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ABSTRACT

The working paper concentrates on the general objective, "How do the agency (Federal) and its policy makers utilize the information conveyed by scientific manpower forecasts?" Section 1 examines reasons for the growth in demand for these forecasts: (1) benefit cost analysis of public projects with long payout periods must rely on forecasts; (2) the evaluation of a government agency is typically accomplished by compiling massive quantities of data; (3) information differs from other economic goods because the seller of information is unable to appropriate all of the returns to his information. In section 2 the methodology which characterizes the available scientific manpower forecasts is critically examined, concentrating on three kinds of forecasts: (1) the academic requirements for new doctorates, (2) the manpower requirements for specific occupations, and (3) the supplies of college educated workers. Finally in section 3 attention is directed to the labor market for Ph.D.'s reviewed with reference to the National Science Foundation projections of doctorate supplies and requirements in 1980. The author outlines a model describing the investment on the part of students in obtaining a doctorate degree and the demand on the part of universities for graduate students, in terms of a market equilibrium. (BP)

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Scientific Manpower Forecasts from the Viewpoint of a Dismal Scientist

by

Walter Y. Oi*
(University of Rochester and Princeton University)

*The author is a Professor of Applied Economics in the Graduate School of Management at the University of Rochester and is currently a Visiting Senior Research Economist in the Industrial Relations Section at Princeton University. He is indebted to the Industrial Relations Section for supplying him with the excellent library and clerical assistance provided by Miss Helen Fairbands and Mrs. Irene Rowe.

Scientific Manpower Forecasts from the Viewpoint
of a Dismal Scientist

Societies have always sought information about the future, and in earlier times, the task of foretelling future events was left to journalists, gypsies, and clergymen. Advances in the physical sciences greatly increased the accuracy of forecasts with respect to physical phenomena such as the movements of the stars and tides, and the location of oil deposits. More recently, the social sciences have achieved modest successes in forecasting the outcomes of elections, patterns of consumer expenditures, etc. Over the course of the last two or three decades, the forecasting industry has been one of our growth industries. Important public and private decisions about the allocation of our scarce resources have been based on forecasts. In this paper, I have three objectives.

First, I try to explain the reasons for the growth in the demand for scientific manpower forecasts. Second, the methodology which characterizes the available scientific manpower forecasts in critically examined in Part II. Finally, in Part III, attention is directed to the market for Ph.D.'s. Past and future levels of doctorate employment and earnings, as well as the production rate of new doctorates, are jointly determined by the market forces of demand and supply. The public funds that have been allocated to higher education in the past and that are likely to be in the future, are clearly important determinants of both the demand and supply of doctoral scientists. The extrapolation of recent trends of enrollment rates, of ratios of non-academic doctorates to R and D spending, etc., presupposes a very rigid structure of demand and supply that is incapable of explaining the historical data for the same variables. It is placing the cart before the horse. The formulation of rational policies toward higher education must begin with an understanding of the labor market for highly trained manpower, and the extrapolation of trends, however sophisticated, simply does not provide us with the necessary empirical information about the structure and functioning of these labor markets.

I

The Public Demand for Scientific Manpower Forecasts

Uncertainty is an unavoidable, and for many, a highly undesirable reality. Individuals and firms allocate part of their resources to protect themselves against the contingent costs of certain risks.[1/] In addition, the private sector is prepared to pay for information about future uncertain states of the world. A complex structure of institutions has indeed evolved to provide such information. Firms like Value-Line, totally ignoring the random walk hypothesis, purport to be able to predict the stock market. Corporations hire economists and statisticians to forecast sales and market conditions. Although it is less obvious and informal, when students and consumers demand the services of psychologists, clergymen, vocational and educational counselors, they are to some extent, demanding information about future uncertain states of the world. No census classification exists, but there is clearly a "forecasting" industry whose product is forecasts, information about future uncertain states.

