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ABSTRACT

This paper provides a critical review of the purposes, current techniques and potential methods for analyzing doctorate and other high-level labor markets. Chapter 1 describes and interprets the doctorate manpower market of the 1960's and early 1970's, as well as the forecasted manpower crisis of the 1970's and early 1980's. Chapter 2 gives a detailed critique of the shortcomings of current forecasting techniques, suggests possible ways to improve the methodology of forecasts, and evaluates the major implications of current forecasts - that the doctorate market and graduate education face a substantial glut of Ph.D.'s in the near future. Chapter 3 deals with the market adjustment process characteristic of Ph.D. labor markets, by which individuals and enterprises respond to supply-demand imbalances. One possible scenario for the doctorate market in the future is sketched out. Chapter 4 discusses policy implications of the analysis and suggests some practical next steps that would further improve our understanding of this complex subject. The paper also includes two technical appendices, dealing with (a) the economics of shortages and surpluses, and (b) models of the market adjustment process. (Author)

Forecasting the Ph.D. Labor Market:

Pitfalls for Policy

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Foreword

The National Board on Graduate Education (NBGE) was established in 1971 by the Conference Board of Associated Research Councils* to provide a means for a thorough analysis of graduate education today and of its relation to American society in the future. In partial fulfillment of that task, three NBGE reports with recommendations have been published to date,† and further Board reports are planned.

In addition to the NBGE reports, several authored reports have been commissioned by the Board to be published in a separate technical report series. One of the purposes of the technical reports is to provide additional information to NBGE which, in some instances, may undergird NBGE policy recommendations. This report, "Forecasting the Ph.D. Labor Market: Pitfalls for Policy," by Richard B. Freeman and David W. Breneman, is the second publication in that series.

The present report contains a critical analysis of labor market forecasting techniques for doctorate manpower, stressing the limitations of existing procedures. An alternative methodology is proposed that holds out the promise of improved information for decision and policy making purposes. The recently published NBGE report on this topic, *Doctorate Manpower*

* Composed of the American Council on Education, the Social Science Research Council, the American Council of Learned Societies, and the National Research Council.

† *Graduate Education: Purposes, Problems and Potential; Doctorate Manpower Forecasts and Policy;* and *Federal Policy Alternatives toward Graduate Education.*

Forecasts and Policy, drew heavily on an earlier version of the present essay to support the NBGE conclusions and recommendations.

We believe this report will be useful to government officials, university administrators, faculty, graduate students, foundation personnel, and others concerned with the nation's policies with respect to graduate education.

DAVID D. HENRY, *Chairman*
National Board on Graduate Education

April 1974

Preface

Developments in the doctorate manpower market during the 1960's and early 1970's are described and interpreted, and forecasts of that market into the 1980's are examined critically. Current forecasting techniques are discussed against a background of past forecasting failures, and are found to suffer from four serious errors of omission: first and most importantly, a failure to consider individual responses to market conditions; second, absence of wage-price phenomena from the computations; third, inability to evaluate the consequence of major policy variables; fourth, failure to take account of the interrelations and feedback processes which govern the market. An alternative methodology that takes account of likely individual responses to market conditions, with particular emphasis on supply-side adjustments, is described. This technique yields substantially different results and provides a more complex and realistic picture of labor market dynamics. These "response adjusted" projections, based on student career decisions, experienced personnel supply behavior, employer decisions and salary determinations, forecast reduced supplies of new Ph.D.'s and smaller supply-demand imbalances than most current projections. Additional adjustments for diverse forms of university and, where possible, governmental behavior should further improve the usefulness of forecasts. The final section contains a brief discussion of the policy implications of the analysis, and suggests some areas in need of further investigation. Two technical appendices conclude the paper.

RICHARD B. FREEMAN
DAVID W. BRENEMAN

April 1974

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Introduction

The late 1960's turnaround in the market for doctorate and related high-level manpower, from the conditions of substantial excess demand that began in the late 1950's to those of relative manpower surplus, raises important questions about the operation of the Ph.D. market, our ability to predict future conditions, and appropriate governmental policies. Past concern with the inadequacy of the supply of scientific and technical manpower produced a variety of manpower requirements forecasts of needs and supplies and extensive federal support for graduate education. Current concern is also yielding numerous forecasts and analogous cutbacks in fellowships and related expenditure programs. The important role of *human capital* (or trained manpower) and of scientifically based *knowledge capital* in our economy, the long gestation period needed to produce Ph.D.'s, the large numbers of individuals and resources involved in graduate education, and the dependence of the doctorate and related work force on federal policy make the analysis of market developments of potentially wide interest and importance.

This paper provides a critical review of the purposes, current techniques, and potential methods for analyzing doctorate and other high-level labor markets. Chapter 1 describes and interprets the doctorate manpower market of the 1960's and early 1970's, as well as the forecasted manpower crises of the late 1970's–early 1980's. Chapter 2 gives a detailed critique of the shortcomings of current forecasting techniques, suggests possible ways to improve the methodology of forecasts, and evaluates the major implications of current forecasts—that the doctorate market and graduate education face a substantial glut of Ph.D.'s in the near future.

Chapter 3 deals with the market adjustment processes characteristic of Ph.D. (and other) labor markets, by which individuals and enterprises respond to supply–demand imbalances. One possible scenario for the doctorate market in the future is sketched out. Chapter 4 discusses policy implications of the analysis and suggests some practical next steps that would further improve our understanding of this complex subject. The paper also includes two technical appendices, dealing with (a) the economics of shortages and surpluses, and (b) models of the market adjustment process.

1 Problems of the Doctorate Labor Market

What has happened in the doctorate manpower market in recent years to raise the spectre of substantial surpluses of Ph.D.'s? Why do manpower forecasts project a major crisis toward the end of the decade and in the 1980's? How did the shortages of the late 1950's–early 1960's which President Kennedy termed "our greatest national problem" become the surpluses and potential surpluses of more recent years? A brief review of the factors that shaped and determined the labor market for Ph.D.'s during the 1960's and early 1970's is an essential first step toward answering these questions.

THE CHANGING MARKET

Two of the major factors that determine demand for Ph.D.'s are enrollments in higher education and expenditures for research. Table 1 provides information on degree-credit enrollments in institutions of higher education for the period 1961–1972.

The rapid growth of the 1961–1970 period can be gauged by noting that college and university enrollments more than doubled, representing an average annual growth rate in excess of 7 percent. This extraordinary rate of increase in higher education enrollments in the 1960's was a major contributor to the booming academic labor market of that period. As Table 2 indicates, the growth in college and university instructional staff grew with similar rapidity during these years.

TABLE 1 Total Degree-Credit Enrollment in All Institutions of Higher Education, 1961–1972

Year	No. Degree-Credit Enrollments, (thousands)	Year	No. Degree-Credit Enrollments, (thousands)
1961	3,861	1967	6,406
1962	4,175	1968	6,928
1963	4,495	1969	7,484
1964	4,950	1970	7,920
1965	5,526	1971	8,116
1966	5,928	1972	8,220

SOURCE: U.S. Office of Education, *Projections of Educational Statistics to 1981-82, 1972 Edition* (Washington, D.C.: U.S. Government Printing Office, 1973) p. 24; and preliminary data for 1972.

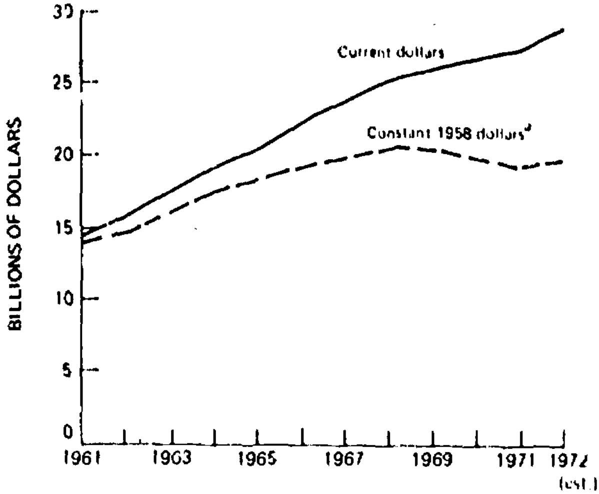
Although the growth rate of enrollments contained in Table 1 had begun to slow in 1971 and 1972 in comparison with that of the 1960's, the turnaround in the labor market for Ph.D.'s (which began in many disciplines approximately in 1969) cannot be attributed to a sudden drop in the number of college students seeking instruction. In fact, college attendance is projected to grow, albeit at a steadily diminishing rate, through the 1970's, before declining in absolute numbers in the early 1980's. The dramatic shifts in demand that help to explain the softening of the labor market in the 1969–1972 period are to be found by examining the statistics on R&D expenditures, as portrayed in Figures 1 and 2.

National R&D expenditures peaked in real terms in 1968 at a level of $20.5 billion (constant 1958 dollars), declining to $19.3 billion in 1971 and an estimated $19.8 billion by 1972 in constant dollar terms. Total R&D expenditures as a percentage of GNP have been declining steadily since 1964, hitting a low for the 12-year period covered in Figure 2 of 2.52 percent in 1972.

TABLE 2 Estimated Full-Time and Part-Time Instructional Staff in Resident Courses in All Institutions of Higher Education, 1961–1971 (Instructor Rank and Above)

Year	Total No. Instructional Staff (thousands)	Year	Total No. Instructional Staff (thousands)
1961	248	1967	389
1962	265	1968	427
1963	281	1969	449
1964	307	1970	477
1965	339	1971	492
1966	361		

SOURCE: U.S. Office of Education, *Projections of Educational Statistics to 1981-82, 1972 Edition*, p. 73.



[a]GNP price deflator was used to convert current to constant dollars

FIGURE 1 National R&D expenditures, total, 1961–1972. [National Science Board, *Science Indicators 1972* (Washington, D.C.: U.S. Government Printing Office, 1973)].

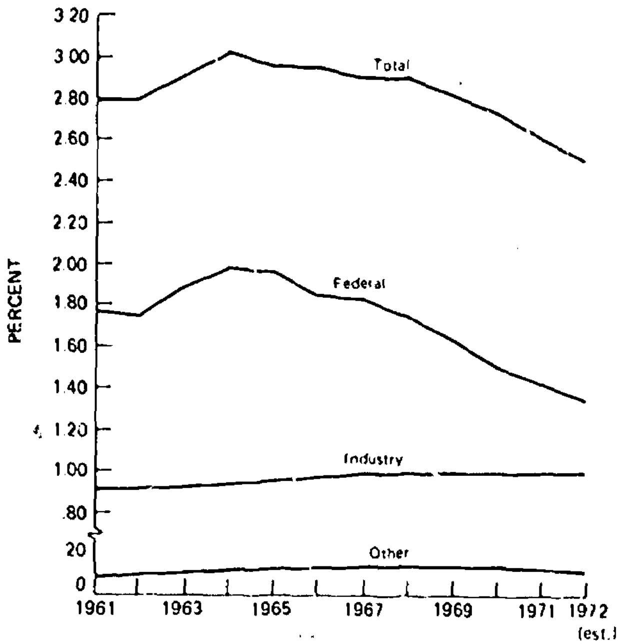
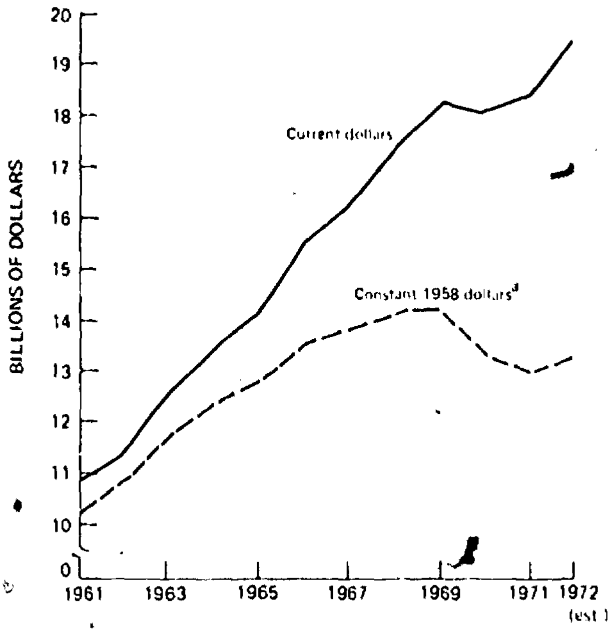


FIGURE 2 National R&D expenditures as a percent of GNP, 1961–1972. [National Science Board, *Science Indicators 1972* (Washington, D.C.: U.S. Government Printing Office, 1973)].

