the wage rate of labor is increased. The higher relative prices for labor intensive goods will prompt consumers to demand fewer of those goods thereby reducing the aggregate demand for labor. This principle was demonstrated by Friedman (1962) in his "Theory of Distribution with Fixed Proportions".

[17] The ratio of the projected requirement to actual employment in the j-th occupation, $(\hat{E}_j/E_j)$ is simply the product of the corresponding ratios for industry employment and occupational ratios. If there are N industries, we have,

$$\frac{\hat{E}_j}{E_j} = \sum_{i=1}^{N} k_i\left(\frac{\hat{r}_{ij}}{r_{ij}}\right)\left(\frac{\hat{E}_i}{E_i}\right)$$

where k_i is the i-th industry's share of employment in the j-th occupation. The relative error in the projected occupational ratios, $(\hat{r}_{ij}/r_{ij})$ is found to be four to five times the relative error in projected industry employment, $(\hat{E}_i/E_i)$.

[18] The linear trend is the simplest functional form, but one could posit polynomial trends, exponential trends, or logistic trend equations.

[19] The NSF procedure is equivalent to invoking the following assumptions about the variance of the error term: (a) $E[e_t^2] = \infty$, for all t prior to the last ten years of the sample data, (b) $E[e_t^2] = \sigma^2$ for the first five years included in the admissable sample, and (c) $E[e_t^2] = 0.5\sigma^2$ for the most recent five years. Finally, it is tacitly assumed that the random errors are serially independent; i.e., $E[e_t e_{t+j}] = 0$ for all $j \neq 0$. Given these assumptions, the parameters are estimated by Aitken's generalized least squares to get a weighted trend line.

[20] One way to see if the relationship has shifted is to estimate it for subperiods. I fitted the linear trend (2.7b) for two five-year subperiods where $T_t = 1$ in 1958 and 10 in 1967. The ordinary least squares trend lines were:

$$H_t = 63.07 + 1.010T_t \qquad [1958\text{-}62 \text{ period}]$$
$$Y_t = 66.27 + 1.060T_t \qquad [1963\text{-}67 \text{ period}]$$

The samples are too small to apply significance tests, but it seems that the intercept α shifted in the most recent five-year period. The linear equation is one of many trend relationships that could have been fitted to the time series data. One could have experimented with logarithmic trends, logistic trend equations, etc. But as I shall argue in section (c) below, trends can only describe a time series and do not "explain" the time-path of the variable in question.

[21] It is assumed here that students go directly from high school to college, and the production period for a bachelor's degree is four years for everyone. The NSF supply projections do allow for delays in starting college and in the time required to earn the degree. However, these lags are reported to be stable over time, and neglect of them here does not affect the principle that is being analyzed here.

[22] The *Digest* only reported data from the biennial surveys. Data for the odd years were taken from *Social Indicators* published by the Bureau of the Census. First-time enrollments (*Digest*, Table 90) include returning veterans as well as students who do not go directly from high school to college. The completion rate, $c_t = 1-\alpha_t$, was calculated as the ratio of bachelor degrees in year t, Z_t, divided by first enrollments four years earlier, E_{t-4}; $1-\alpha_t = Z_t/E_{t-4}$. The data of Table 9.2-3 apply to both sexes. The NSF methodology computes separate rates for males and females.

[23] The fifth column of Table 9.2-4 presents the ratio of doctorate degrees awarded in year t divided by bachelor degrees awarded in year t-5. A three-year moving average of bachelor degrees awarded in years t-4, t-5, and t-6 was used in the denominator of the ratios appearing in the sixth column. Since the number of bachelor degrees awarded exhibited a fairly smooth upward trend over this period, the two ratios of doctorates to lagged bachelors are not appreciably different.

[24] The cost of a college education has fallen with the rapid expansion of low tuition public colleges and universities. The available cross-section data indicate that the income elasticity of the demand for college education is positive and large. To the best of my knowledge, we do not yet have good empirical studies that estimate the response of first-time enrollment rates to the private costs of college education and family income.

[25] The following data on student enrollments (in thousands) by control of institution were taken from the *Digest of Educational Statistics*, 1972, Table 87.

Year	Total	Public	Private	Public/Private
1952	2,134	1,101	1,033	1.066
1960	3,583	2,116	1.467	1.442
1971	8,116	6.014	2,102	2.861
1971:1952	3.80	5.46	2.04	—

Enrollments in the public institutions over the period 1952-71 increased at an annual compound growth rate of 9.3 percent while that of the private institutions was only 3.8 percent. Further, Table 88 of the *Digest* revealed that graduate students constituted 10.1 percent of total enrollment in 1952, and 11.9 percent in 1970. The shift toward more graduate study is thus considerably less than that toward more publicly financed higher education.

[26] I have borrowed heavily from Breneman (1970A) and strongly recommend it to the reader.

[27] In their review article, Wolfle and Kidd (1971) summarized several projections of doctorate supplies and requirements including those by Cartter, NSF, Balderston and Radner, and others. The *caveat* that projections are *not* forecasts, is reiterated in this article. However, the authors write, "The agreement among these three studies indicates that the projected faculty requirements given in Table 3 can be taken as a reasonable base for estimating the future academic market for new doctorates." A skeptic would ask if these were "independent" studies and would question their underlying projection models before accepting the "reasonableness" of the estimates.

[28] It is my understanding that NSF is revising these projections by re-estimating trend equa-

tions in the light of more recent data on first-year graduate enrollments, supplies of doctorates, Federal R and D spending, etc. The inventory of doctorate scientific utilization is also being updated, and the methodology attempts to incorporate a feedback in which first-year enrollments are related to the supply/utilization projections.

[29] Further evidence on the sensitivity of this methodology can be found in Lincoln E. Moses (1972). Moses using a similar technique but having the advantage of more recent time series data on bachelor degrees and first graduate enrollments in physics, developed his own projections of the output of Ph.D. physicists which were (not surprisingly) considerably below the earlier projections by the Office of Education and by Cartter.

[30] The data for doctorates represent geometric means of annual incomes from all sources for six cohorts of Ph.D.'s who responded to the NRC survey; confer "Careers of Ph.D.'s", NRC (1968). The NRC questionnaire asked each respondent to report his 1963 annual income and to report (based on recollection) his income in 1960, 1955, and on back to 1935. In developing Table 9.3-4, I assumed that cohort 6, (degree recipients in 1960) was, on average, 30 years of age. The income for 35 year-old Ph.D.'s was taken to be the geometric mean for cohort 5 (degrees conferred in 1955), etc. Annual earnings for the intervening ages (e.g. 32 or 58) were calculated from log-linear interpolations and extrapolations. I also assumed that in his first four years of employment, (ages 26-29), annual earnings increase at 4 percent per annum, and jump by 10 percent upon receipt of his degree. The income data for "bachelors" are the annual incomes of white males with exactly four years of college education as reported in the 1960 Population Census. I wish to express my thanks to Prof. Sherwin Rosen who supplied these data to me.