Whatever is demanded by the private sector will almost surely be demanded by the public sector, and forecasts are no exception. Scientific manpower forecasts (SMF) constitute only part of the forecasts demanded by the public sector. At least three reasons can be offered to explain this public demand. First, benefit-cost analyses of public projects with long payout periods must rely on forecasts.[2/] The production of highly trained scientific manpower surely involves an investment whose payout period extends over the lifetime of the trained scientist, but this does not explain why forecasts of the returns ought to be made by the government. Second, the evaluation of a government agency is typically accomplished by compiling massive quantities of data because the performance of an agency is not subjected to the same market tests of profitability and survival which apply to the private sector. The availability of large amounts of data greatly reduces the cost of developing forecasts, and when the "price" of a forecast is lowered, more of them will be demanded. Third, information differs from other economic goods because the seller of information (especially about the future) is unable to appropriate <u>all</u> of the returns to his information. Arrow (1969) has argued that the marginal cost of distributing information which has already been produced, is zero, and hence, optimality calls for making such information freely available to all. If the production, sale, and distribution of information were left to the free market, the inability to appropriate all of the returns might easily result in an equilibrium in which "too few" resources were being allocated to the forecasting industry. In the light of this argument, it is not surprising to find that the collection and distribution of many kinds of information, including forecasts, have fallen into the domain of the public sector.

More specific rationalizations have been proposed to justify the public demand for SMF's. Six possible justifications were considered and discussed by Freeman and Breneman; these are paraphrased below:3/

1. Forecasts are needed as a part of a manpower planning system to balance supplies and demands because individual decisions do not reflect economic reality.
2. Forecasts provide important information to guidance counselors enabling them to aid students in career planning.
3. Forecasts can serve as an "early warning system" directing attention to the unforeseen consequences of current market responses and developments.
4. Forecasts are needed to advise educators on the number of slots to be offered in college courses and thus determine the supply of new specialists.
5. Forecasts are needed to evaluate the potential effect of large scale governmental programs on the market.
6. Forecasts are a useful device for organizing and analyzing information about market phenomena that are taken as given by individual decision makers.

Freeman and Breneman conclude that in the setting of a free labor market, only three of these reasons, [3, 5, and 6 above], are valid ones justifying the public demand for SMF's.

An articulation of these reasons tells us something about the objective functions of the public agencies that demand these forecasts. Reasons 1 and 4 suggest that private sources will not provide reliable information about future employment opportunities and student demands for college courses.4/ Public agencies must thus assume the responsibility of supplying the requisite (and hopefully accurate) information. Reasons 1 and 3 tacitly assume that in the absence of publicly supplied manpower forecasts and policies, labor markets for trained scientists will be inherently unstable with recurring cycles of manpower shortages and surpluses.

Freeman and Breneman reject the thesis that imperfect student information could generate these cycles, but later in their essay, they strongly support the proposition of inherent market instability. Implicit in these reasons is the theme that public agencies must assume the responsibility of stabilizing the employment and incomes of scientists via their controls over the production and employment of scientists. Finally, reasons 5 and 6 argue that there is a positive value that can be realized from sound economic analyses on the functioning of labor markets, and on this score, I am in complete agreement with Freeman and Breneman.

Whatever the reason, we have observed a substantial growth in the demand for scientific manpower forecasts. The prior availability of data which lowers the price of a forecast is surely responsible for part of this increased demand. If the Bureau of the Census and the Dept. of Labor had not already compiled detailed statistics on employment by industry and occupation, it is unlikely that a public agency like NSF would have demanded more projections of manpower requirements for specific occupations. What is less clear to an external observer like myself, is, "How does the agency and its policy-makers utilize the information conveyed by these manpower forecasts?"