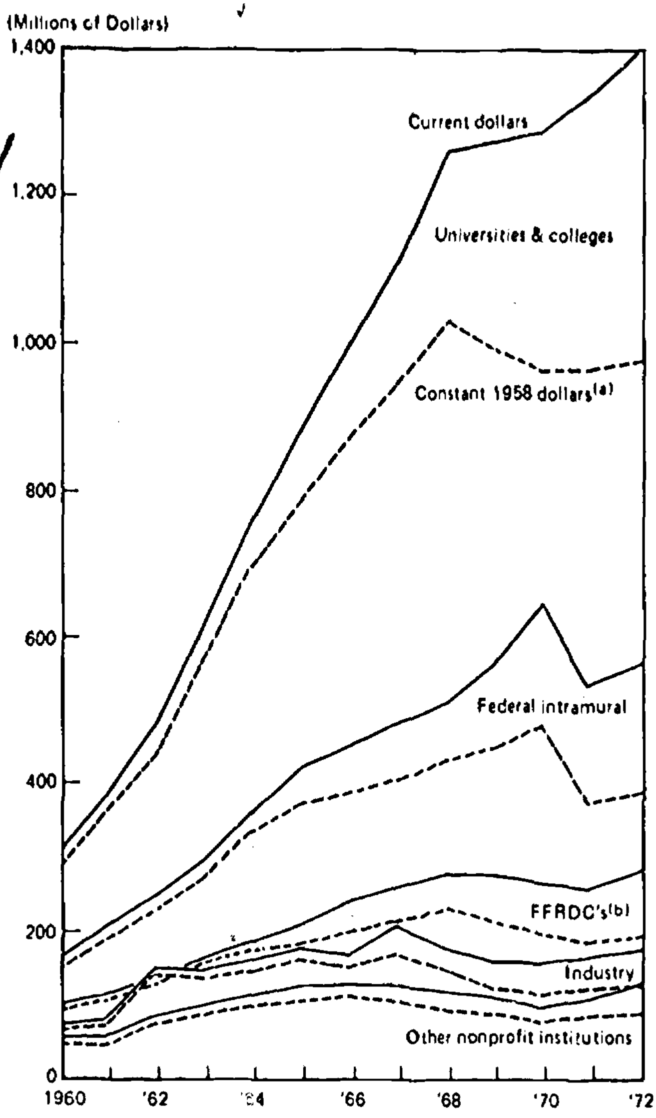
A sharp discontinuity in R&D expenditures in 1969 is evident in Figures 3 and 4. Figure 3 depicts the reductions in R&D performed by industry since 1969. All of this decline is attributable to cutbacks in federal government support of R&D performed by industry; funds provided by industry itself have been approximately level in constant dollar terms since 1969. Figure 4 portrays the discontinuity in federal support of basic research by performer occurring in 1969. The university and college sector has been particularly hard hit since it performs the majority of the basic research supported by the government.

The reduced real expenditures for R&D described above have had two major effects on the market for doctorate and related manpower. First, and most obviously, these funding cutbacks were translated into absolute reductions in R&D employment for scientists and engineers, as depicted in Figure 5. Secondly, this reduced flow of funds to universities and colleges has contributed substantially to the well-documented recent financial difficulties of these institutions, resulting in more general reduced demands for new faculty as a cost-saving measure.



[a]GNP price deflator was used to convert current to constant dollars

FIGURE 3 Industrial R&D expenditures, total, 1961–1972. [National Science Board, *Science Indicators 1972* (Washington, D.C.: U.S. Government Printing Office, 1973)].



(a) GNP price deflator was used to convert current to constant dollars.
(b) Administered by universities.

FIGURE 4 Federal expenditures for basic research by performer, 1960–1972. [National Science Board, *Science Indicators 1972* (Washington, D.C.: U.S. Government Printing Office, 1973)].

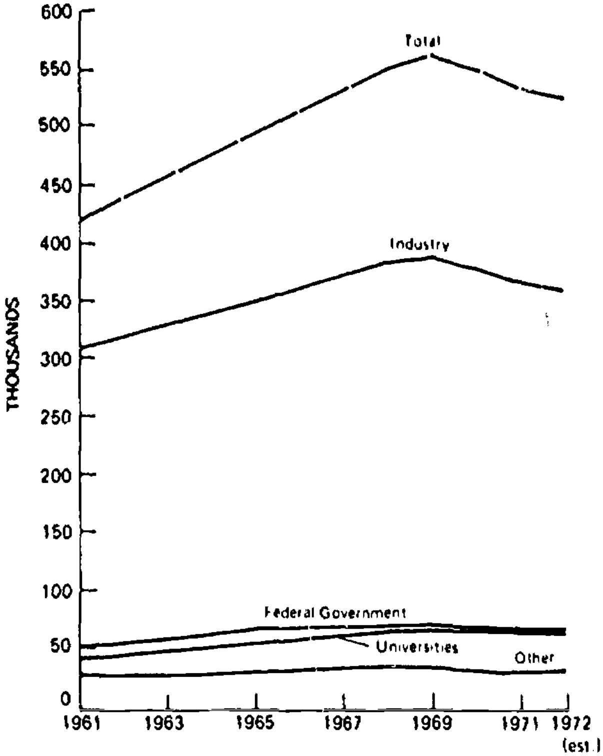


FIGURE 5 Scientists and engineers employed in R&D by sector, 1961–1972 (includes all scientists and engineers on full-time equivalent basis). [National Science Board, *Science Indicators 1972* (Washington, D.C.: U.S. Government Printing Office, 1973)].

Since the state of the labor market reflects the changing relationships of demand with supply, we must turn next to the supply side in order to complete our interpretation of the factors influencing the doctorate labor market of the past decade. Table 3 documents the rapid rise in graduate enrollments over this period. From 1960 to 1970, total graduate enrollments increased by an average annual rate in excess of 10 percent, a rate considerably larger than the 7 percent average annual growth of total higher education enrollments. This increase in graduate enrollments produced more than a tripling in the number of Ph.D.'s awarded over this period, as shown in Table 4.

By combining these data on supply and demand, the following picture of labor market dynamics clearly emerges. From the late 1950's until approximately 1969, shifts in the demand curve for Ph.D. and related manpower

TABLE 3 Enrollments for Master's and Doctor's Degrees, Fall 1960 to Fall 1971

Year	No. Enrollments
1960	314,349
1962	373,845
1964	477,535
1966	555,025
1968	703,745
1970	816,207
1971	836,294

SOURCE: U.S. Office of Education, *Digest of Educational Statistics, 1971* (Washington, D.C.: U.S. Government Printing Office, 1972), p. 73; and preliminary figures for 1971.

were more pronounced than the corresponding increases in supply, producing a labor market of excess demand and rising wages. Median salaries of assistant professors, one index of demand pressures, increased from $5,595 to $10,698 over the period 1958–1970, an average annual increase of approximately 5.3 percent in current dollars. This market, which shaped the attitudes of many Ph.D. specialists and educators about the place of graduate education and degrees in the economy, is *not*, it should be noted, to be viewed as the normal state of affairs for highly educated workers. The 1960's were, in comparison to the past and potential future, a peculiar "golden age" for Ph.D.'s and academics, when demand for their services expanded much more rapidly than ever before.

By contrast, the 1969–1972 period was characterized by a continued increase in the number of Ph.D.'s—i.e., the supply of highly trained workers expanded as, or more, rapidly than in the 1960's—and a reduction in the rate of increase of demand. While some of the slowdown in demand resulted from a lessening in extraordinary rates of exponential growth (a "natural process"), the federal cutbacks in R&D expenditures were particularly significant. With supply increasing at rates determined by the rapid

TABLE 4 Ph.D. Degrees Awarded, 1961–1972

Year	No. Degrees Awarded	Year	No. Degrees Awarded
1961	10,412	1967	20,384
1962	11,505	1968	22,916
1963	12,724	1969	25,728
1964	14,324	1970	29,479
1965	16,340	1971	31,841
1966	17,953	1972	33,001

SOURCE: National Research Council, *Summary Report 1972, Doctorate Recipients from United States Universities* (Washington, D.C.: National Academy of Sciences, 1973), p. 2.

graduate enrollment increases in the 1960's, and the growth of demand lessening or declining, the doctorate market entered a period of economic downturn. The sharpness of the downturn is attributable in large measure to two phenomena. The first was the responsiveness of students to the economic incentives for graduate training (high salaries, stipend support, job opportunities) of the 1960's, which underlay the increase in supply of graduate students. The second was the change in federal policies, which encouraged graduate training in the 1960's and then reduced demand for services of these graduates in the early 1970's. The lessons for policy of this experience will be considered further in Chapter 4.

The complex process of adjustment to this sudden turnaround in the doctorate manpower market is now underway, and much of the policy debate—whether in Washington, in state assemblies, or on campus—is clouded by uncertainty and a lack of understanding of the forces operating to guide the adjustment process. Some point to the long-run stability in the growth rate of Ph.D. output, as displayed in Figure 6 (a fitted trend line from 1870 to 1970 shows a 7 percent average annual increase in Ph.D. output, with deviations reflecting major events such as wars and the Great

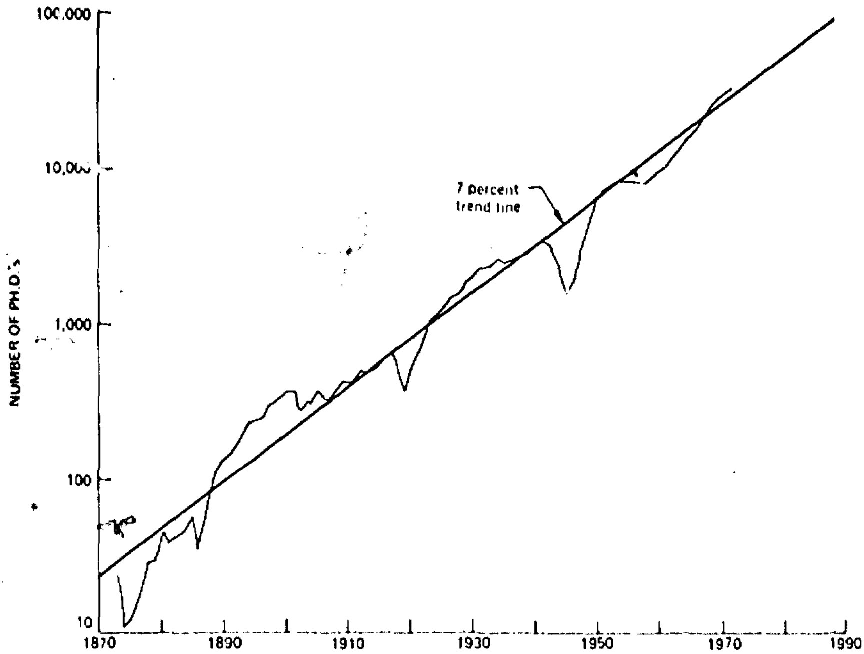


FIGURE 6 United States Ph.D. production, 1870–1970. (Lindsey R. Harmon, "Doctorates of the 1970's: Postdocs and Employment," unpublished paper presented at the Association of Graduate Schools meeting, October 18, 1973.)