[31] The annual equivalent income streams appearing on lines 3-a and 3-b of Table 9.3-4 are simply the constant income levels that would have generated the present values shown on lines 2-a and 2-b. Lines 4-a and 4-b simply show the difference in lifetime earnings.

[32] The "always nonacademic" group earns roughly 20 percent more than all doctorates due largely to the fact that the always nonacademic doctorates are more likely to be in engineering, chemistry, physics, and some of the biological sciences.

[33] Technological advances and an increasing ratio of capital to labor are the two most frequently cited explanations for the secular growth in real per capita income. The permanent rate of inflation cannot be predicted, but growth rates for money incomes of 3 to 8 percent seem plausible. In deriving (3.1'), I tacitly assume that relative incomes [e.g. ratios like (Y_D/Y_B)] will be unaffected by inflation and growth.

[34] The importance of this adjustment for the secular growth in money incomes was recognized by Weiss (1971) who used data for 5,868 scientists to estimate the monetary returns to the Masters and Ph.D. degrees. In a sense, the distinction between r and r^* is akin to the distinction between real and nominal interest rates.

[35] The NRC data on starting Ph.D. salaries pertain to individuals who have just received the degree. They are thus *not* representative of the starting pay on the first appointment immediately following full-time graduate stud

[36] Since living expenses will be incurred irrespective of the decision to invest in a Ph.D., only the extraordinary incremental living costs arising out of having to live in specific localities, should be included in the full economic costs.

[37] The data were taken from Table 128 of the *Digest of Educational Statistics*, 1972. The same table presents data from the survey on tuition and room and board expenses for four- and two-year colleges. I have limited the data shown in Table 9.3-6 to universities.

[38] The Endicott data on starting salaries are higher than the 1959 Census data on earnings of white male college graduates, 22-24 years of age. Similar discrepancies are also observed for 1949 and 1969. If I had used the Census figures for foregone income, it would have reduced the economic costs by around 15 to 20 percent.

[39] Weiss (1971) estimated the internal rate of return to the Ph.D degree for an unsubsidized student with no outside income at 6.67 percent. Confer Weiss (1971) for comparisons with other estimates of the rate of return.

[40] The data reported in Table 98 of the *Digest* do not indicate the size of the stipend. The sample is a head count with 45.5 percent of all graduate students being 29 years of age or older. The percentage holding stipends fell with age, but this may be due to a contemporaneous correlation with larger fractions of older students being part-time graduate students, only 26 percent of part-time students held stipends. Some 66 percent of full-time students received stipends. There was very little difference between public and private universities, this may, in part, reflect different ratios of full to part-time students.

[41] The Mooney sample included fellowship recipients in 1959-61. His cut-off data of 1966 may partially account for the low completion rate. It will be shown below that only 54.1 percent of all Ph.D. recipients complete the requirements in less than eight years.

[42] This does not mean that the Ph.D. is a pre-requisite for these positions. Non-doctorates do hold down important positions on graduate faculties and make important contributions to the

scientific literature. The value of the Ph.D. in securing such positions is, however, substantial as evidenced by the recent embarrassing confessions by two heads of research organizations in Colorado who admitted that they had fabricated their Ph.D. degrees.

[43] A truly optimal (ideal) equilibrium would be one in which given the salaries and attributes of various jobs, no Ph.D. would want to trade positions with any other Ph.D. and no employing institution would want to swap with another. This presumes that the Ph.D.'s involved in these conceptual exchanges possess comparable talents.

[44] Weiss (1971) found very low rates of return to the masters degree, and in some fields, it was even negative. Breneman (1970A) seems to feel that the monetary returns to graduate education are negligible for those who do not complete the Ph.D. degree. The issue here is an empirical one that could, in principle, be settled by a good empirical study on the returns to partial graduate education.

[45] The ratio of monetary returns to cost, (E/y) has exhibited considerable variations across fields. In the 1950's, when fellowships, TA, and RA funds were relatively scarce, medical schools were able to attract the very best of each senior class. As more public funds were allocated to fellowships, it was alleged that the quality of first-year medical students declined. Finally, the previous links between undergraduate and graduate fields seem to be breaking down. Most of us would agree that an AB degree in history is unlikely to qualify a study for admission to a doctoral program in physics. Medical schools would not have admitted history and mathematics majors only a decade ago, but many are now doing just that.

[46] The problem of quality adjustments is present in all studies. We must somehow combine Ford Pintos and Pontiacs in constructing a measure of the output of the automotive industry. The problem here is relatively simple since market prices provide a measure of quality differentials. The heterogeneity of individuals who are awarded the same degree, creates a difficult problem in defining the "output" of *equivalent* degrees. In the model proposed by Breneman (1970A), Ph.D.'s are classified according to a five point scale. By attaching a cardinal measure to the scale, it would be possible to construct a measure of the output of equivalent Ph.D.'s.

[47] State appropriations for higher education are often tied to student enrollments (U,G), and the variable part of such appropriations should properly be included in R. The marginal revenue from an increase in undergraduate inputs, $R_u = dR/dU$, should include the "net tuition" [less scholarships] plus tied appropriations. If fellowship, TA and RA awards to students exceed tuition plus state appropriations, it might happen that the marginal revenue of an additional graduate student, $R_g = dR/dG$, could be negative. Research X that is funded by public agencies, non-profit organizations, or private parties, usually contributes to the university's revenue. If, however, more research is financed out of the "general funds" of the univesity, $R_x = dR/dX$ will be negative. Presumably, when $R_x < 0$, the research contributes enough to the achievement W to warrant the outlay.

[48] The effects of faculty inputs on the outputs, (B,D), are buried in some unspecified relationship of F to the attrition rates (α,δ). Further, more graduate students can affect the output of bachelors, especially if they are used as TA's. The difficulties of measuring *equivalent* outputs and inputs will be discussed in the text.

[49] This conclusion is obvious under the first path since increasingly larger stipends must be offered to attract qualified applicants away from competing institutions. The marginal revenue, $R_g = dR/dG$, would be negative if stipends over and above tuition waivers were needed to attract another student. Under the second path, we must somehow convert students into equivalent quality units. The exceptional cases of students with low GRE scores from poor schools who do well in graduate school [and earn Ph.D.'s], prove the rule that there are trade-offs along the quality dimension. There is, in principle, some number of students with GRE scores of 80 from Ferdonia State who together are equivalent in quality to one student from Reed with a GRE of 95.

[50] Senior, tenured faculty are more likely to be assigned to the graduate courses, and the new faculty are often used to replace senior faculty in undergraduate courses. If the expansion is accomplished by hiring tenured faculty, the university incurs a long run obligation that may have serious impacts on future budgets.