II

The Market Response to the Public Demand

An individual or firm that demands a new good or service can either purchase it from an outside supplier or produce it himself thereby becoming a vertically integrated firm. In the case of SMF's, the public agency buyers have done both. The Bureau of Labor Statistics (BLS) initially began by employing its own staff of analysts who produced the first BLS manpower projections. Later BLS collaborated with NSF thus becoming both a supplier as well as a demander of SMF's. Other agencies like NSF, various national commissions and task forces have typically turned to what I have called the forecasting industry which, in these instances, usually consisted of non-profit research organizations and academic consultants. None of the principal investigators who produced these manpower forecasts in response to the public demands, possessed the audacity, chutzpah, or reliance on a competitive market for their services that was apparently exhibited by Prof. Niblo.[5/]

> "Six (professional clairvoyants) advertised in the San Francisco Chronicle, the day before the 1906 earthquake, and of these, the boldest was a Prof. Niblo whose academic affiliation was not given. His generous one dollar offer concluded with:
>
> > '411A Ellis Street, permanently located at his own home'
>
> In the issue of the Chronicle for May 24, 1906, the first available after the earthquake, he was the only member of his craft to advertise:
>
> > 'Prof. Niblo, clairvoyant has warned the public of San Francisco for years of the earthquake of 1906. Permanently located at 1220 Broadway'."

The forecasts that have been produced are quite heterogeneous, but they do share one common attribute that has been perceptively described by Hugh Folk as follows:

> "Despite attempts to shield forecasts from criticism by labelling them 'projections', they are used as forecasts, therefore must be treated as such. .... Policy-makers must be continually cautioned on the appropriate use of these numbers, but one might as well put a loaded pistol in the hands of a child and caution him that it is not a toy, as place a conditional projection in the hands of a decision-maker and warn him that it is not a forecast. 'Toys' are what children play with, and they play with what they have. 'Forecasts' are what policy-makers use to foretell the future, and they use anything that comes to hand."
>
> [Folk (1970) p. 240]

Many manpower forecasts[6/] have been produced in the last thirty years, and these have presumably influenced public policy and individual decisions. The usefulness of these forecasts as guides to policy-makers has been questioned by among others, Folk (1970), Ahamad and Blaug (1973), and Freeman and Breneman (1973). There is a substantial literature which critically discusses the methodology and accuracy of previous manpower forecasts. I shall not try to summarize that literature but propose instead to direct attention to two related issues:

1. What information do these forecasts convey to policy-makers and other users?
2. How do policy-makers and other users utilize this information in their decision processes?

In this Part of the paper, I try to determine the information content of three kinds of forecasts: (1) the academic requirements for new doctorates, (2) the manpower requirements for specific occupations, and (3) the supplies of college-educated workers.

2.1 The Academic Requirements for New Doctorates

The employment outlook in higher education for the decade of the 1980's is bleak. Anyone who had thought about the implications of the historical data on U.S. birth rates should have realized that the population of college-age youths will decline sharply in the 1980's.[7/] It seems, however, that the gravity of the problem was not fully appreciated by policy-makers until Allan Cartter dramatically illustrated the possible numerical magnitudes of the imbalances between projected requirements and supplies. More recently, Balderston and Radner (1971) developed a slightly more complicated model which Wolfle and Kidd (1971) described as "a test of the sensitivity of

Cartter's projections to some of the underlying assumptions".[8] The Balderston-Radner (BR) model is, however, simply an exercise in simulation which translates alternative data inputs into numerical descriptions of the time path of a dependent variable (new doctorate requirements in academia). It is not a test in the scientific sense of that term. The BR projections convey little additional information to the policy-maker other than what he could have inferred for himself from the underlying projections of college student enrollments. This conclusion becomes apparent when one writes out the reduced-form equation implied by the BR model.