Depression). They argue that labor market conditions exert only minimal influence on what appears to be an inexorable process, growth in numbers of the highly educated. Others, including one author of this report, have presented evidence suggesting that labor market forces do effect an approximate balance between supply of and demand for the highly educated, although the labor market is rarely in equilibrium since the multi-year process of schooling generates a 4-year (or more) lag in the supply response.[1] In its simplest form, this latter hypothesis states that students make career decisions and enter degree programs on the basis of current labor market and salary conditions, becoming the new supply four or five years later. Thus, if demand is great and salaries are climbing in year t in a particular profession, many students embark on the necessary career preparation; when they graduate in year t + 5, they may over-supply the market, with a consequent depressing effect on salaries and employment opportunities. Econometric models based on this hypothesis have been particularly effective in "explaining" labor market experience for bachelor degree engineers, for example, as Figure 7 indicates. An important, and as yet unresolved, question is the degree to which labor market forces can be relied upon to adjust the supply of and demand for Ph.D.'s in the next decade, an issue that will be discussed later in the paper. Evidence presented below, however, suggests that the adjustment process to a declining market for Ph.D.'s is underway.

Table 5 presents statistics on *first-year* graduate enrollments, a more sensitive indicator of future supply response than changes in total enrollments. Between 1960 and 1968, first-year graduate enrollments increased at an average annual rate of approximately 11 percent; between 1970 and 1971, this dropped markedly to an increase of only 0.1 percent. Unfortunately, figures for 1972 and 1973 are not yet available from the United States Office of Education; however, large sample surveys by the Council of Graduate Schools reported a 3.5 percent increase in first-year graduate enrollments in 1972 over 1971, and a 4.8 percent increase in 1973 over 1972. Consequently, it is not clear that a continuous decline in first-year enrollments is developing as a student response to the declining market, although it is apparent that the high enrollment growth rates of the 1960's have ended. A further cause of uncertainty is the impossibility of separating terminal master's enrollments from intended Ph.D. enrollments in these first-year enrollment figures; if shifts are occurring away from enroll-

[1] See Richard B. Freeman, *The Market for College-Trained Manpower* (Cambridge, Mass.: Harvard University Press, 1971); and "Supply and Salary Adjustments to the *Changing Science Manpower Market: Physics, 1948–1973*," "*Legal Cobwebs: the* Changing Market for Lawyers," and "Recent Changes in Engineering Manpower, 1948–1972: Applicability of Cobweb Type Models" (Cambridge, Mass.: Study Papers for the MIT Center for Policy Alternatives, 1973).

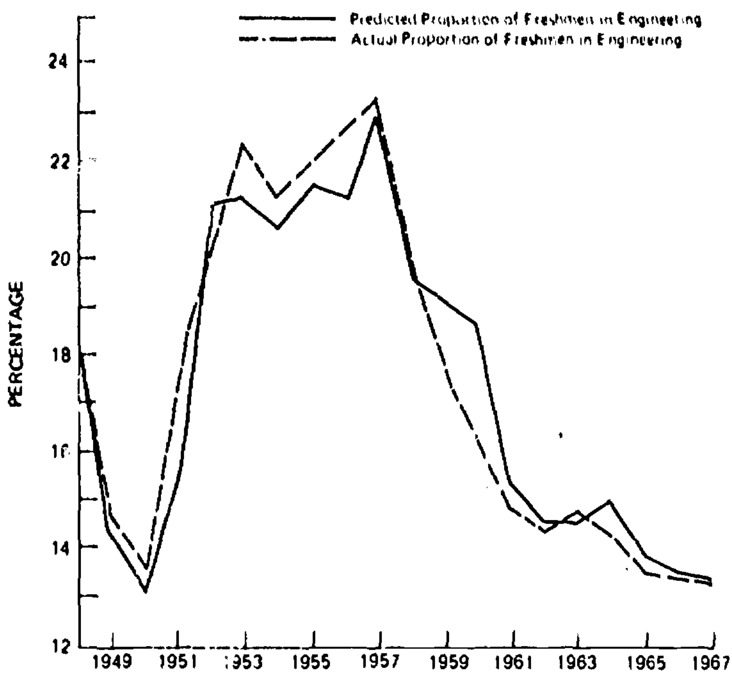


FIGURE 7 *Freshmen in engineering, 1948–1967.* [Richard B. Freeman, *The Market for College-Trained Manpower*, (Cambridge, Mass.: Harvard University Press, 1971)].

ment in Ph.D. programs toward terminal master's programs, as some believe, these data are incapable of detecting it.

Table 6 demonstrates another important feature of the adjustment process—the reaction of the federal government in sharply curtailing fellowship and traineeship support. The 85-percent reduction in the number

TABLE 5 First-Year Enrollments for Master's and Higher Degrees, 1960–1971

Year	No. First-Year Enrollments
1960	197,180
1962	240,468
1964	317,808
1966	370,772
1968	458,334
1969	494,363
1970	527,834
1971	528,151

SOURCE: U.S. Office of Education, *Students Enrolled for Advanced Degrees: Fall 1970* (Washington, D.C.: U.S. Government Printing Office, 1971), and preliminary figures for 1971.

TABLE 6 Number of Graduate Students Supported on Federal Fellowships and Traineeships, FY 1961–1974

Fiscal Year	No. Students	Fiscal Year	No. Students
1961	11,591	1968	51,446
1962	13,528	1969	42,551
1963	15,601	1970	33,240
1964	20,442	1971	28,973
1965	26,425	1972	24,808
1966	40,007	1973	19,649
1967	51,289	1974 (est.)	6,602

SOURCE: Federal Interagency Committee on Education, *Report of Federal Predoctoral Student Support, Part 1* (Washington, D.C.: U.S. Government Printing Office, 1970), and unpublished data for recent years.

of graduate students receiving federal fellowship and traineeship support in the 6-year period, FY 1968–1974, is clear evidence of a pronounced government response to changing labor market conditions for Ph.D.'s.

The growing concern of statewide coordinating agencies with the proliferation of doctoral programs during the 1960's is producing a variety of attempts to control further growth and to eliminate programs that appear inefficient or which needlessly duplicate offerings at other universities within the state. The growing power of such agencies suggests that they will probably exercise a substantial force toward contraction of doctoral programs during this decade.

FORECASTS OF DECLINE

Numerous forecasts of an impending labor market crisis for Ph.D.'s have received considerable attention, beginning with Allan Cartter's forecasts of an oversupply of Ph.D.'s seeking work as faculty. These forecasts are based on two developments: (1) the projected decline in the number of college age persons in the 1980's which—even with extremely high enrollment ratios—implies a significant fall in the college student population and consequent decline in academic employment possibilities; and (2) a continued steady increase in the production of new Ph.D.'s who want academic jobs.

Figure 8 depicts one projection of the declining trend in growth rates of full-time-equivalent enrollments in higher education, with projected absolute reductions in enrollments beginning in the early 1980's. This projected decline in the United States college age population (aged 18–21) is unalterable, although the United States could export education by enrolling foreign students, or could enroll older students, and thus increase the population of college students. With the rapid growth of European and Japanese incomes, differential income and costs may not be as serious a

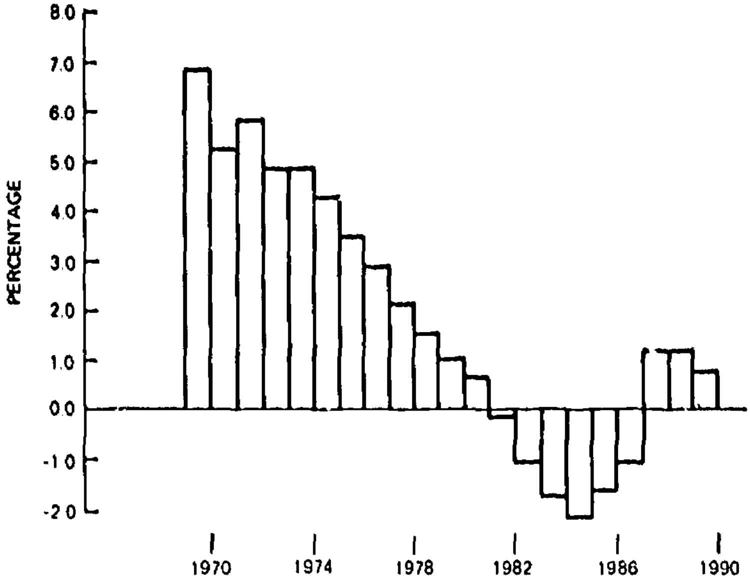


FIGURE 8 Annual percentage change in full-time equivalent enrollment in higher education, actual, 1969–70, and projected, 1970–1990. [Carnegie Commission, *College Graduates and Jobs* (New York: McGraw-Hill, 1973)].

deterrent to foreign enrollments as they have been to date. Such possibilities aside, however, these forecasts have served a useful function in directing attention to the demographic realities which will impinge on academia. The forecasts predicting continued growth of Ph.D. supply, on the other hand, are not based on such realities, for—as we argue later—the decline in the market may reduce the number of new Ph.D. graduates far below most currently projected levels. For example, as recently as 1972, the United States Office of Education was projecting a supply of 68,700 new Ph.D.'s in 1980–1981; in 1973's revision, the projected number was reduced to 52,000,[3] a number that we believe is still too large. In sum there is a serious future market problem to worry about as the trend forecasts indicate; the nature and extent of the problem may, however, differ from the supply–demand imbalance stressed at present. The next issue is to consider the quality and shortcomings of the forecasts.

[3] U.S. Office of Education, *Projections of Educational Statistics to 1980–81, 1971 Edition* (Washington, D.C.: U.S. Government Printing Office, 1972), p. 43; and U.S. Office of Education, *Projections of Educational Statistics to 1981–82, 1972 Edition*, pp. 58–59.

2 Evaluation of Manpower Forecasts

As noted above, much of current concern about doctorate manpower hinges on a set of forecasts of future market conditions. How are such forecasts typically made? What are their shortcomings and how can they be improved? The bulk of this section is concerned with these related technical issues. At the onset, however, it is important to raise a more basic question about forecasting: its potential value or lack of value in a free labor market, where individual decisions, not centralized plans, determine numbers of persons and remuneration in various vocations. It has been argued by some that manpower forecasting is, quality of forecasts aside, an inappropriate exercise in economies such as our own that are not centrally planned. Contrarily, examination of the manpower forecast literature provides a large number of "justifications" of forecasting. Some, as critics have noted, are relevant only to economies with poorly functioning markets or centralized planning; others are valid even in the most perfect of market situations. We consider six possible reasons for manpower forecasts, including some that are pertinent to the doctorate market in the United States and others that reflect a fallacious perception of the operation of the labor market.

REASONS GIVEN FOR PREPARING MANPOWER FORECASTS

Reason 1

Forecasts are needed as part of a manpower planning system to balance supplies and demands because individual decisions—especially career decisions

—*do not reflect economic reality*. This justification of forecasting is based on an incorrect perception of individual behavior in the market. Contrary to the "planning perspective," students and other decision-makers are highly responsive to market opportunities, and they can be expected, over the long haul, to keep markets at or near equilibrium. As the post-Sputnik increase in doctorate specialists should make clear, a free labor market is extremely adept at changing the number of highly trained workers when demands change.

Reason 2

Forecasts provide important information to guidance counselors, enabling them to aid students in career planning. The principal difficulty with this justification, which underlies Bureau of Labor Statistics (BLS) occupational outlook forecasts, is that students tend to ignore formal guidance as a way of learning about the market. Direct observations, obtained by summer or part-time jobs, older friends, or professors are far more important information channels than career counseling.[3]

Reason 3

Forecasts can serve as an early warning system, directing attention to the unforeseen consequences of current market responses and developments. In markets, like that for Ph.D.'s, with long lead times, this is an especially important reason for forecasts. Two types of adjustment problems generally arise that could be identified by manpower forecasts—*cobweb cycles*, in which relative shortages (surpluses) are transformed into the converse several periods later (i.e., individuals respond to the initial situation without allowing for the comparable response of their fellows), and *incomplete adjustments*, in which the market falls short of equilibrium for extended periods due to costs of adjustment or unexpected continual exogenous developments. In both cases, forecasts might provide information that—filtered through the media—perhaps, would alter individual decisions in the direction of reducing the length of the adjustment period or the extent of the problem. Alternatively, such forecasts could motivate governmental activities designed to accomplish the same goal.