[51] It should be repeated that the incubation period is measured here in calendar time and *not* time spent in full-time graduate study. The observations in the right tail of these frequency distributions reflect (a) delays in beginning graduate study, (b) part-time study toward the degree, (c) delays in completing the dissertation after taking a full-time position, etc. Weiss (1971) reports that the variance of the time input needed to earn a Ph.D. (measured in semesters or quarters of full-time registered study) is considerably smaller than the variance in calendar time.

[52] It is my understanding that the NSF supply model is based on estimates (by field of study) of the time profiles of completion probabilities, π_t, calculated from the first-year graduate enrollment data assembled by the Office of Education. There are substantial differences in both the mean incubation period and the ultimate completion probability. Women and Blacks tend to take longer to complete the Ph.D. and smaller fractions of them earn the degree.

[53] Breneman specified a production function in which the output of Ph.D.'s (in relation to

graduate enrollment) was related to the output of terminal Masters degrees, the faculty/student ratio, the proportions of graduate students receiving fellowships, RA's, and TA's, and the AEC rating of the department. He assumed a linear form for this production function and estimated its parameters using cross-sectional data for a sample of Berkeley departments. Breneman's model tacitly assumes that all departments (Chemistry, French, Economics, etc.) confront the *same* technical production function for producing Ph.D.'s. Further, his data implicitly assume that students are homogeneous both within and across departments. His model is suggestive, and it would be enlightening to urge further research along these lines. The model could, for example, be extended to incorporate micro-economic data on the student inputs, to allow for the allocation of faculty time to research as well as to undergraduate and graduate teaching, etc.

[54] The following formula was reported by Breneman (1970B) as the one which was used by the California State University system to determine the number of full-time equivalent (FTE) faculty positions in each department.

$$FTE = \frac{1.0(LD) + 1.5(UD) + 2.5G_1 + 3.5G_2}{38}$$

where LD = lower division enrollment, UD = upper division enrollment, G_1 = first-year graduate enrollment, and G_2 = advanced graduate enrollment. The direct faculty cost per graduate student is 2.5 to 3 times greater than that for an undergraduate, even though the two pay the same tuition. The formula makes no allowance for authorized faculty slots that are supported by internal or external research funds.

[55] According to Breneman (1970A), many students interpret their admission to a doctoral program as implicit evidence that in the view of the department's faculty, they possess the necessary qualifications to earn a Ph.D. degree.

[56] In his scenario of the Berkeley Chemistry department, Breneman argued that nonacademic appointments were "neutral" with respect to the department's reputation and prestige index W that was presumably being maximized. Hence, the Chemistry department expanded its demand for graduate student enrollments by lowering the attrition rate and the time required to earn the degree. I suspect that many of these nonacademic chemists were employed in research positions that encouraged publications and participation in professional meetings and conferences. If so, their research output would make a positive contribution to the department's prestige. If the nonacademic jobs were *not* in research, would the Chemistry department behave in the same manner?

[57] Moses (1972) pointed out that between 1969 and 1972, the fifteen largest departments reduced their physics enrollments by 30 percent, while physics enrollments in all institutions fell by only 17 percent. It seems reasonable to suppose that the fifteen largest departments are likely to be the older institutions. No clear inference can, however, be drawn since it might have been the case that the contraction in Federal and public funds was larger for these fifteen departments.

[58] In the light of the long incubation periods that are needed to produce Ph.D.'s, it should be possible to assemble fairly reliable data on the inventory of "Ph.D.'s in process". Nearly all of the students who will be receiving doctorate degrees in the next four to six years, either are already in the pipeline or have accepted admission offers to enter the doctoral programs for the coming fall semester. The graduate deans who presumably have such data at their disposal, predict virtually no change in the annual output of Ph.D.'s for the next four to five years.

[59] Certain private and one or two public universities point with pride to their track records of employing faculty members who have made significant and original scholarly contributions to the advancement of the sciences and arts. It is not surprising to find that these institutions typically have lower student to faculty ratios because their faculties are making substantial contributions to scientific and literary research. Moreoever, to the extent that public agencies and non-profit research organizations are prepared to allocate research funds to the university's budget, these financial considerations will also affect the equilibrium students to faculty ratio.

[60] Institutional practices with respect to tenure arrangements and salary policies may prevent a university from implementing some of these substitutions.

[61] The validity of even this modest contention can be debated. If there are lags in adjustment, a policy initiated and undertaken in year t may affect doctorate supplies in demands in years t+1, t+2, In this event, the policies prevailing in the recent past may generate time paths for doctoate supplies and demands that are very different from extrapolations of trends on the dependent variables.

[62] It is reminiscent of the story of the two rabbis who were studying the question, "Which is more important, the sun or the moon?". After considerable debate, they concluded that it was the moon because it gave light in the night when it was most needed.

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Appendix Note A: BLS Projections of Industry Employment and Occupational Ratios

The employment projections by industry are developed in various ways. One approach is to begin with prior projections of final output demands which are then converted into industry employment requirements by using input-output matrices. A second approach is to relate industry employment to certain aggregate variables. According to Bulletin 1606, employment for many industries were projected from regression equations of the form,

(B.) $E_{it} = \beta_{0i} + \beta_{1i}X_{1t} + \ldots + \beta_{5i}X_{5t} + e_{it}$

where E_{it} = employment in industry i in year t, X_{1t} = GNP in constant dollars, X_{2t} = the national unemployment rate, X_{3t} = the number of persons in the Armed Forces, X_{4t} = the civilian non-institutional population 14 years of age and older, and X_{5t} = t = a trend variable. The parameters of equation (B.1) were estimated by ordinary least squares using annual historical data for the period 1947-66.[1] If we let X_{hp} denote the assumed values for the explanatory variables in the projection year p, [h = 1,2 . . . 5], the projected employment for the i-th industry is obtained as follows:

(B.2) $\hat{E}_{i.} = \hat{E}_{ip} = \hat{\beta}_{0i} + \hat{\beta}_{1i}X_{1p} + \ldots + \hat{\beta}_{5i}\hat{X}_{5p}.$

Thus, projected industry employment is a conditional forecast which depends on the assumed values for the exogenous aggregate variables. Since the parameter estimates, $(\beta_{0i}, \ldots \beta_{5i})$ are random variables, it follows that $E_{i.}$ is also a random variable. If the projections generated by this simple model generated implausible results, [or if it did not exhibit an acceptable statistical fit to the sample data], it was replaced by a projection based on judgment or extraneous information possibly including a regression equation with explanatory variables other than those identified in equation (B.1). Finally, the industry employment projections, $\hat{E}_{i.}$, are normalized to be consistent with the assumed projected level of total employment in the economy as a whole.