BR begin by disaggregating higher education into six sectors according to control (public vs. private) and type of institution (university, four, and two year colleges). The model specifies a system of four structural equations for each sector which can be solved for a reduced-form equation in which the requirement for new doctorates in year t by schools in the j-th sector, $D_j(t)$ is a function of five exogenous variables: P_j = the proportion of new faculty appointments with doctorate degrees, R_j = the student/faculty ratio, k_j = the fraction of all students enrolling in the j-th sector, $S(t)$ = projected student enrollment in all six sectors, and $\sigma = 1-\delta$ = the continuation rate of incumbent faculty members (i.e. the fraction of last year's faculty who do not retire or withdraw).[9]

(2.1) $$D_j(t) = \left[\frac{P_j(t)k_j(t)}{R_j(t)}\right]S(t) - \sigma\left[\frac{P_j(t)k_j(t-1)}{R_j(t-1)}\right]S(t-1)$$

By summing over the six sectors, the academic requirements for new doctorates in all six sectors of higher education, $D(t)$, is described by a first-order difference equation.

(2.2a) $D(t) = W(t)S(t) - \sigma V(t-1)S(t-1),$ $[t = 0,1,2,\ldots 20]$

where t = 0 corresponds to the starting point of the projections, 1970. The parameter $W(t)$ can be interpreted as the marginal doctorate/student ratio for the entire academic sector, while $V(t-1)$ is akin to a LesPeyres index being equal to the marginal doctorate/student ratio in the preceding year multiplied by the assumed increment in the doctorate share of new hires. More precisely,

$$(2.2b) \qquad W(t) = \sum_{j=1}^{6}\left[\frac{P_j(t)k_j(t)}{R_j(t)}\right]$$

$$(2.2c) \qquad V_j(t-1) = \sum_{j=1}^{6}\left[\frac{P_j(t)k_j(t-1)}{R_j(t-1)}\right] \simeq \left[\frac{P(t)}{P(t-1)}\right]W(t-1)$$

Finally, $\sigma = 1-\delta$ is the survival rate of incumbent faculty which is assumed to be equal to .98 over the entire projection period. The parameters (P_j, R_j, k_j) were initially equated to their observed values in 1967, while the time path of aggregate student enrollment, $S(t)$ was taken from two earlier projections, one by Cartter and the other by G. Haggstrom. BR then invoked judgemental assumptions about the time paths of the parameters to generate six different projections of new doctorate requirements.

We can get a simpler picture of the information content of the BR projections by adopting the following notation:

$$W(t) = W(t-1) + dW = W + dW, \qquad S(t) = S(t-1) + dS = S + dS$$

$$V(t-1) = \left[1 + \left(\frac{dP}{P}\right)\right]W$$

Upon substitution into (2.2a), we get,

(2.3a) $D(t) = (W+dW)(S+dS) - \sigma[1+(\frac{dP}{P})]WS.$

Recalling that $\sigma = 1-\delta$ and ignoring the second-order term in dWdS, the academic requirements for new doctorates in year t can be written,

(2.3b) $D(t) = W(t-1)S(t-1)[\delta + (\frac{dS}{S}) - (\frac{dR}{R}) + \delta(\frac{dP}{P})].$

where we make use of the identity, $W = P/R$ so that,

(2.3c) $\frac{dW}{W} = \frac{dP}{P} - \frac{dR}{R}$.

Thus, in the BR model, the academic requirements, D(t), can be decomposed into a scale parameter, $WS = W(t-1)S(t-1)$, times the bracketed term describing the relative time rates of change in student enrollment, (dS/S), student/faculty ratio (dR/R), and the doctorate share of new appointments (dP/P).

In their "no change" projections, BR assumed that the doctorate share of new appointments P_m and student/faculty ratios R_j would remain unchanged at their 1967 values. Using their judgements (presumably supported by a perusal of some time series data), they assumed that the public four and two year colleges would increase their shares of total student enrollments over the projection period, 1970-90. The parameter values for all six sectors applicable to the "no change" projections can be found in Table 2.1 by looking at the entries for 1970.