An important "warning device" function of even crude forecasts is to point out possible incompatibilities in trend rates of change, incompatibilities that might otherwise be extrapolated into the future by decision-makers. The impossibility of continued high exponential growth of college enrollments, and the potential incompatibility between trend increases in under-

[3] See Freeman (1971), for evidence on sources of career information.

graduate demands for faculty and in the supply of doctorates, are cases in point. While trend forecasts of incompatible developments will never be realized, they can focus attention on the need for adjustments in behavior and provide one element in a more complete analysis of market developments and possibilities.

Reason 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. While forecasts may be of some value in university planning, the evidence of the 1950–1970 decades is that colleges and universities are highly responsive to market needs, as reflected particularly in student educational demands. For the most part, 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 geographic mobility of the highly educated labor force.

Reason 5

Forecasts are needed to evaluate the potential effect of large-scale governmental programs on the market. Because the federal government has a great influence on the demand side of the market—as employer of Ph.D.'s and as purchaser or subsidizer of their services—and because of its significant role in financing the supply of new entrants, forecasts are a necessary and potentially invaluable *policy tool.* Whether one likes or dislikes the visible hand of government in doctorate and related markets, the hand exists and should be guided by knowledge of how it influences market outcomes. The long lead time in producing Ph.D.'s, which makes tomorrow's market depend on today's decisions, requires *contingent forecasts*—estimates of how the future depends on today's policy alternatives.

Reason 6

Forecasts are a useful device for organizing and analyzing information about market phenomena that are taken as given by individual decision-makers. In a competitive market, where individual actions do not alter outcomes, marketwide phenomena fall outside the responsibility of participants, necessitating outside analysis. The effects of broad economic or demographic changes, for example, on demand for college training are not the concern of a single university; these are clearly critical, however, to the entire higher educational system and should be so examined. While many forecasts view data organization and analysis of current conditions as secondary, these steps often constitute their major contribution.

To sum up, three valid uses for manpower forecasting and analysis in a free labor market have been identified: First, and most importantly, as a tool for evaluating governmental policies; second, as an early warning system which may reduce adjustment problems, and third, as an information or diagnostic device to direct attention to market problems beyond the purview of individual decision-makers.

THE FORECAST METHODOLOGY

Granting that forecasts have a role to play as a tool in analyzing and dealing with manpower problems, what can be said about present forecasting techniques?

Current forecast methodology typically involves the application of *fixed coefficient* extrapolations to supply and demand variables along the lines of input–output analysis. In some forecasts, trend ratios (change in Ph.D.'s per B.S. engineer, for example) are extrapolated; in others the levels of parameters are treated as fundamental constants. Judgmental adjustments are often introduced at the end of the procedure to keep results in the realm of contemporary wisdom. The more sophisticated demand side projections derive labor requirements from an input–output growth model. A typical procedure would involve the following:

1. calculation of expected levels of output by detailed sectors from the input–output matrix and economic growth projections;
2. estimation of expected employment by applying productivity factors (usually extrapolations of past rates of growth) to the outputs;
3. multiplication of total employment estimates by manpower coefficients reflecting the proportion of specialists in each sector of employment; and
4. summation of employment across specialties to obtain the final requirements estimate.

In the case of Ph.D.'s who are primarily employed as teachers, the forecasts are based on estimated faculty–student ratios and numbers of students in diverse curricula and levels of education.

A recent NSF study [4] of science–engineering Ph.D.'s provides a reasonably sophisticated and careful example of the requirements approach. To obtain

[4] National Science Foundation. *1969 & 1980 Science & Engineering Doctorate Supply & Utilization* (Washington, D.C.: U.S. Government Printing Office, 1971).

estimates of doctorate utilization in 1980, the following assumptions were made:

1. an increase in graduate–undergraduate faculty in proportion to projected growth of enrollments, with the Ph.D. share of faculty rising at judgmental rates;
2. future employment of Ph.D.'s at some academic R&D jobs equal to the ratio of expected R&D—taken as a constant share of GNP—to the cost of R&D per worker, based on a weighted trend projection of the growth of costs;
3. growth of nonacademic non-R&D jobs at 1960–1968 rates of change; and
4. estimated growth of demand for new Ph.D.'s due to death or retirement based on historic death and working life tables.

Given a wide band of uncertainty about the likely size of some of the ratios and exogeneous factors, particularly R&D funding, alternative projections were made, providing high and low estimates.

On the supply side the NSF projections focused largely on the number of new science–engineering Ph.D.'s, determined by applying various ratios to the estimated number of future baccalaureates, taken from Office of Education extrapolations based on demographic developments. The number of bachelor's degrees is multipled by trend-projected ratios of

1. science to all bachelor's degrees,
2. first-year graduate science enrollments to B.S. degrees,
3. total science graduate to first-year enrollments, and
4. doctorates awarded to total enrollments three years earlier to obtain estimates of Ph.D. graduates.

The estimates are then adjusted for immigration and emigration on the basis of historic experience to yield a net supply projection.[5]

The final step in the requirements analysis is a comparison of the projected number of jobs available with the number of workers available. The hypothetical and provisional nature of the calculations is invariably stressed, often by distinguishing them as projections, not predictions, despite the effort

[5] NSF is now preparing new sets of projections of the supply and utilization of science and engineering doctorates to 1985. The supply models being projected incorporate two additional years of past experience in comparison to the projections described above. The unfavorable labor market conditions of these additional years have been reflected in the recent trends of entry into graduate school; thus some implicit feedback from demand to supply is incorporated into the new supply models. Furthermore, the forthcoming supply and utilization projection report will incorporate feedback from the relationships between projected utilization patterns and the basic supply models to develop supply models which are, to an increasing degree, market-related.

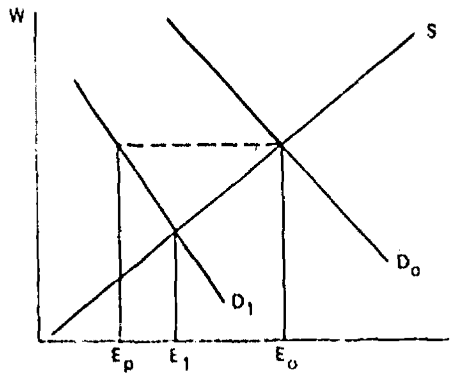


FIGURE 9 Exaggeration of employment changes in forecast analysis.

in obtaining "best" parameter estimates and the extensive use of judgmental assumptions to give good results.

There are four aspects of the requirements methodology which limit its validity as a forecast or analytic device and its possible use as a policy tool.

First is the complete absence of wages or prices in the exercise—either as exogeneous information to aid in forecasting quantity variables or, by themselves, as one half of the market determination of quantities and prices. Since wages and related job opportunities are important determinants of career decisions, bringing available wage data to bear on supply behavior should improve forecasts of supply developments. Similarly, demand projections ought to be improved by taking account of likely price and wage patterns. As separate phenomena, moreover, the salaries of Ph.D.'s and prices charged for their output—cost of R&D, tuition in universities—deserve attention in forecasts. They are of interest to decision-makers on both sides of the market and are needed for a complete picture of the future state of the market.

A second related problem with the requirements analysis is its treatment of the likely responses of individuals to prospective surplus and shortage disequilibria. In general, requirements calculations treat individuals as if they mimicked past patterns of behavior despite changed economic circumstances. On the demand side, for example, fixed faculty-student ratios assume that universities have inflexible hiring plans, regardless of the salaries of prospective faculty, availability of personnel, and the like—an assumption that is both theoretically and empirically unreasonable. By failing to modify projections for normal economic responses, forecasts tend to exaggerate the extent of problems. Figure 9 depicts this *exaggeration* *effect* in the case of a decline in demand from D_0 to D_1: In the absence of economizing behavior by employers, the forecast predicts a decline in employment from E_0 to $E_{1'}$, while in fact the drop is less—from E_0 to E_1, as employers hire additional members of the "surplus" occupation. Where, as in the NSF projections described above, some employer adjustments are assumed (increases in the proportion of faculty with Ph.D.'s), they are tacked on as judgmental adjustments and are not linked to observed behavior patterns nor to motivating factors, like declines in salaries. The inflexibility of the forecast methodology is even more striking on the supply side, where two types of adjustment behavior are uniformly ignored: changes in career plans, which alter the ratio of graduates in specialties to the relevant population; and changes in the occupations of persons with particular types of education. Howard Bowen, among others, has criticized strongly the tight one-to-one occupation–education tie which dominates the requirements approach.[6] *The failure to bring individual responses to market incentives into the projection process represents the major conceptual flaw in fixed coefficient requirement calculations.*

Third, despite—or perhaps because of—the predominance of governmental agencies in the forecasting business, forecasts rarely link market outcomes to policy alternatives. Supply forecasts, for example, do not relate numbers of students to the key policy variables of fellowship availability and educational subsidies. Demand forecasts do not generally link demands to federal R&D spending or mission-related agency programs and ignore the complicated substitution and complementarity relations between private and public spending and employment. Contingent forecasts to pin down the sensitivity of outcomes to possible policies are rarely made. Absence of policy variables from the forecast process and the lack of contingency projections severely limits the value of even the best requirements forecasts to policymakers.

Fourth and finally, the requirements methodology ignores the interactions and feedback among economic phenomena which constitute economic reality. Such omission is especially harmful in long-run forecasts, where sufficient time exists for end-period variables to be significantly influenced by intermediate period phenomena. The supply of new Ph.D.'s in the tenth year of a 10-year forecast, for example, necessarily depends on market conditions five years earlier when career decisions were made, and thus requires forecasts of those conditions. By extrapolating current conditions into the future, the requirements methodology increases the likelihood of significant *cumulation of errors* and rules out forecasts of fluctuations due to feedback relations.

[6] Howard R. Bowen, "Manpower Management and Higher Education," *Educational Record, 54*, No. 1 (Winter 1973), pp. 5–14.

TABLE 7 Scientific Manpower Projections, 1960–1970

Manpower Projections	Number (thousands)			Percent Changes, 1960-1970[a]		
	Projection A	Projection B	Actual	Projection A	Projection B	Actual
Requirements for 1970						
Engineers	1484	1375	1126	90	67	37
Scientists	548	580	583	75	73	74
Chemists	163	170	145	72	64	39
Physicists	57	59	59	103	98	97
Geologists	31	29	35	41	25	53
Mathematicians	60	65	81	107	107	161
Med. sci.	53	60	63	77	90	101
Agric. sci.	70	66	59	71	67	48
Biol. sci.	27	77	91	73	88	123

Supplies, 1969	*Projected*	*Actual*	*Projected*	*Actual*
B.S. degrees				
Biology	29.2	35.6	86	22
Mathematics	28.4	-27.3	155	140
Chemistry	14.9	11.8	97	55
Agric. sci.	7.1	8.1	45	14
Physics	8.9	5.5	107	28
Geology	2.8	2	17	−20
Engineering	34.0	41.6	−11	11
Ph.D.'s in Eng., math and phys. sciences (EMP)				
Ofc. of Educ.	5.5	9	90	210
NSF	6.1	—	110	—
National goals for grad. education in EMP				
M.S. graduates	30.0	28	150	133
Ph.D. graduates	7.5	9	159	210

* Percent change projection A for period 1959-1970; percent change projection B, for 1961-1970.