The BLS method for projecting occupational ratios is less clear. The Census data for 1950 and 1960 were used to calculate the observed occupational matrices, (r_{ij}), for all industries and occupations. Such detailed data were not available for intervening years, but for a smaller set of broader occupation/industry groups, it was apparently possible to estimate observed ratios by using data from the CPS and other industry sources. Trend equations were apparently fitted to these time series data, and the extrapolation of these trend equations gives one set of estimates for the occupational ratios in the projection year. I assume that ratio projections $\hat{r}_{ij}$, for all occupations and industries were somehow generated by interpolation using the complete occupational matrices in 1950 and 1960 as benchmarks. Again, when the trend equations and interpolations yielded implausible values, subjective estimates based on conventional wisdom, employer surveys, or judgments by experts and BLS analysts were substituted. The projected occupational ratios can surely be regarded as random variables even though the BLS methodology does not allow us to identify the probability distribution of $\hat{r}_{ij}$.

The projected manpower requirement for the j-th occupation, $\hat{E}_{.j}$, is simply the product of the two projections summed over all industries.

(B.3) $\hat{E}_{.j} = \Sigma \hat{E}_{i.} \hat{r}_{ij}$

It is thus the sum of the product of two random variables. If we knew the probability distributions of $\hat{E}_{i.}$ and $\hat{r}_{ij}$, we could, in principle, derive the sampling distribution for the occupational requirement $\hat{E}_{.j}$ thereby allowing the construction of a confidence interval.[2] However, a confidence interval is useful to a policy-maker if and only if the estimate of the occupational requirement, $E_{.j}$, is unbiased, and the retrospective evidence relating the projection to subsequent realization, soundly rejects this hypothesis.

[1]The industry employment data used for these regressions referred to wage and salary employees. The projections of wage and salary employees were then inflated to include the "other employed persons" with suitable adjustments made to net out multiple job-holders. Equation (B.1) describes the initial model specification. If some explanatory variables were insignificant, they were omitted from the final equation that was used for the projections. Some examples of these equations are shown in BLS Bulletin 1606, Vol. IV, Appendix A.

[2]Let $Z_{ij} = \hat{r}_{ij}\hat{E}_{i.}$ denote the product of two random variables. If $\hat{r}_{ij}$ and $E_{i.}$ were independently normally distributed, a Bessel function describes the probability distribution of Z_{ij}. When $\hat{r}_{ij}$ and $\hat{E}_{i.}$ are jointly normally distributed and their correlation approaches plus one, the distribution of Z_{ij} approaches a non-central chi-square distribution. In short, deriving the sampling distribution of Z_{ij} [let alone the sum of such variables] calls for more information than that which can be provided by the BLS methodology. It is thus not surprising to find that no attempts are made to indicate the sampling errors implicit in the BLS projections.

10. Roundtable Summary

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Herbert E. Carter, Presiding:

In 1968 Congress saw fit to alter the statutes with regard to the National Scienc Foundation and the National Science Board, and some very deep-seated and important changes were made. The wording was changed from NSF "may" support social science to NSF "should" support social science. Applied research was to be given greater attention.

The National Science Board was required to issue a yearly report, and its first report (1969) was issued in two parts; the first, more general, section was entitled "Toward Policy for Graduate Education." The second part, prepared by Mr. Hartman, had an enormous amount of data about the graduate educational process over the past hundred years.

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That first Board report, prepared largely by Phil Handler and Charles Slichter, expressed the optimism and euphoria which were just on the verge of disappearing at the end of the golden age of science. The philosophy of the report was that it is impossible to educate too many or too high a percentage of our bright people to the limit of their intellectual ability as long as there is an adequate diversity to the process (not every member of the Board accepted this caveat).

At that time, the Foundation and the Board were suppotting and getting funds for centers of excellence for institutional grants to expand the Ph.D. competency of this country. Departmental grants, fellowships, and then traineeships were being provided. It was, indeed, an optimistic and expanding economy at that time.

The change began, slowly, and later came ever more rapidly. Space and defense began to cut down, then there was a transition to cuts in civilian sectors of the economy. The traineeships program disappeared; fellowships were reduced to almost a minimum. Unemployment began to appear somewhat later.

Some in the scientific community made bitter accusations against the Foundation for having engaged in policies over the years that were now contributing to putting scientists out of work. Indeed, NSF and the National Science Board have been deeply and increasingly concerned about the manpower problems.

Increasingly in this transition period from a goods to a service economy, and with changes one can foresee in the universities, there were and are questions such as: Should graduate education be dissociated more from basic research? And, of course, with the advent of economists at the Board table new imputs were added. We began to learn that in the last four or five years the sophistication and methodology for studying manpower problems was expanding at a rapid rate. This has been an area of ferment, of research, of bright young people devoting their attention to these problems. Of course, a better understanding of these problems is fundamental to a number of the challenges that the Foundation faces.

We felt that if a group could get together for a day or so, there might be some progress in understanding the manpower problems and we could better establish our priorities as a board. We wanted to provide catalyzing interactions which would be useful to experts in the field and to others. I hope that this will be the first of a series of such meetings that might be held over the next five years or so to enable us to do a much better job of looking at manpower.

Russell D. O'Neal:

The National Science Board Manpower Subcommittee has been charged by the Board with carrying out a critical, comparative study of existing manpower analyses and the assumptions which underlie them. Bob Dicke, Glenn Campbell, Marshall Hahn, and Harvey Brooks have joined me in this task.

In structuring this seminar, we sought the participation of people who would present various points of view regarding the value of projections, and whether and how projections might be improved. We wanted to bring together leading experts, as well as users in industry, government, and universities, for the lively discussion and controversy which this forum would generate. Perhaps it will be possible in this roundtable summary to develop some conclusions and guidelines for future efforts, even if they need to be tentative.

We wish to focus on three topics, listed in order of priority as follows:

1. What is the status and use of scientific and technical manpower projections? What are their limitations and impacts? And, what can be done to improve them so that they will be more useful to various users, but particularly to students (either directly or indirectly) in making their career decisions?

2. What trends can we see in supply-demand, and particularly what is happening in the demand area?

3. What can or should be done to design programs more flexibly so that students can have more options for meeting changing job opportunities, particularly in industry?

Given the whole of this seminar, it is my impression that significant improvements have been made in projections. Dr. Oi and Dr. Freeman have proposed more sophisticated approaches and analyses. Yet we must still go a long way before projections really become useful. There is a need for a greater disaggregation. Bob Evans and Fred Bolling pointed out that all engineering disciplines should not be lumped together, and Bill Hamilton has talked of great differences in trends between various fields of engineering. Lee Grodzins pointed out a need for both global and microscopic data, and suggested that a bottom-up rather than a top-down approach is needed when looking at manpower requirements.

Dave Breneman and others have emphasized the inability of models to take into account Federal policy changes. It seems important that Government policy and legislation be incorporated into projections, at least on a "what if" basis. Dr. Lecht spoke of environmental legislation. Mr. Goldstein mentioned that an impact study was made at the beginning of the Space program. That study should be examined to see how it looks in retrospect. We have a golden opportunity right now, as Lowell Paige and I discused briefly, to study the impact of the energy program, and to collect data in such a way that the accuracy of the projections can be checked at a later date.