In the "no change" projections, the marginal doctorate/student ratio for public universities is $X_1 = P_1/R_1 = .0326$ meaning a student to new doctorate ratio of $1/X_1 = 30.6$; the corresponding parameters for two year public colleges were $X_5 = .0027$ and $1/X_5 = 367$ students per doctorate hired. This ratio for all six sectors, $W(t)$, declines linearly over the projection period because by assumption, the two public sectors that are assumed to increase their shares of aggregate student enrollment had marginal doctorate/student ratios below the mean ratio.[10/] However, the secular fall in $W(t)$ is slight, and for all intents, the projected requirements in the "no change" case can be expressed as follows:

$$(2.4) \qquad D(t) = W^0 S(t-1)[\delta + (\frac{dS}{S})]$$

where $W^0 = .0225$ is the marginal doctorate/student ratio in 1970. It is evident from (2.4) that the sign of $D(t)$ is entirely determined by projected student enrollments $S(t)$ which is exogenous in the BR model. If projected enrollment declines by more than the assumed attrition rate of $\delta = .02$, the new doctorate requirement, $D(\cdot)$ will be negative irrespective of the value assigned to W^0. A larger value for W^0 [which could have been obtained by assuming either a higher doctorate share of new hires P or a lower student/faculty ratio R] simply magnifies the temporal fluctuations in $D(t)$ and expands the accumulated sum of new doctorate demands. The BR "no change" projection reveals a negative requirement, $D(t) < 0$, in 1984 when the projected student enrollment falls by more than 2 percent.

For each projection of student enrollments, BR generated two additional projections which they labeled "intermediate" and 'adequate finance". The authors arbitrarily assumed that the student/faculty ratios R_j would fall, and the doctorate shares of new appointments P_j would climb according to linear trend equations which are shown below. The numerical equations on the right pertain to the first sector, public universities; the parameters for the remaining sectors are given in Table 2.1.[11/]

(2.5a)	$P_j(t) = P_j + H_j t$	$P_1(t) = .543 + .01785t.$
(2.5b)	$R_j(t) = R_j - G_j t$	$R_1(t) = 16.64 - .132t$
(2.5c)	$k_j(t) = k_j \pm f_j t$	$k_1(t) = .242 - .0017t\ .$

where $t = 0,1,\ldots 20$. BR arbitrarily assume that over the twenty year period, 1970-90, the student to faculty ratio R (which is a proxy for class size) will decline from 16.64 to 15.00 for public universities and that the proportion of new appointments with doctorate degrees, P_j, will climb from 54.3 percent to 90 percent. The two reinforce one another so that the marginal doctorate/student ratio W(t) rises at an increasing rate. For public universities, the ratio climbs from .0326 to .0643, and for two year public colleges, from .0027 to .0158. In the "adequate finance" projections, an exact functional form for W(t) involves a ratio of two polynomials in t, and this non-linearity suggests that in this case, there may be a need for the simulations. However, equation (2.3b) gives us nearly all of the information conveyed by the "adequate finance" projections.

The relative rate of change in projected student enrollment, (dS/S), is exogenous in the BR model and comes from another study that presumably was available to the policy-maker. One could insert his own assumption about the relative change in the student/faculty ratio, (dR/R). The driving force in the "adequate finance" projections is the time path of the marginal doctorate/student ratio W(t) which determines the size of the scale parameter,

$WS = W(t - 1)S(t - 1)$, in (2.3b). By using the approximation of (2.3c) based on the identity, $W = P/R$, [which ignores the aggregation of the six sectors], a policy-maker can substitute his own judgements about the doctorate share of new appointments P and the student/faculty ratio; the requisite calculations could be done on the ba .. of an envelope.

An excerpt from the BR simulations of the academic requirements for new doctorates is presented in Table 2.2A. A decomposition of the projected requirements for selected years, using the approximation of (2.3b), is shown in Table 2.2B. It will be noticed that in this decomposition for the "adequate finance" projections, the growth in the scale parameter, WS, dominates the projection. Balderston and Radner pointed out that their projections for $D(t)$ were "more sensitive" to assumptions about P than they were to assumptions about R. Their conclusion should have been obvious from (2.3c) which divides the growth in the marginal doctorate/student ratio W between changes in P and R. Reference to Table 2.1 reveals that in their simulations for the "adequate finance" case, the assumed values for the doctorate shares of new appointments P_j nearly double over the projection period, while student/faculty ratios R_j fall by only around 15 percent.