SOURCE: Projection A—National Science Foundation, *Long Range Demand for Scientific and Technical Personnel* (Washington, D.C.: U.S. Government Printing Office, 1961); Projection B—National Science Foundation, *Scientists, Engineers, and Technicians in the 1960's* (Washington, D.C.: U.S. Government Printing Office, 1963), Table A-2 and Table 5; Supply projections—B.S. degrees: National Science Foundation, *Scientists, Engineers, and Technicians in the 1960's*, Table A; Ph.D.'s and national goals: President's Science Advisory Committee Report, *Meeting Manpower Needs* (Washington, D.C.: U.S. Government Printing Office, 1962).

THE ACCURACY OF FORECASTS

The four errors of omission just documented could be ignored if other methods of forecasting manpower developments were lacking or if, analytic problems aside, requirements calculations were reasonably accurate—particularly in predicting changes in market conditions. In fact, alternative techniques do exist and past forecasts have not been very accurate, as will be seen.

As to the accuracy of projections, Tables 7 and 8 summarize a variety of past and current forecasts and compare the former to actual developments. Despite the oft-asserted proviso that projections are not meant to be predictions, comparisons provide the only posterior check on the technique and must be used if the computations are taken seriously.

The results of the comparisons in Table 7 reveal significant discrepancies between projected and actual developments. Supply projections made in the early 1960's failed to foresee the response of students to the strong market incentives then existing and thus fell short of actual supplies. Even the President's Science Advisory Committee's (PSAC) national goals for 1970 engineering, mathematics, and physical science enrollments and Ph.D.'s were surpassed by actual supplies. On the demand side, the failure to recognize the conditions of rapid growth of supply and the slowdown in R&D and related spending stands out. Forecasts continued to estimate shortages until the market actually declined in the early 1970's, with few exceptions (notably Allan Cartter's academic market projects). While other methodologies might also have missed the timing of the change, it is clear that a history of good forecasts cannot be produced in support of requirements calculations.

Table 8 reveals another disheartening feature of the forecasts—their tendency to vary greatly depending on whether fixed or trend-growth assumptions are used to project key ratios, the time period used in the base for the projections, and the application of judgmental adjustments. While a careful reading of the forecast assumptions permits some choice among them, based on the forecaster's perception of broader market developments and on the key assumptions that give particular results, the divergence suggests deeper problems with the entire approach. With no accepted operating rules as to which factors are to be postulated as fixed, growing at trend rate with what trend length, or set at judgmental levels, the result is almost necessarily arbitrary.

A superior methodology would take account of the adjustment responses of individuals and market interactions, (described in Chapter 3) in the context of an econometric model of the manpower market similar to those used for forecasting national economic developments. Appendix B describes

TABLE 8 Diversity in Current Projections of Ph.D. Market

Type of Projection	Source	Number (thousands)	
Total Ph.D.'s awarded, 1971-1980	Haggstrom(A)	520	
	Hall—NRC	479	
	Office of Education	476	
	Haggstrom(B)	455	
	Haggstrom(C)	431	
	NSF	392	
	Cartter	381	
	Froomkin	369	
		Demand[a]	Supply[a]
Demand and Supply, 1980	NSF(1969)	339	352
	NSF(1971)	284	325
		Cartter	Haggstrom
Full-time equivalent enrollment, 1970-1990 (alternative projections)	1970	6,303	6,697
	1975	8,197	8,925
	1980	9,537	10,428
	1985	9,228	10,312
	1990	8,674	10,378

[a] Midpoints of range.

SOURCE: Dael Wolfe and Charles V. Kidd, "The Future Market for Ph.D.'s," *Science*, 173, 784-794; National Science Foundation, *Science and Engineering Doctorate Supply and Utilization* (Washington, D.C.: U.S. Government Printing Office, 1969), and NSF, *1969-1980 Science and Engineering Doctorate Supply and Utilization*; and F. E. Balderston and Roy Radner, "Academic Demand for New Ph.D.'s, 1970-90: Its Sensitivity to Alternative Policies," Ford Foundation Research Program in University Administration, Paper P-26 (Berkeley: University of California, December 1971).

briefly an appropriate structure for such an improved analysis of doctorate and related manpower market developments.

FORECASTS FOR THE 1970's AND 1980's

While forecast methodology suffers from many difficulties, this does not mean that current forecasts of impending Ph.D. gluts are wrong in warning us about the future state of the market. As pointed out earlier, the key fact on which these forecasts focus—the demographic decline in the number of prospective college students, which will reduce demand for faculty, causing a decline in the Ph.D. manpower market—is as "hard" a trend on which to base simple forecasts as can be imagined. This does not mean, however, that the projected imbalances will necessarily occur, for *market adjustment* processes may lead to a somewhat different outcome and set of problems.

3 Market Adjustments and Response Patterns

The preceding discussion of manpower forecast methodology suggests the value of a more detailed look at individual responses to market conditions and at the market adjustment process. This section examines the key forms of response to market changes, shows how they can affect forecast variables, and sketches a scenario of adjustment to current and future Ph.D. market imbalances.

PATTERNS OF RESPONSE AND FORECASTS

There are six important forms of individuals, university, employer, and governmental response to changes in the doctorate market that are important in understanding ongoing changes in conditions and likely future developments.

Student Career Decisions

The way in which students react to market incentives—in the present case to the well-publicized decline in Ph.D. job opportunities, stipends, and relative salaries—is a key determinant of the future state of the doctorate manpower market. A variety of studies [7] have indicated that the educational and career choices of at least some students are significantly affected by

[7] See footnote 1.

economic conditions, which suggests that the bleak outlook should result in absolute reductions or shifts in the composition of graduate enrollments now and in the future. Table 9 presents evidence on trends in first-year graduate enrollments as well as first-year enrollments for professional degrees in law, medicine, and dentistry. As noted earlier, the growth rate in first-year graduate enrollments slowed to 0.1 percent from 1970 to 1971, a sudden change from the average annual increases in excess of 10 percent that had marked the 1960's.[8] By contrast, first-year enrollments for professional degrees not oriented toward the declining academic market continued to increase, registering a 10.5 percent jump from 1970 to 1971.

Looking more closely at 1970–1971 changes in individual disciplines, percentage reductions in first-year graduate enrollments are noted (Table 10). These reductions occurred in fields which are either heavily oriented toward the (declining) academic market or which had experienced well-publicized job shortages in the late 1960's–early 1970's. The major anomaly to this pattern is the field of biology, which experienced a 16-percent increase in first-year enrollments. The increased popularity of this field may be explained in part by the growing interest in ecological, environmental, and health concerns, although it is worth noting that in the late 1960's the salary position of the biological fields improved relative to physical sciences, with median salary of biologists vis-à-vis that of physicists rising from 0.89 in 1964 to 0.94 in 1970.

Table 11 documents the rapid growth in first-year enrollments in the applied disciplines and in the professions. The patterns displayed in Tables 10 and 11 suggest that a combination of enrollment reductions in the traditional academic disciplines and enrollment increases in those applied and professional areas where job markets are still expanding may be the emerging trend. Although evidence from subsequent years will be necessary to establish this with greater certainty, the evidence contained in Table 9 is broadly consistent with the hypothesis of student responsiveness to market incentives.

Incorporating empirical estimates of the degree of student responsiveness to market conditions has a pronounced effect on forecasts of future Ph.D. supply. Elasticities of the supply of new entrants (the percent change in entrants caused by a 1 percent change in incentives) in the physical sciences have been estimated to be on the order of 2 with respect to salaries (assumed to reflect lifetime income expectations); stipends or fellowships appear to have similar effects, when translated into appropriate present value terms.[9] Table 12 shows the effect of bringing student career responsiveness into

[8] Comparable data for more recent years are not yet available from the United States Office of Education.

[9] See footnote 1.

TABLE 9 First-Year Enrollment For Master's and Higher Degrees, and for First Professional Degrees

Field	1964	1966	1968	1969	1970	1971	Percent Change, 1970–1971
All Fields, for Master's or Doctor's Degrees	317,808	370,772	458,334	494,363	527,834	528,151	0.1
English and literature	14,597	16,921	19,104	20,568	21,036	20,576	– 2.19
Philosophy	1,776	2,123	2,079	2,134	2,276	2,099	– 7.78
Foreign languages	6,482	8,633	9,713	10,137	9,794	9,089	– 7.19
Physical sciences, total	16,123	16,509	16,825	16,789	17,356	16,665	– 3.98
Physics	5,927	5,268	5,364	5,320	5,326	4,417	–17.07
Chemistry	6,953	7,344	7,142	7,166	7,149	6,678	– 6.59
Biological sciences, total	11,821	14,200	14,875	16,285	17,245	18,042	4.62
Biochemistry	1,070	1,010	1,069	1,119	1,078	1,058	– 1.85
Biology	4,121	5,085	5,687	6,798	7,238	8,38[illegible]	15.85
Mathematical sciences	11,830	12,624	13,299	13,748	13,604	11,996	–11.82

Economics	4,583	4,840	5,104	5,[illegible]73	5,956	5,008	−15.92
History	9,182	10,733	11,790	12,894	13,182	11,929	− 9.51
Political science	3,940	5,036	5,238	6,022	6,397	6,382	− 0.23
Psychology	7,673	8,459	10,645	12,200	14,262	14,754	3.45
Engineering, total	30,245	32,278	34,438	36,626	35,477	30,545	−13.50
Civil	NA	3,618	3,714	4,254	4,503	4,760	5.71
Electrical	NA	8,842	9,109	9,592	9,099	8,021	−11.85
Health professions[a]	4,587	5,414	7,140	7,522	8,270	9,993	20.83
Architecture and city planning[a]	NA	1,719	2,108	2,779	3,322	4,002	20.47
Business and commerce[a]	32,909	41,038	50,530	56,283	62,182	66,392	6.77
Education, total	106,237	125,599	170,131	180,971	191,748	192,040	0.15
All Fields, for First Professional Degrees	NA	36,328	47,044	56,057	63,265	69,909	10.50
Dentistry	NA	3,295	4,285	4,354	4,639	5,103	10.00
Medicine	NA	7,906	9,843	10,832	11,394	12,946	13.62
Law	NA	19,268	25,249	30,433	36,136	40,003	10.70

[a] Adjustments for changes in taxonomy during the period were made. A detailed explanation of the method of calculation is available upon request.

SOURCE: U.S. Office of Education, *Enrollment for Master's and Higher Degrees, Fall 1964; Students Enrolled for Advanced Degrees: Fall 1966* (and Fall 1968, Fall 1969, Fall 1970), Washington, D.C.; and preliminary figures from U.S. Office of Education on enrollment for advanced degrees, Fall 1971. Adjustments for changes in taxonomy as appropriate were made.

TABLE 10 Change in First-Year Graduate Enrollments, 1970–1971

Field	Percent Change, 1970-1971
English and literature	− 2
Philosophy	− 8
Foreign languages	− 7
Physics	−17
Chemistry	− 7
Mathematics and statistics	−12
Economics	−16
History	−10
Electrical engineering	−12

SOURCE: U.S. Office of Education, *Students Enrolled for Advanced Degrees: Fall 1970*; and preliminary figures from U.S. Office of Education on enrollment for advanced degrees, Fall 1971.

TABLE 11 Change in First-Year Graduate Enrollments, 1970–1971 (Applied and First Professional Degree Programs)

Field	Percent Change, 1970-1971
Architecture and city planning	+21
Applied social sciences[a]	+14
Health professions	+21
Business and commerce	+ 7
Medicine	+14
Law	+11
Dentisty	+10

[a] This category includes disciplines considered to have an applied social science and public affairs orientation such as public administration, social work, urban studies, foreign service, etc., but specifically omits the "academic" disciplines of anthropology, archaeology, economics, history, geography, and political science.
SOURCE: U.S. Office of Education, *Students Enrolled for Advanced Degrees: Fall 1970*; and preliminary figures from U.S. Office of Education on enrollment for advanced degrees, Fall 1971.

manpower forecasts in the case of physics and the physical sciences. With relative salaries declining in the late 1960's–early 1970's, projections adjusted for economic behavior predict much smaller supplies of graduates in the future than requirements projections, and, allowing for experienced personnel responses (see below), smaller total supplies.