Dr. Breneman emphasized that we need research on behavioral factors affecting supply and demand, and Ken Clark has said that much useful data is available just waiting to be analyzed. Harold Goldstein warned that manpower projections must not be done on an ad hoc basis, but must be carried on with continuing and unremitting research, within the broad context of the entire economy. It has been emphasized that there is a need for a much deeper study of the causal effects of deviations of actual experience with forecast results.

Bob Evans made an interesting suggestion when he asked whether a bellweather can be found that will wield trends. He suggested computer systems. Are there other bellweather areas that should be considered? The comment was made that there exists a need for a range to be given to the projections, and certainly Charles Falk has given us two ranges.

There is a lack of good data from industry on manpower projections to industry. Long-range manpower requirements are only as good as the long-range technology forecasting and the long-range business planning. Business planning is becoming much more sophisticated, and it probably can be expected to provide better manpower data. However, as Bolling told us yesterday, we will always be affected by major impacts such as energy.

There is no reason not to plan. On the contrary, it is important to have a baseline plan. If there is a good baseline plan, it is easier to make intelligent changes as dictated by impacts. Sophisticated business planning includes contingency plans. Perhaps this is analogous to the "what if" efforts of impacts on projections which have been mentioned during this seminar. Dr. White has pointed out that projections have not been in a form which is very useful to industry, except possibly in long range planning.

In regard to the second priority item, *trends in demand*, the seminar has not shed much light on trends. On one hand, we know that engineering unemployment is under 1 percent and there is a lot of talk about potential shortages in engineering and chemistry, while on the other hand Bill Hamilton (Boeing Aerospace) told us that he is doing the same dollar business with one-half the engineering people that were used four or five years ago.

In regard to the third priority item, *motivation toward greater flexibility*, a number of comments were made. Dr. Kidd pointed out that people must be trained to be able to move or transfer. Dr. Hubbard said that attitudes and behaviors of the schools must change in order to meet the challenges ahead, and Dr. Barrow pointed out that Exxon was hiring fewer Ph.D.'s, because Ph.D.'s had become too specialized. Dr. Grodzins said we need to formulate policies that could transfer easily. In concluding, it is for others to tell us the specifics of what should be done in these various areas of the manpower projections and policy related matters.

Dr. Kenneth E. Clark:

Although we have been talking about a series of models and devices to make predictions, this is a society in which career choices are not controlled. The system is one in which there are widely dispersed influences operating at widely dispersed control points. The choice of options is sometimes in the hands of the individual who is selecting a major or selecting an institution, and sometimes is in the hands of the faculty, or the admissions office, or of employers. We are trying with our analytical approach to understand how the whole system works. These analyses will improve if our data base improves, and that's a necessary prerequisite. Some of the analytical descriptions presented here include untested assumptions which are made in order to develop the system but which may be wrong. Guesses should be avoided when empirical evidence is available.

As a second point, it should be mentioned that in order for an individual to make educational and career decisions in a realistic fashion, it is not a necessary condition that an individual know precisely which factors influenced his decision. Asking him to tell why he did things may not provide the sort of information that will be most useful.

On the other hand, any prediction system or any form of analysis of the total should define the separate parts or factors of the system and indicate the way in which they operate.

I am uncomfortable with statistical pragmatism in which the only intention is to see whether or not the prediction comes close to an end result. We want to be able to predict the effects of any sort of intrusion into the system, and to know in some rational fashion that those intrusions work as predicted, because it is then that we can see how the total model works.

There are several things which need to be done in order to improve the analysis of manpower problems. First, there is a need for better organization of manpower data; most of our data is pretty disorganized. It is not even collected in an orderly fashion. Specifically, there should be an up-to-date taxonomy of scientific manpower. Everyone likes to cite his own index numbers. Why is it that the last available student figures are for 1971? This is the academic year 1973-74. Enrollments have been known since last September, and it is already known what degrees are going to be awarded in May and June. But what is known locally will not be known nationally for two more years. The need, then, is for a system which is orderly and up-to-date.

Certain data ought to be collected in some sort of telegraphic fashion early in every year or even in every semester, including: student choices of courses and majors, the number of students in certain key beginning courses, the number of beginning graduate students, the number of fellowships and assistantships, and the number of degrees to be awarded.

Second, there should be some way of assessing the effects of various forms of influence on choice of fields and choice of jobs. This requires more than merely counting large numbers. It requires the collection of data on cohort groups with the same subjects being followed over a period of time. Studies of cohort groups have been initiated before, but it is very difficult to keep the files going. It turns out to be so expensive that most think it not worthwhile. But we suffer in the long run by not having this important information. Manpower data systems also need to be more sensitive to quality. A zero change in numbers does not necessarily mean that everything is in an equilibrium state.

A *third* point is that the present methods for making projections include some assumptions which are testable, yet remain untested. There should be commissioned a series of planned and coordinated reviews of past data collection projects in order to evaluate the possibility of testing some of the assumptions in our current models. We then need to translate these reviews into a new set of data collection procedures and analytical methods which we can progressively improve by a series of iterations. Such a sequential procedure might also lead to the discovery of other, not yet recognized influences on the total manpower picture.

Allan M. Cartter:

One good thing is that the discussion is coming together again on the problem of fixed coefficient models versus recursive feedback models. The issue has been thrown up in some kind of stark relief. The so-called fixed coefficient models are not necessarily *constant* coefficient models. That distinction should be made. It is true that merely extrapolating trends does imply a certain independence of market forces. However, the last two or three years have encouraged us to look more and more at the market.

The market models are a major step forward, a step toward the real world. Yet even in a model with elasticity assumptions, there is a kind of fixed coefficient once removed because the supply and demand schedules are not linear, and small changes will have somewhat different effects than large changes.

Most of the models prior to 1970 were more or less fixed coefficient models and were intended to be projections, not predictions. They were intended for their shock effect, to show that the system was on a collision course and something needed to be done. Most people who built fixed coefficient models qualified their conclusions with the recognition that the real world can't act that way—that the system would have to (indeed does) respond to changes in retirement, relative salaries, etc.

It would be a step forward to build such adjustments into the models and really try to predict the future. We are more interested now in real forecasts, and understanding response mechanisms and adjustment processes of the real world. In the context of this conference, we are concerned about whether or not public policy should intervene, either to reduce the time lags or to attempt to stabilize the system by anticipating future market needs.

Another distinction which should be made between the extremes of fixed coefficient and pure market models is that different procedures may be appropriate at different levels. If one is talking about high school graduation rates, they may be 5 percent market influenced and about 95 percent determined by State policy, plus parental and societal expectations. In regard to college attendance or graduation rates, the influence is perhaps about 15 percent market and 85 percent non-market. However, at the graduate and professional school level, the ratio is 50/50, or perhaps 75 percent market and 25 percent non-market.