A systematic critique of the Balderston-Radner model (and those like it) is deferred to Part III. Several remarks can, however, be made at this point:

1. An examination of the reduced-form equation (2.2a) reveals that the projected academic requirement in year t, $D(t)$, is determined by three data inputs: (a) the projected student enrollment $S(t)$, (b) the marginal

doctorate/student ratio W(t) which in turn depends on the assumptions about the doctorate share of new appointments P and the student/faculty ratio R, and (c) the attrition rate of incumbent faculty, $\delta = 1-\sigma$.

2. The projected student enrollment, S(t), in all sectors is exogenous and is assumed to be unaffected by the assumed demands for new faculty. The BR model implicitly assumes that future levels of student enrollment in higher education will be invariant to the way in which students are distributed to the six sectors or to the quality of higher education as measured by student/faculty ratios or the proportion of college faculties who hold doctorate degrees.[12/] Further, optimistic or pessimistic projections of the demands for new doctorates presumably have no effect on graduate student enrollments.

3. A variation of 1 percentage point in the assumed attrition rate of δ = 2 percent, changes the projected requirement for new doctorates by roughly 3,000. The NSF model, [NSF 71-20] derived the attrition rate δ from the age structure of incumbent faculty; the deviations from the assumed constant rate of $\delta = .02$ were small over the 1970-90 period.

4. Although the disaggregation into six sectors unduly complicates the arithmetic of the BR model,[13/] the reduced-form equation reveals that the variables driving the projected requirements are (a) projected student enrollments, S(t) which BR take as given, and (b) the marginal doctorate/ student ratio, W(t) which is judgementally determined.

5. The so-called sensitivity of the BR projections to the underlying assumptions could have been easily calculated by using the approximation to

the reduced-form equation given by (2.3b). The policy-maker could have substituted his own assumptions about the marginal doctorate/student ratio W, the rate of change in student enrollments (dS/S), and the change in student/faculty ratios (dR/R).

6. The BR model is essentially a variant of the "fixed coefficients" approach to manpower forecasting, and all of the criticisms that have been lodged against that methodology are equally applicable here.

7. Finally and most serious, no attempt is made in the study to place the projected academic requirements for new doctorates into an equilibrium model for the higher education sector as a whole. The "adequate finance" projections presuppose that funds from somewhere, will become available to finance lower class sizes and larger fractions of Ph.D.'s on college faculties. If these funds are raised through higher tuition, is the student enrollment projection plausible? What is the magnitude of the "adequate finance" needed to attain the assumed time tracks for P_j and R_j? What are the implications of nearly doubling the fraction of new appointments with doctorate degrees with respect to salaries of doctorate and non-doctorate faculty members and with respect to the conformance of higher education to the affirmative action policies of H.E.W.? None of these issues is addressed, in the BR study, and the study must, in my opinion, be regarded as an exercise in the simulation of a wholly hypothetical world.

2.2 BLS Projections of Occupational Requirements

Projections of manpower requirements for specific occupations have been developed by the Bureau of Labor Statistics for many years.[14/] These projections are intended to represent estimates of future "demands" or requirements for particular occupations without regard to the availability of supplies to meet those "demands". When these projected requirements are juxtaposed to supply projections, they are supposed to indicate possible future in-balances in specific labor markets. Since at least one other paper at this Conference deals with these projections, the discussion here is limited to a brief review of the BLS methodology.