Experienced Personnel Decisions

While the responsiveness of experienced Ph.D.'s will, in general, be less than that of potential new entrants because of past commitments and investments in careers, the way in which such workers shift fields, employers, hours of work, and retirement plans will also affect market conditions and forecasts. Recent NSF surveys of scientists and engineers provide some indication of the reactions of experienced personnel to the market decline; this evidence significantly alters the picture of future supply–demand relations. In par-

TABLE 12 Forecasts of the Supply of Ph.D.'s, Adjusted and Unadjusted for Supply Responses

Field	Number, 1980	Absolute Change, 1970 1980	Percent Change, 1970-1980
New Physics Ph.D.'s			
Unadjusted			
Cartter	2,680	1,080	68
Office of Education	2,608	1,008	63
NAS-NRC	3,908	2,108	123
Adjusted	790	−810	−51
New Physical Sciences Ph.D.'s			
Unadjusted (NSF)	4,190	−90	−2
Adjusted	2,560	−1,720	−40
Total Physical Science Supply (Ph.D.)			
Unadjusted (NSF)	82,300	30,900	60
Adjusted	74,300	22,900	45

SOURCE: National Science Foundation, *1969 and 1980 Science and Engineering Doctorate Supply and Utilization*; Allan M. Cartter, "Science Manpower for 1970-1985," *Science*, *172*, 132-140; and Freeman, "Science Manpower in the 1970's," and "Supply and Salary Adjustments to the Changing Science Manpower Market: Physics, 1948-1973" (Cambridge, Mass.: Study Papers for the MIT Center for Policy Alternatives).

ticular, according to the NSF figures, the 1970–1971 market fall caused a 1.1 percent increase in unemployment over the previous rate for Ph.D. scientists and a 1.6 percent outflow of workers from the scientific fields. The unemployment and mobility of scientists under 30 was especially great, with an unemployment rate of 5.4 percent and a movement of 2.8 percent of young scientists to other occupations.[10] With fewer young entrants and a decline in the number of young experienced scientists, there is growing concern over an impending imbalance in the age distribution of scientific workers. To the extent that the young are more creative than older specialists, the pattern of market adjustment is probably socially undesirable.

Considered next is the way in which responses of experienced Ph.D. specialists can affect forecasts of demands for new Ph.D.'s. The behavior of the experienced is critical to such forecasts because experienced workers far outnumber new Ph.D.'s: A 1 percent decline in salaries, for example, or an increase in the unemployment rate—which might reduce the supply of new Ph.D.'s by 2 percent and that of experienced workers by just 0.2 percent—will reduce the total supply by the same amount, if the latter outnumber the former by ten to one. In 1970, the ratios of flows to stocks

[10] See National Science Foundation, *Unemployment Rates for Scientists, Spring 1971* (Washington, D.C.: U.S. Government Printing Office, 1971).

of Ph.D.'s in key specialties were on the order of one to ten, indicating that even relatively small experienced worker responses are critical in a set of forecasts.

Table 13 shows the potential effect of the supply behavior of experienced college and university faculty on the estimated number seeking jobs in 1980 and on the *net demand* for new Ph.D. faculty (total demand minus existing experienced work force), which has received considerable attention recently. Line 1 of the table records the 1969 employment of physical science Ph.D.'s in total and on college and university faculties. Line 2 gives the NSF projected "low" demand for Ph.D.'s, and line 3 records the NSF estimated demand for new Ph.D.'s that results from expansion of Ph.D.-employing industries and replacement needs. Line 4 is the NSF "low" estimate of the supply of new Ph.D.'s less expected attrition. The gap between supply and demand (line 4 minus line 3) represents the "surplus" of doctorate specialists forecast for the 1970's.

To evaluate the effect of experienced worker supply on the surplus, it is assumed in line (5a) that *relative* Ph.D. salaries decline by 15 percent due to the loose labor market and that the response of experienced workers (in terms of retirement decisions and movement into "non-Ph.D." work) is reflected in an elasticity of supply of 0.4 (a reasonable, though low, estimate given postwar experience). Current evidence does not allow us to

TABLE 13 Effect of Experienced Worker and Employer Responsiveness on Demand for Ph.D.'s and Ph.D. Faculty

	No. Physical Science Ph.D's Working as Scientists	
	Total	Faculty Only
(1) 1969 employment	51,400	20,700
(2) NSF projected "low" demand, 1980	75,600	28,000
(3) NSF projected demand for new Ph.D's, 1969-1980	33,800	10,400
(4) NSF projected supply of new Ph.D's, less attrition and immigration, 1969-1980	42,600	17,200
(5) Adjustments in demand for new Ph.D's, 1969-1980		
a. Additional demand due to reduced supply of experienced workers	4,300	1,900
b. Additional demand due to reduction in cost of Ph.D.'s and employer demand responses	5,700	2,100
(6) Adjusted demand for new Ph.D.'s, 1968-1980 [(3) + (5a) + (5b)]	44,300	14,400

SOURCE: NSF Projections from *1969 and 1980 Science and Engineering Doctorate Supply and Utilization.*

specify the fields to which the experienced Ph.D.'s are likely to move, though presumably they would shift into various white-collar, managerial, sales or professional jobs.

Applying the 15 percent salary decrease to the 0.4 elasticity yields a predicted decline in the number of experienced Ph.D.'s offering to work as Ph.D. physical science specialists in the 1970's of 4,800 persons (or 55 percent of the gap between incremental supply and demand for new workers). Despite the small postulated elasticity, the net demand forecast is especially sensitive to the postulated experienced worker behavior.

Employer Decisions

The extent to which supply-demand imbalances produce significant unemployment and underemployment or labor hoarding and shortage problems hinges critically on the flexibility of salaries to market conditions and the elasticity of employment to salaries. The more elastic are hiring decisions, the easier the adjustment to changes in relative supplies or demands. Estimates of the elasticity of demand for R&D workers (largely Ph.D.'s) and Ph.D. faculty suggest relatively small employment responses—perhaps ½ percent change in employment per 1 percent change in salary or cost per research worker—as might be expected given the highly specialized nature of the manpower. Even such limited responsiveness, however, can significantly alter the forecasted number of jobs, especially for new Ph.D.'s. In Table 13, line (5b), the *requirements forecasts* of demand for new Ph.D.'s and Ph.D. faculty are adjusted to take account of the postulated 15 percent relative salary decline and a 0.5 demand elasticity.[11] While not all of the projected imbalance disappears as a result of the demand response, the extent of the supply-demand gap is greatly diminished for new Ph.D.'s. Indeed, taking account of both the experienced worker supply [(5)a] and employer demand responses [(5)b], the supply-demand imbalance in the market as a whole "disappears" under these assumptions: A 15 percent reduction in relative wages would clear the market. In the faculty market, however, supplies continue to exceed demands, implying that the major adjustment problem will be to shift potential academic Ph.D.'s to other jobs and to reduce relative faculty salaries even further. Note, however, that our knowledge of the demand for Ph.D.'s by nonacademic employers and the possibility of substituting Ph.D.'s for other personnel is highly limited, as is our knowledge of supply response to academic-nonacademic salary and opportunity differentials. These subjects require detailed investigation.

[11] Richard B. Freeman, "Scientists and Engineers in the Industrial Economy," unpublished report to NSF, reports evidence on the elasticity of demand for scientists and engineers.

The story thus far is that both supplies of labor and employers will respond to economic conditions in ways that ameliorate market imbalances and lessen potential manpower crises. Indeed, assuming that real salaries decline and that the estimated elasticities are reasonably accurate, as used in Tables 12 and 13, current forecasts of a significant glut of Ph.D.'s in the market *far overstate* the potential supply–demand imbalance of the 1970's and early 1980's. The question naturally arises: What are current and likely future salary adjustments? Are salaries sufficiently flexible in the Ph.D. market to bear much of the burden of adjustment to change?

Salary Determination

Currently available studies of salary determination show changes in salaries to be explicable by market conditions, as reflected in changed numbers of new graduates, R&D budgets, output in Ph.D. or R&D-intensive industries, student enrollments and the like, though with a lag of 1–2 years. As an indication of the extent of salary responsiveness, the pattern of change that has accompanied the recent market decline is considered (Table 14). Nominal

TABLE 14 Changes in the Starting Salaries of Ph.D. Scientists and Engineers and of Professors, 1964–1973

Group	1964-1969[a]		1969-1973[b]	
	% Change in Salaries	% Change in Salaries minus Change in Consumer Price Index	% Change in Salaries	% Change in Salaries minus Change in Consumer Price Index
Ph.D. chemical engineering	31.5	13.4	7.1	−16.3
Electrical	23.0	4.9	9.0	−14.4
Mechanical	28.7	10.6	10.1	−13.3
Civil	NA	NA	9.2	−14.2
Chemists	28.2	10.1	2.9	−20.5
Mathematics	22.2	4.1	3.9	−19.5
Physics	29.8	11.7	0.3	−23.1
Academic faculty, professors	36.6	18.5	11.4[c]	− 2.7
Change in hourly earnings	28.8	10.7	28.3	4.9

[a] Period of relative market boom.
[b] Period of relative market bust.
[c] 1969-1972.

SOURCE: Ph.D. starting salaries: College Placement Council, "Men's Salary Survey" (Bethlehem, Pennsylvania: Survey results for 1965-1973); Faculty salaries, for academic years: American Association of University Professors *Economic Status of the Profession* (AAUP Bulletins Summer editions, 1964-1973); Consumer Price Index (CPI) and average hourly earnings: U.S. Department of Labor, *Manpower Report of the President* and *Monthly Labor Review*.

changes in the starting salaries of Ph.D.'s in industry and science–engineering have been close to zero or negative in fields like physics, with the result that *real* salaries and salaries relative to earnings elsewhere have dropped markedly. The salaries of academics have also declined in real terms. The existence of sizeable alterations in salaries in response to market downturns—the classic price system reaction to manpower surpluses—is certainly evident in these figures, but additional information and research is clearly desirable to improve our estimates of the postulated supply–demand responses in Tables 12 and 13.

University Responses

A wide variety of other modes of non-price adjustments to the declining labor market can substitute for or amplify the postulated price response. University departments may restrict new enrollments, and some doctoral programs will be eliminated. In addition, graduate faculty may tighten their standards for awarding the Ph.D. in response to diminished market demand, as well as increase the requirements for the degree. The combination of these two "producer" adjustments will both lengthen the time to degree and increase attrition rates, thus reducing the degree/enrollment ratio. Evidence of this type of behavior at one major university has been described elsewhere by one of the authors.[12]

In the faculty market, lengthier periods for attaining tenure, as well as reduced probabilities of achieving it, represent one important adjustment. Another is the likely increase in teaching loads from the reduced levels of the 1960's. Ranks such as instructorships, which became less important or disappeared in some institutions as a response to the heavy demand for faculty during the 1960's, are likely to become more important in a declining market. In the sciences, postdoctorate "holding patterns," in which graduates who might previously have obtained academic jobs are hired—at considerably lower pay—as postdoctoral workers, is yet another non-price adjustment, operating in the same direction as a decline in salaries. All of these patterns of change in incentives—accompanied by the decline in fellowship support—should generate a reduction in graduate enrollments and in numbers of new Ph.D.'s in the future, as suggested by the estimated "supply response" forecasts of Table 12.

Governmental Responses

Finally, and most speculatively, it would be extremely useful in analyzing and forecasting manpower developments if some governmental activities

[12] David W. Breneman, "The Ph.D. Production Process: A Study of Departmental Behavior," unpublished Ph.D. Dissertation (Berkeley: University of California, 1970).

could be treated as endogenous to the analysis, reflecting foreseeable responses to economic circumstances. The rapid change in stipend policy from heavy to limited support as the Ph.D. market moved from tight to loose conditions suggests the existence of some such predictable behavior, which might be brought into the analysis. More generally, the possibility that, as some have argued, policymakers *overreact* to market conditions, deserves detailed investigation, for the purpose of corrective action and forecasting market problems.