Another way of saying it, in economists' terms, is that undergraduate education is probably 85 percent consumption and 15 percent investment, whereas graduate and professional education, because of its career-oriented nature, is probably 75 percent investment and only 25 percent consumption.

Thus, when looking at the market for doctorates, you have to build in market assumptions or ignore reality. Similarly, for models such as the NSF supply and utilization models, the further ahead you look the more you have to build in the market. If one only looks five years ahead the market can probably be ignored. Students are already in the pipeline, and the market does not have much influence on those individuals. If Charles Falk starts looking fifteen or twenty years ahead, however, then obviously it has to be with a market-oriented model.

I would like to second Ken Clark's remarks. If we are to know more, we *must* improve the data. The one thing about building market models is that it reveals what data are needed. On the other hand, if one merely extrapolates and uses fixed coefficient models, you can keep score on your accuracy, but know nothing new when you're finished.

The point made by both Freeman and Oi is valid. Forecasting ought to be a learning experience. You should have feedback so that the model can be improved, so that it reflects the real world. We need to better monitor the system, to know more about the flows in specialized disciplines. The physics society has done a first-rate job. If all disciplines had done what physics has done over the last seven or eight years, manpower modeling would be much further advanced.

We need better data on employment, on mobility, and on compensation. In any given year in the academic market place there are new teachers hired; there are faculty members who switched institutions but stayed within the system; there are senior people who retire; there are people coming and going from government and industry; and there are individuals who have offers to move but chose to stay. Taken together, all of these categories add up to 25 to 40 percent of all college teachers, so in a sense this many are subject to market influences in any given year. The assumption that faculty members are insulated from the market appears to be inappropriate. We need much better data on this subject.

One example of the problem of limited information is provided by the Office of Education statistics on college faculty. Two large surveys were conducted in 1962 and 1963. Biennially since then, OE has done small sample surveys of college faculty. Yet the *Digest of Statistics* gives a series of data going back 10 or 15 years which is half-guess and half-interpolation. The 1972 Projections of the National Center for Educational Statistics rewrote the history of the last 10 years, and reduced by 12 percent the number of faculty previously claimed in the system in the early 1960's, and raised other numbers for the early 1970's by ten percent, changing definitions and interpretations.

There is not even a good faculty survey that has been done since the year 1968. How can one hope to build a sensible model, if he finds that the whole history of the last dozen years has been rewritten and changed. The incremental faculty-student ratio additions have been changed by something like 25 percent for the last decade.

It should also be clearly stated in advance that all projections of so-called doctorate surpluses or shortages are bound to be disproved by the facts. There are not going to be empty classrooms, and Ph.D.'s will not be selling apples. Economic forces really do clear the market by causing changes in hiring standards and salary rates. If doctorates are in short supply, individuals with lesser qualifications are hired, and if doctorates are in abundant supply, individuals with stronger qualifications are hired. Salary levels, particularly at the point of entry, are flexible. If there are insufficient jobs in R&D or teaching, then there will be large changes in the so-called "other employment" category. The Ph.D.'s will be employed somewhere, even if self-employed or driving taxicabs; unemployment is an unlikely alternative for doctorates.

Finally, Dr. Solmon's comments on the nature of the definition of underemployment are very important. This is an area that needs serious attention. Often, the terms "underemployment" and "enrichment" are used as though they are synonymous; however, in a qualitative sense these are two very different states. So, in conclusion, I would plead for much better data, more research, and more forecasting with a variety of more sophisticated models.

Mina S. Rees

Dr. Hubbard talked about government policy being an overriding variable in its impact on projections, and the government policy of equal opportunity, translated into the various rules for operation, does raise some questions for women about how to interpret what has been going on.

How should young women view the projections which should make free personal choice better informed? We have been talking about that problem. People have been warning about lowering standards if the requirements for women on faculties are to be met. I take the position that that is quite false. There is no reason whatsoever to believe that women will not be just as qualified and just as able as men.

There were eighty-six finalists in this yea. - Dissertation Fellowships in Women's Studies administered by the Woodrow Wilson National Fellowship Foundation. Virtually all eighty-six of these were absolutely first-class. Their thesis proposals were interesting and quite imaginative, and they were recommended (usually by men) as among the best students at their universities in their many disciplines. Each of these women was planning to teach, and none had been turned off by recent threatening projections.

However, if we follow Dr. Breneman's suggestion and explore behavioral parameters, it would be well to investigate how universities are threatening the employment of women. Are women to have preferred positions in new hires, or are they not? Young women are assuming that they are going to get jobs, but it is unclear how universities are going to treat this situation.

It was interesting to hear from Dr. Kelley earlier that the most recent results of the National Research Council indicate women are earning Ph.D.'s in the social sciences, a fair number in the biological sciences, but not many in the physical sciences. However, the pattern is apparently changing.

Nevertheless, it is extremely important that universities have role models on their faculties, as Dr. Cooke suggested, particularly in the natural sciences. Virtually all of the professional societies have been compiling rosters of qualified and available women, and the AAAS has been coordinating these various rosters so that they may be presented in usable form. There are still many frustrated older women who are well qualified and who simply feel that they are not getting recognition, and it is extremely important that there be role models in the sciences so that additional women do go into science.

How are graduate schools reacting? A little over a year ago, I reported on this at a meeting of the American Council on Education devoted to women in higher education. In most good graduate schools, there has not been serious discrimination on admission and fellowships, but the reports on dropout rates and completion of Ph.D. have been generally unfavorable in the past.

However, at the City University of New York where an institutional study was made last year, the findings were that on the average, and in nearly all fields, women are performing at about the same level as men. The City University is an unusual institution and has unusual students But one of the most unusual things about the University is that I was head of the graduate program in spite of my being a woman. This role model may have had real impact. Universities are now attempting to appoint women to important administrative posts. However, until this is realized on a broad scale there will be an important factor weighing against the attainment of rates of completion of graduate school comparable to rates for men.

If we do achieve public debate on the manpower budget needed to support the kinds of new programs that were discussed earlier, hopefully a few of you will remember that womanpower is an important aspect of what is called "manpower." Particularly in new programs of energy research and environmental protection there is need for affirmative action. I hope that NSF will incorporate an affirmative action program in its research activities by making an effort to include the competent women who are becoming increasingly available.

One final comment: Dr. Hubbard observed more or less parenthetically that birth rates have fallen specifically in the societal groups that have provided the graduate students in our universities. I call attention to the fact that, provided the birth rate does not fall to zero, there will be twice as many people in the appropriate age group, eligible to be graduate students as Dr. Hubbard was counting since, if present trends continue, both men and women should be counted in the future while a very large proportion of the graduate students included in the past statistics have been men.

Lewis M. Branscomb:

I will treat myself as a test subject for this conference. Because I am not an experienced manpower forecaster, I associate myself with those in industry who don't really know how to use manpower forecasts in their aggregate form. These are my questions: Am I supposed to worry about whether or not there will be enough engineers in 1985? Do government fellowships and traineeships have anything to do with the quality or quantity of scientists and engineers? Are the present surpluses unfortunate side-effects of the self-prescribed medicine of fellowships, traineeships, and institutional support programs advocated by those who saw a need for scientists and engineers for the space and other programs? Is supply highly responsive to wages or not? If it is, what is it that keeps employers from paying what it takes to get all the good people?

Professor Oi impresses me very much with his discussion of the risks of focusing on numbers alone. The hidden assumptions and difficulties of definition that plague the art of making projections perhaps should be, themselves, the subjects of primary interest. We really ought to study the process of people undertaking scientific and engineering careers, and try to understand the conditions that affect quality and various career patterns. Perhaps we should not attempt to define boundaries so narrowly that single numbers can be used in aggregate descriptions. If in manpower studies we identify the phenomenology and then focus on that phenomenology, then we will be less likely to draw the wrong conclusions from numbers.

Macro-analysis obscures skill levels, quality, and the dynamics of utilization. If I am told that 5 percent of the science and engineering pool each year are going to have to find something else to be, I don't know how to respond. It is quite certain that this country could get along with at least fifty fewer universities giving Ph.D.'s in chemistry and physics. Certainly IBM does not want to hire the bottom quartile of that production, and neither does anybody else, although someone probably will. It may be that society will be better off for the something else they do, and we shouldn't assume that the fact that some percentage of the people who receive this very expensive education only utilize it for ten years then leave, represents a poor return on investment. The total investment in the educational system is clearly reflected in the aggregate contributions of all of its products. If amortizing the investment of the bottom quartile over five or ten years and then moving them out enables the system to have a quality competition that serves to raise the quality of the top quartile, then we may be very much better off.

So I would endorse Dr. Freeman's stress on the need for policy models, that is, models which incorporate policy alternatives of appropriate institutions. There has been a moderate, but not very great, amount of discussion of government policies. There has been only a little discussion of industrial recruiting policies, and very little discussion of university policies. The feedback is there, but it is a loosely complex system.

Since Freeman tells us that occupational structures are more flexible than wage structures, I assume that aggregated numbers of people are not really of primary interest.

Indeed, I find it difficult to take the aggregate numbers seriously, when I see engineer, scientist, and discipline breakdowns, but nowhere breakdowns for programmers, systems architects and engineers, information specialists, or other such specialties that IBM would like to have in large numbers. In fact, IBM employs full-time teachers to teach electrical and mechanical engineers the skills needed to enter the above professions. Although computer science departments of universities train people which IBM finds exceedingly valuable in its research division, and indeed 90 percent of the people in IBM's R&D are trained by the universities, there still remain specialties that have been overlooked by the educational system.

The IBM business strategy for the next fifteen years is based on a technology with a future growth that is limited by the availability of skilled manpower for its customers. Because of the need for new professional specialties, IBM is actively involved with a number of universities in the creation, development, and support of new graduate programs.

Dr. Kennedy made a point in which he noted the very fortunate fact that M.D. researchers receive the type of training which permits them to evolve from research activity into practitioner activity very easily and with very little social strain. Perhaps medicine is unique in this, because the practitioners are well paid and highly respected. You are not taking a step down to go from researcher to medical practitioner. One might think it is a step down to go from physics research to product development, the analogy for engineering, but this should not be the case.

A very hard look should be taken at the structure of the professions and the kind of training people receive. We should ask whether or not there is a way in which young people can get practical training early, training with enough basic science and excitement to stimulate interest in research. It would be easier for an individual, at a later time, to make the choice to get deeper and deeper into research or to be an even better practitioner than otherwise.

If you look at a number of very outstanding basic scientists in this country who came to America from abroad, you will find a number who were graduates in electrical or civil engineering in some far-off university. Many had strange undergraduate backgrounds, very sophisticated basic science training in graduate school here, and then combined in their future lives that extraordinary ability to mix application and basic knowledge.

Finally, this conference really has not talked much about R&D productivity (i.e., the dollars of business produced from a manhour of R&D effort) and the inflation in costs of R&D manpower. In some sense, NSF needs to help address for the society as a whole the problem which some at IBM call the "technical vitality" issue. That is, how does one maintain an innovative and flexible R&D community in a growing economy where manpower growth rate is significantly slower than economic growth rate? This is one of the broad questions we need to ask about the country's R&D infrastructure.

Very little attention is given to the question of research and development productivity and the many things I think the government can do to enhance it. The load-leveling of the universities is another important issue, as is the whole problem of mid-career guidance and evolution. These two issues are related. Whenever the utilization rate falls short of supply, the dynamics should be managed by lateral transfer throughout the career chain, rather than by imposing the burden on the universities and on the students where both the financial and emotional impact is hardest to handle.

H. Guyford Stever:

The level of research support for manpower studies should be raised so that there are more accurate and better understood manpower projections. It should be pointed out, however, that when projections are published, other people will take the data and put their own construction on it, so we must be cautious about what we say.

Which way should we be going? That is a question being asked by this seminar. There is not yet a convincing rationale to reestablish large-scale, direct support of graduate students, but this does not mean the NSF and the National Science Board will not work for more fellowships. Science must have its share of extremely qualified people, but the numbers who can be aided by the fellowship programs will be so few that their effect on the total number of graduate students will be minimal.

The National Science Foundation and the National Science Board keep pressure on many programs—fellowships, basic research, applied research, education support, etc., but necessarily concentrate on a few. This year, emphasis was placed on two things. The first and overwhelming activity was the support of Project Basic Research, 98 or 99 percent of which is carried on in the universities. Second, NSF's position in the energy field, both basic and applied, was strengthened. The budget for these two items went up 25 percent.

The results of this meeting seem to indicate that even if the NSF were to concentrate on fellowships for next year, additional financial support might well not be forthcoming. However, the basic research program does support first-rate graduate students, and it does focus on the best universities. There is a very strong connection between quality of university and batting average on proposals in basic research.

The United States needs a very strong science community. Scientists and engineers are going to be deeply involved in such problems as energy, materials, and food. Communicating with society on that relationship may be the most effective way to influence this manpower supply. There is some evidence that enrollment in graduate schools and in engineering schools and enrollment in courses that relate to a modern and long-lasting problem, namely, energy, reflects the influence of societal problems on students. Yet it is important to go forward with manpower studies. Such studies may begin to give us the detailed structure of the future of manpower needs, and manpower supply, and will help sort out major policy questions. That is our hope for the future.