In the absence of appropriate knowledge of potential governmental behavior, it is necessary, of course, to perform detailed simulations contingent on policy alternatives and to pin down the response of individuals and market outcomes to these policies.

THE STRUCTURE OF THE DOCTORATE MARKET

The way these various individual responses to changes in economic incentives *interact* in the market is important in understanding or forecasting manpower developments. There are two distinctive structural aspects to the Ph.D. market which deserve attention. First, due to the long training lag in producing Ph.D.'s resulting from the "technology of production," the time path of response in the market has a recursive feedback structure. In simplest form, the market follows the classic cobweb described earlier. There will be a general tendency to oscillate from shortage to surplus conditions with a periodicity of about 5–6 years. The important implication of the cobweb structure is that the doctorate market has an inherent cyclic adjustment mechanism, with today's surplus (shortage), all else the same, becoming tomorrow's shortage (surplus). Policies which alter current Ph.D. enrollments, in particular, determine market supply 5–6 years ahead and must take account of these consequences. In part, at least, the surplus problems of the 1970's can be traced to past policies, which led to great increases in Ph.D. production years after the need for doctorate specialists was a serious national problem. Similarly, the current cutback in salaries, employment opportunities, and enrollments means, as argued, reduced supplies of new Ph.D.'s in certain disciplines in the late 1970's–early 1980's—which may or may not be desirable, depending on future demands.

The second important structural feature of the Ph.D. market results from the fact that Ph.D. faculty produce Ph.D.'s. As a result, the demand for graduate education in year t, which increases demand for faculty in that year, also increases the supply of future faculty. This creates a more complex adjustment pattern than the cobweb system. Fields where a large proportion of faculty are involved in graduate education, and whose graduates are likely to become academicians, will experience endogenous fluctuations in supply and demand as a result of the graduate student–faculty link. One important implication is that the future problems of graduate specialties like English, which primarily train faculty, and others such as engineering, which train industrial specialists, are likely to be quite different. A cutback in graduate training will have a greater effect on the English-type fields than those with engineering-type patterns of demand and supply.

A SCENARIO OF CHANGE

If the doctorate manpower market follows the adjustment pattern described above, the 1970's–early 1980's will experience a somewhat different set of manpower problems than those being currently forecasted. First, there will be a significant relative decline in the number of Ph.D. workers and an aging of the doctorate population. While, given the likely shift in demand against faculty in the 1980's, the fall in Ph.D.'s is not likely to produce cobweb shortages in most fields, it may do so in specialties like chemistry or engineering, where many Ph.D.'s work outside academia. Furthermore, the reduced number of young scientists may create serious problems in the rate of scientific progress. Second, the income of Ph.D.'s and academic faculty will be considerably lower relative to other workers than has been the case in the recent past. A decline in relative (though not real) income on the order of 20 percent beyond that already obtained is quite possible. The potential ways in which this decline is distributed—who has the largest relative loss of income and in what form—are important issues which policy can affect. Third, there will be—even with all of the postulated adjustments—a likely "maldistribution" of doctorate specialists, with some of those trained for faculty research or teaching obligated to seek industrial or other nonacademic employment. This could create problems in graduate education unless programs are adjusted for the training of industrial rather than academic specialists. Fourth, with supplies declining, any new R&D, or related Ph.D.-intensive initiative—as in the energy area—will run into possible Ph.D. shortages which, because of the period of production, will not be lessened until the early 1980's.

4 Policy Implications and Further Research Needs

The analysis of doctorate manpower problems, forecasts, and related market adjustment processes presented in this essay suggests several policy implications and directions for further investigation.

1. The fact that the labor market performs an allocative function for highly educated manpower does not mean that a hands-off, *laissez-faire*, policy, is desirable. Rather, the cyclical imbalances between supply and demand caused by the long training lags suggests a positive role for governmental policy in offsetting or counterbalancing the market's natural tendency to oscillate. To do this effectively, however, requires the recognition that the impact of current policies will be felt five or more years hence—the *immediate state of the labor market should be used as a guide for appropriate countercyclical* policies that will dampen rather than increase the periodic fluctuations. Unfortunately, over the last 20 years, the federal government has generally played a destabilizing role by overreacting to the shortages of the 1960's—thereby contributing to the surpluses of the early 1970's—and by overreacting to these immediate surpluses in a manner likely to create shortages in some fields in the late 1970's. This experience suggests that the wisest policy would be one of *gradual change in federal and related* policies, as opposed to the sharp swings in support for graduate training and Ph.D. work activities. Graduate education and research should be viewed as *long-run* resources and activities, and not be subject to exogenous, policy-induced fluctuations based on a short-term crisis psychology.

2. In order to monitor trends affecting the labor market for the highly trained, improved and more up-to-date information, organized in a fashion useful for policy making, is required. At a minimum, the desired data base should include total and first-year enrollment trends by field and institution; trends in financial support for graduate students by field and institution; job placements and salaries of graduates, as well as analysis of unemployment and underemployment; trends in research and development expenditures, and the distribution of these expenditures by type of institution and source of funds. While many of these data are currently collected by the United States Office of Education, National Science Foundation, Department of Labor, and other agencies, there is no central point at which the relevant data are brought together and analyzed for purposes of guiding federal policy. One of the major benefits to be derived from the econometric model-building activity described in Appendix B would be the systematic collection, organization and analysis of data that such an effort would require, apart from any benefits that might result from the model's forecasts. A particular need exists for continuous monitoring of trends in relative salaries together with testing and refinement of our estimates of supply and demand elasticities, in light of their potential significance in improving forecasts.

3. There is considerable need for disaggregated, field-by-field labor market analysis, as opposed to broad studies of supply and demand for all Ph.D.'s. The next decade may witness substantial surpluses in some disciplines (those heavily dependent upon the academic market), and shortages in others, unless the system is closely monitored and corrective policies taken.

4. Given that relative Ph.D. and academic salaries will and should decline in the future as a result of the supply–demand situation, the different ways of reducing relative salaries, ranging from alteration of tenure rules to early retirement policies merit consideration. Since individual fields will face differing labor markets in the future, additional widening of the academic salary structure may prove desirable.

Appendix A
Economics of Shortages and Surpluses

The terms "shortage" and "surplus" hold center stage in manpower forecasting and discussions of manpower problems for the highly educated. In general, the terms are loosely used to indicate differences between projected supplies and demand, with little attention given to the adjustments or economic costs that such disequilibria engender. We consider next a more meaningful interpretation of shortages and surpluses and the evaluation of their costs in the context of applied welfare economics.

To begin with, the simple shortage or surplus concept found in forecast analysis contrasts a single point estimate of manpower *requirements* with *supplies*. With fixed labor coefficients and unavailable human capital, the imbalance of the two creates bottlenecks either in production (requirements exceeding supplies) or unemployment. Even as a rough first approximation, this methodology is too simplistic to afford much insight into the real world. By inadversion, the forecast concepts assume constancy in prices or the failure of individuals to respond to price incentives—assumptions that are surely invalid in competitive markets.

Alternative, more rigorous, definitions of a shortage and surplus have been made by several economists: Blank and Stigler used increases in relative wages as a measure of shortage of scientific personnel in their study;[13] Arrow and Capron dealt with the notion of a dynamic shortage resulting from continuous unexpected shifts in demand and slowly adjusting wages,

[13] D. Blank and G. Stigler, *The Demand and Supply of Scientific Personnel* (Washington, D.C.: National Bureau of Economic Research, 1957).

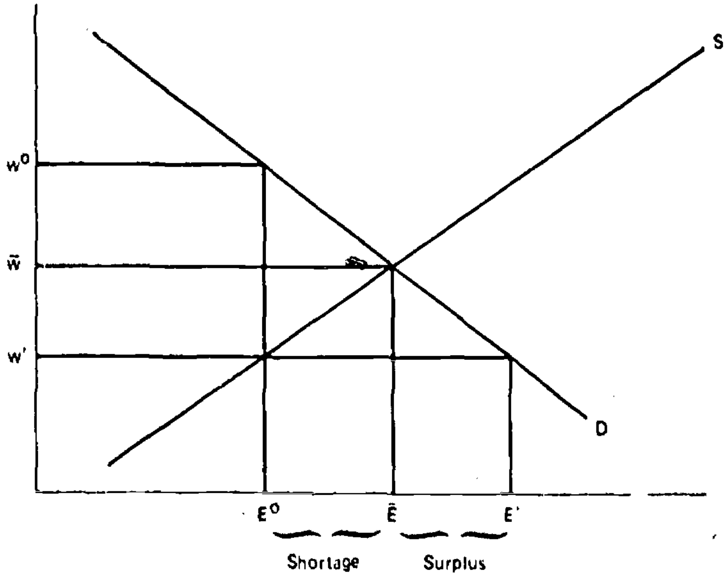


FIGURE A.1 Shortages and surpluses in a market.

which produce excess demand at any attained wage level.[14] In the human capital framework, the rate of return to investment in an occupation has received wide acceptance as a measure of shortage or surplus, with rates exceeding those in competing fields indicating a shortage in a specialty. W. Lee Hansen, in particular, has applied the return concept to shortage and surplus problems in medical and scientific areas.

For the purpose of evaluating the cost of shortages and surpluses to the economy, it will be useful to define the concept more generally as the *deviation of employment and wages (or rate of return) from their equilibrium levels,* where equilibrium refers to the market outcome that would result if each person had perfect foresight about wages and opportunities and made "correct" decisions. Put another way, in equilibrium, no one would be willing to pay for clairvoyance.

This concept of a shortage or surplus is depicted for a single market in Figure A.1 where ($\bar{E}$, $\bar{w}$) represents equilibrium, (E^o,w^o) a point of manpower shortage, and (E',w'), a point of surplus. Viewing $\bar{w}$ as the appropriate rate of return, there is a clear link between the return concept of shortages and surpluses and the disequilibrium concept: in both cases $w > \bar{w}$ implies a shortage and $w < \bar{w}$, a surplus; as the actual wage converges to $\bar{w}$

[14] K. J. Arrow and W. M. Capron, "Dynamic Shortage and Price Rises: the Engineer-Scientist Case," *Quarterly Journal of Economics,* 1959.

and employment to $\bar{E}$, the result is also the same—market equilibrium. Despite its similarity with the rate of return concept, however, the *disequilibrium* interpretation of the diagram is more general and useful. First, it deals with disequilibrium in both wages *and* employment, with the latter providing the analogue to the usual interpretation of a shortage or surplus as too few or too many workers. In the diagram, $\bar{E} - E^o$ is the shortage associated with $\bar{w} - w^o$. Knowledge of both the employment and wage disequilibria are required in applied welfare economics to evaluate the economic cost of the disequilibria. Second, the disequilibrium analysis can uncover shortages or surpluses resulting from market dynamics that would be misinterpreted as equilibrium situations by the rate of return. The point $(\bar{w}, E^o)$, for example, which is a feasible disequilibrium point, has a shortage of specialized workers at the equilibrium rate of return; alternatively, $(w', \bar{E})$ represents disequilibria in wages but not in numbers. While the particular "random" shocks and dynamic adjustments leading to these outcomes might be peculiar or farfetched, knowledge of dynamic labor market behavior is sufficiently limited that it would be foolhardy to foreclose possibilities, especially in a study of market problems. Third, by concentrating on deviations from market equilibrium, the approach of the diagram highlights the problem of determining equilibrium rates of return when occupations differ in nonpecuniary characteristics—a problem readily ignored in the usual rate of return.

COSTS OF SHORTAGES AND SURPLUSES

The output of most high-level manpower forecast studies is a series of quantitative estimates of expected shortages or surpluses in particular specialties. Such computations offer no clues to the economic cost of the potential disequilibria and thus of sensible levels of corrective policy expenditures. To evaluate the cost of shortages or surpluses and eventually to develop benefit/cost estimates of various policies, it is necessary to go beyond "requirements accounting" and attach monetary values to various market outcomes.

There are two related ways of doing this. In the first, policy makers specify a *loss function*, giving the subjective costs to disequilibria of various types. With such a function and information about policy effects, optimal forecasts and policies can be determined. The second approach places the valuation problem in the context of applied welfare economics, in which the competitive market determination of prices and wages provides the valuation of outcomes. While applied welfare economics is widely used in studies of economic development—including those in the manpower area—it has been ignored in discussions of United States manpower problems for the highly trained. By placing the shortage or surplus issue in this framework, the value of analysis can be greatly enhanced.

The principal tool of applied welfare analysis is the familiar consumer–producer surplus concept, which uses observed demand and supply schedules to calculate the gain or loss due to economic changes. Since demand and supply schedules are derived from utility maximization, it is possible to regard the surplus measures as indicators of welfare changes. Even where market wages and prices are *not* regarded as proper measures of social valuation, the general approach is still valid, requiring the replacement of market demand or supply relations with policymaker loss functions.

Figure A.2 illustrates the application of the applied welfare analysis to the manpower shortage–surplus problem. The shortage $\bar{E} - E^o$ involves the loss of consumer surplus in the triangle determined by points (w_o,E^o), $(\bar{w},E^o)$ and $(\bar{w},\bar{E})$ and by the producer surplus lost in triangle $(\bar{w},E^o)$, (w',E^o) and $(\bar{w},\bar{E})$. The sum of these triangles measures the social loss due to the disequilibrium shortage of manpower. For a fixed $\bar{E} - E^o$, the loss is greater the more inelastic the demand for workers in the specialty (i.e., the greater the "need") and the more inelastic the supply (i.e., the greater the problem of finding work elsewhere). Analogously the darkened area bounded by (w_o,E'), (w',E') and $(\bar{w},\bar{E})$ represents the economic loss associated with the surplus $E' - \bar{E}$. In this case, the loss is greater the less elastic are the two schedules.

Since markets tend to correct disequilibria over time, the static picture of the cost of shortages and surpluses must be expanded to several time periods in actual application. A simple example may be of value: consider

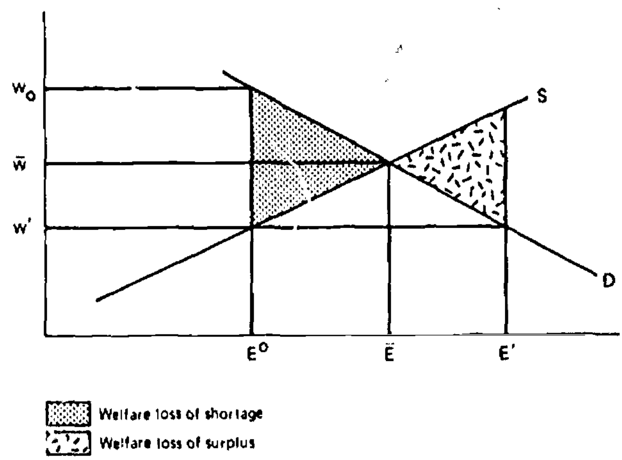


FIGURE A.2 Evaluating manpower shortages and surpluses in applied welfare economics.

a Ph.D. market which is expected to face a shortage of specialists for five years, with the number in short supply declining annually by 1,000 men from 5,000 to zero over the period. If the deviation between equilibrium and actual wage is proportionate to the shortage (say = \$500 per 1,000 men) the cost of the disequilibria can be calculated, ignoring discounting, by summing "welfare triangles" of the form shown in Figure A.2 over the five years. The formulae for the area of the triangle is just $1/2(\Delta w)(\Delta E)$, when Δw is the deviation of wages from equilibria and ΔE, the deviation of numbers. The result is $1/2\ (\$500 \times 5)\ (5{,}000) + 1/2\ (500 \times 4)\ (4{,}000) + \ldots$, which equals \$18,750,000. By providing a measure of the dollar cost of the shortage—an estimate of the extra resources available to the economy in equilibrium—the welfare analysis transforms the discussion from one of dubious economic merit, comparing single point estimates of supply-demand divergencies, to one amenable to price theory and benefit/cost analyses.

Appendix B
A Note on Models of the Market Adjustment Process

In Chapter 3 of the report, six forms of response to a changing doctorate labor market were discussed:

1. students career decisions, which determine the supply of new entrants;
2. experienced personnel decisions, which affect the supply forthcoming from the existing stock of specialized manpower;
3. employer decisions, which determine demands;
4. salary determination, a potential market clearing adjustment;
5. university responses, which may affect the supply of new Ph.D.'s; and
6. governmental responses, which can affect supply via subsidy policies as well as market demands.

This note discusses briefly the basic model which can be used to link these factors and provide econometric estimates of the relevant parameters.

The model structure in which the analysis and estimate-of-response parameters and forecasts are imbedded is necessarily critical to the success of the process. Long-term forecasting (5–10 years) is particularly sensitive to the feedback relations among forecasted variables, as decisions about variables at the end of the period will depend on previous conditions which must be forecast themselves.

Due to the long training lag in the doctorate market resulting from the "technology of production," the structure of feedback relations and consequently the appropriate market model fall into a relatively simple recursive pattern—in simplest form, the classic cobweb system described in this paper, with an approximate 5-year lag in supply response. While not all of the relevant decisions and variables fit into a pure cobweb lag system, the basic recursive structure of the market provides an overall framework about which to organize forecast analysis. Estimation of the important behavioral parameters is especially simple in a recursive model for, as long as disturbances among equations are uncorrelated, ordinary least-squares regression procedures are appropriate. It is also especially easy to simulate market outcomes, given various policy or other exogenous developments, in a recursive framework.

Within the overall model structure, a variety of simplifications or complications can be assayed, depending on the goals of the analysis, availability of data, and the like. Since recursivity is especially significant in the market for new Ph.D.'s due to the timing lag, and simultaneity more likely in the experienced Ph.D. market, one possible simplification is to decouple the model to focus on new Ph.D.'s and starting salaries (which may be viewed as indicators of cohort lifetime income possibilities). The resultant structure is extremely simple to estimate and use: Salaries in a given year are taken as a function of new Ph.D.'s (a predetermined variable), and various exogenous demand factors; industrial output in Ph.D.-using industries, college enrollments, R&D spending, and so on. Initial enrollments in Ph.D. programs are then dependent on the predetermined salaries relative to those in alternatives and on fellowships (also exogenous to this simple model). Finally, the system is closed with an equation relating Ph.D. graduates in the future to enrollments, either as a simple proportionate function or as a function of other economic factors—such as changes in market opportunities that cause "dropouts," for instance. The model thus collapses into three equations: one for salary determination, one for the initial enrollment decision, and one for the doctorate graduation decision. These can be represented algebraically as follows:

Salary determination,

$$\text{SAL} = -a_1\text{PHD} + a_2\text{RD} + a_3\text{OUT} + u_1; \quad (1)$$

Initial enrollment,

$$\text{ENR} = b_1\text{SAL} - b_2\text{ASAL} + b_3\text{FEL} + b_4\text{BA} + u_2; \text{ and} \quad (2)$$

Doctorate degrees,

$$\text{PHD} = c_1\text{ENR} + u_3; \quad (3)$$

where SAL = salary of Ph.D.'s

PHD = number of graduates,

RD = research and development spending,

OUT = output of Ph.D.-intensive industries,

ENR = first-year enrollees,

ASAL = salary of alternative careers,

BA = number of bachelor graduates, and

FEL = fellowship support.

In Eqs. (1)–(3) decisions are assumed, for simplicity, to depend solely on current market conditions, and all Ph.D.'s are postulated to take four years to complete their studies. More complex versions of supply response, Eq. (2) would take account of the complexities of forming salary expectations—by assuming, for example, that decisions depend on a weighted average of past salaries or that expected salaries are determined by the same factors as actual salaries or by bringing *nonsalary* information, such as unemployment rates and vacancies, to bear on the problem. Equation (3) could also be expanded, possibly by linking completion to market conditions during the period of study, while Eq. (1) might be made more elaborate with the addition of various terms reflecting prices of substitute and complementary resources.

These modifications aside, the stripped down model of Eqs. (1)–(3) exhibits the critical recursive nature of the Ph.D. market, with Ph.D.'s in year t influencing salaries in t, enrollments in t, and Ph.D.'s four years later. An important feature of the model, which suggests a nonsalary interpretation of supply responses, is found by solving Eqs. (1)–(3) for Ph.D.'s as a recursive function of past Ph.D.'s, yielding the *cobweb supply equation*:

$$\text{PHD}(4) = c_1[-b_1a_1\text{PHD} + b_1a_2\text{RD} + b_1c_3\text{OUT} - b_2\text{ASAL} + b_3\text{FEL} + b_4\text{BA}] + u_4. \qquad (4)$$

Equation (4) is the reduced form of the system, linking Ph.D.'s to past market conditions as determined by the number seeking work, demand, salaries in alternative occupations, fellowships and the size of the prospective Ph.D. population, but not to salaries of Ph.D.'s. Alternatively, Eq. (4) can be interpreted as a nonsalary job opportunities supply equation, showing the response of students to opportunities that depend on the market factors just enumerated. In the absence of good salary data, or in situations in which supply is more properly taken as dependent on opportunities, Eq. (4) rather than Eq. (2) is the more tractable forecast equation.

In the total market, where some simultaneity in salary and employment determination arises, the recursive structure of the system must be at least partially modified, though sluggish responses of salaries to market conditions may substantially reduce simultaneity problems—at least for some variables. Larger or smaller models, dealing with particular block-recursive sectors of the overall market, can be estimated. The basic structure is applicable to all Ph.D.'s and to individual fields, with consistency requirements and more complicated estimating techniques, by taking account of cross-field equation information and constraints, possible when several specialties are examined simultaneously. Indeed, given the substantial diversity in the job market for Ph.D.'s in year past, such *decomposition by field* would appear to be a necessary prerequisite for useful and realistic model-building.

Analysis of specific fields undergoing similar or dissimilar experiences (as in past increases in the relative demand for doctorate mathematicians and engineers compared to decreases for chemists and geologists) is likely to enhance the policy-value of investigations as well as increase understanding of various response mechanisms. It is particularly important to distinguish between specialties whose demand is almost exclusively academic and those with significant industrial opportunities and many specialties, such as the social, physical, and biological sciences, whose demand depends on different government programs and decisions. Such decompositions can be handled by building separate models for various fields, with second stage linking thereafter.

Finally, in view of the likely levelling off in the rate of expansion of academic and related Ph.D.-intensive activities in the future, it is important to investigate extensively the replacement demand segment of the overall Ph.D. market. Replacement demands and the retirement and mobility decision of experienced Ph.D.'s will be far more important determinants of market conditions than in the 1960's, requiring explanation of these currently neglected areas of market response.

While development of a formal econometric forecast model along the lines suggested here will not solve the problem of minimizing the economic costs of shortages and surpluses of highly-educated manpower, it should yield improved forecasts and more knowledgeable policy decisions—just as have national economic models, like that of the Wharton school. In addition, such model-building provides an appropriate framework for gathering and organizing data on Ph.D. and related manpower markets, highlighting information needs.

As a tool for analysis, used in conjunction with *a priori* knowledge of market responses and adjustment processes, such a model will be more valuable in policy development than the current requirements calculations.

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1. *Graduate Education: Purposes, Problems and Potential,* November 1972, 18 pp.
2. *Doctorate Manpower Forecasts and Policy,* November 1973, 22 pp.
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TR 2. *Forecasting the Ph.D. Labor Market: Pitfalls for Policy,* by Richard Freeman and David W. Breneman, April 1974, 50 pp.

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