General Discussion

Comments and concerns were expressed as follows in the period of general discussion which followed the Roundtable Summary:

- There are some who react simplistically to projections that appear to show statistical oversupply, and some in the larger community of non-scientists who parrot back casually, "Why do you want fellowship money when there are too many doctorates?" At this conference, there has been a considerable demonstration of the awareness of the real problem, the character of the problem, and the meaning of projections. It is unfortunate that the larger number of people, those who have been making simplistic decisions, could not participate in this discussion.

- An opinion was offered that fellowships probably have something to do with encouraging bright kids to try for graduate degrees and therefore might be used to strengthen certain disciplines. It was explained that NSF fellowships are given on a straight talent basis and that students are free to choose school and field of study. If physics were to be strengthened, for example, traineeships, not fellowships, would be required.

- Rhetorically it was asked, "Is there going to be a single job open for white males in 1980? It may turn out that with the affirmative action program and the Civil Rights Act in effect, there may be zero jobs for some." In reply, it was suggested that what was interpreted as affecting white males affects all and that the biggest manpower problem in science and engineering today is, "What do we do to insure that we do not have a missing generation of teachers and researchers in the universities?"

Dr. Cartter spoke of looking at this question by applying apparent academic needs and supply to the future age distribution of college faculties, taking into account retirement rates, senior people into and out of various fields, and other factors. Suddenly, by 1990 only 3.5 percent of college teachers are under age thirty-five. That's the missing generation, but the market won't work that way. What will happen is that there will be somewhat lower retirement ages, and deterioration in the relative salary of academic as against non-academic people. During the 1960's about 3 percent of faculty left each year to take jobs in industry and government, while an equivalent number came back from industry and government. However, if there were a change in the wage structure so the outflow were 4 percent and the inflow were 2 percent, then 6,000-7,000 new jobs per year would be created for young graduate students. Yet if there is a period of roughly fifteen years when there is no expansion in higher education and the only jobs are created by retirement and death, then there could be a missing generation of teachers and academic researchers.

- "Is there any concrete suggestion that might come out of this conference, about specific activities at specific agencies which could be initiated to explore inadequacies in manpower data and determine ways of improvement? For example, the whole area of the humanities, which is a large part of the university view of the whole manpower problem, is excluded from the excellent data collection and related activities of NSF."

It was suggested that if these kinds of comprehensive data were now being collected by the Office of Education, that somehow the NSF and the National Endowments for the Arts and Humanities might jointly undertake such an effort. Further remarks brought out the point that neither of these national endowments is heavily involved in manpower production. The endowments are growing successfully, so why should they become involved in this controversial area? But on the other hand, the Modern Language Association does have considerable worry about the market.

- A distinction should be made between two kinds of data. One kind is *status data*, such as the number of students and amount of fellowship support; the other is *behavioral data*. Enough longitudinal data have been collected so that with very marginal amounts of money, much of it can be brought up to date and made useful. The Office of Education should concentrate on publishing the status data quickly. We don't need another longitudinal survey.

- It was pointed out that models which emphasize one variable, such as earnings, and ignore others could lead to erroneous conclusions. The question appears to be: "If it should turn out that all sorts of factors are involved—the employment of the parents, socioeconomic class, and other social matters—would it be possible to determine whether or not these sophisticated and complicated correlations could actually be dominating the whole system?"

  Dr. Freeman responded, saying that most market models have not been one variable against another. They have been mutual regression models that often use somewhat sophisticated techniques. The distribution of family backgrounds does not change much over five to ten year periods, so this type of question can be appropriately addressed at a different level than in these models. Further, this type of information does not necessarily alter the elasticity estimates. They are derived through the use of multiple equations.

  In further discussion it was pointed out that it may be true that family background, etc., may not change rapidly, but public attitude or what one may call the rhetorical climate does change profoundly in short periods of time. The prevailing attitude toward things like science and technology may change abruptly. If the rhetorical climate is swinging at the same time that some measurable parameter in a model is changing, the analysis may give a fallaciously large wieght to this parameter. One must be aware of this type of problem. It is true that non-quantifiable factors make big differences in the way people behave.

- It would be erroneous to assume that data are so lacking or so conflicting that one cannot make decisions about any aspect of the manpower problem. For example, it is known that the average age of the faculty in physics is increasing at an alarming rate. Further, the number of physics graduate students is declining, and the number of postdoctorals is, at best, not increasing.

  There are two questions about the above facts. First, is the quality of graduate students in physics changing? Secondly, who is going to do the physics research? When university professors are asked to teach more because the student to faculty ratio is increasing, then they will do less research. There are enough data to address the above two questions in a substantive way; it is hoped we do not go away thinking that we should ignore the future while we wait for some better understanding of the available data.

- Using American Council of Education ratings, we can count the number of new Ph.D.'s who took their first jobs in institutions of equal or superior quality to their graduate institution. For the time period 1967 to 1972, the percent of male Ph.D.'s who took jobs in institutions of equal or superior quality dropped from something like 22 percent to about 16 or 17 percent, while for women Ph.D.'s it rose from about 15 percent to 18 percent. One can only guess at the situation ten years in the future, but for now it looks as though discrimination in terms of the kind of institution where men and women took their first jobs has now disappeared. Beginning salary and level of appointment are another matter.

- Marketplace equilibrium needs to be studied very carefully. It is unfortunate that the university marketplace has not been discussed vis a vis a drop in fellowships. There are all kinds of pressures on state colleges to keep student enrollment high. A reservoir of teaching assistantships is needed for instructional purposes and for this the states supply, or a school supplies its own money. Fellowships tend to represent a fixed and inflexible amount of money, but teaching assistantships and research assistantships can be increased by cutting down on post-doctoral appointments. This kind of tradeoff is made when it is necessary to keep enrollment high so that professors doing research have an adequate number of research assistants.

- A zero-growth phenomenon for universities, when suddenly imposed at the end of a rapid growth phase, has very drastic and serious consequences that must be met by some kind of response. Some universities are spending resources to encourage early retirement. An attempt is being made to change the structure of the faculty in terms of the distribution of ages because it is absolutely necessary that these schools have an opportunity to bring in bright young men and women. With one, two, or three-year terminal contracts, the lower ranks can be turned around until the top ranks move out at the other end of the system, and a better distribution can be achieved. There are other pressures also—those related to civil rights issues, the failure to bring in sufficient women and blacks. The onus of proof of compliance is on the university.

- In regard to the dissociation of undergraduate teaching from the graduate basic research activities, it was suggested that careful thought be given to whether a complete separation of basic research from the university or reorganization of the structure within the university is needed.

- Finally then, it was stated that the conference had shown that the real issues for scientific manpower lie in the strength of the university, and in the total resources available for graduate education and in the dimensions of quality of that education. All of these are affected by Federal fellowships—even though such fellowships are a relatively small part of the total complex of factors which relate to scientific and technical manpower issues.

APPENDIX

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