The methodology essentially involves three steps. First, projections of employment by industry, $\hat{E}_{i.}$, are developed for the projection year. Second, projections of occupational ratios, $\hat{r}_{ij}$, [the proportion of total employment in industry i that falls into occupation j] are generated for the projection year. Third, the two projections are multiplied and summed over industries to arrive at the manpower requirement for the j-th occupation in the projection year.

$$(2.6) \qquad \hat{E}_{.j} = \sum_i \hat{E}_{i.} \hat{r}_{ij} \ .$$

The BLS methods and their underlying assumptions for estimating $\hat{E}_{i.}$ and $\hat{r}_{ij}$ are more fully discussed in Appendix A to this paper. The lack of adequate time series data on employment by detailed occupations largely dominates the BLS methodology. If such data were available, one could avoid the two step procedure of projecting both $\hat{E}_{i.}$ and $\hat{r}_{ij}$.[15/]

What can we learn from these BLS projections? The equations that are used to project industry employment cannot, by any stretch of the imagination, be interpreted as labor demand equations. They are naive reduced-form equations that totally ignore the fact that observed employment in prior years was jointly determined by the intersection of market demand and supply functions. When this fact is acknowledged, industry employment projections cannot be interpreted as manpower requirements or "demands"; they represent BLS estimates of what they think will be the equilibrium industry employments in the projection year.

That occupational ratios are likely to vary over time, is acknowledged in the following excerpt:

> "The relative importance of particular occupations changes over time, however, in response to technical advancement and changes in the scale of production, product mix, and organization of industries among other factors." [BLS Bulletin 1606, Vol. IV, p. 9]

Of the reasons ennumerated here, the substitution of factors in response to changing factor prices is conspicuous by its absence unless it is included in the "other factors". Hollister (1966), Folk (1970), and others have roundly criticized the BLS for neglecting the substitutability of factors in production. But despite these criticisms, the BLS has never attempted to rationalize their projections of occupational ratios by developing companion projections of occupational wage differentials. In passing, the opportunities for factor substitutions through product substitutions have received little attention in the critical literature. Even if every production function involved fixed technical coefficients, a rise in the price of a factor will lead to a decrease in the demand for that factor because consumers will reduce their demands for products using this factor.[16/] A defender of the BLS methodology might contend that there is, in principle, some structure of occupational wage rates and product prices such that the projected occupational ratios (and industry employments) would have been optimal, cost-minimizing combinations. This is surely correct, but what are these shadow wage rates and product prices?

Several researchers have assessed the accuracy of the BLS projections by retrospectively comparing the projected requirement to the realized employment in each occupation for the projection year. Two conclusions can be drawn from these retrospective comparisons. First, the magnitudes of the relative forecast errors are quite large, especially for detailed occupational specialties. When detailed occupations are aggregated into larger groups, [the upper limit being all occupations or economy-wide employment], the size of the forecast errors typically gets smaller and can sometimes be traced to discrepancies between assumed and actual values for some of the exogenous variables such as real GNP, the size of the Armed Forces, etc. Second, if the relative forecast errors are decomposed into errors in industry employment projections vs. errors in occupational ratios, the latter accounts for the largest part of the forecast errors.[17/] In the light of these findings, I agree with earlier writers that the BLS projections of occupational requirements do not provide policy-makers and other users with accurate predictions of future labor demands when judged by conventional criteria for good statistical predictions.

The impossibility of the BLS methodology is articulated in the concluding remarks by Gannicott and Blaug (1973):

> "It is not enough to assume, as seems to be implied by the latest works from the BLS, that forecasting errors will be reduced if only the data and statistics can be refined. What is needed is what the BLS has not carried out in the ten years we have reviewed, a fundamental assessment of the relevance and objectives of the manpower requirements approach itself." [p. 76]

The BLS methodology still does not adequately cope with the obvious facts that the occupational employment patterns which were observed in the past and which are likely to prevail in the future are jointly determined by the market forces of demand and supply. If the short run supply for a specific occupation is extremely elastic, [meaning workers can easily shift from this occupation to another and vice versa], there is little to be gained by projecting the manpower requirements for that occupation. Until the BLS methodology embraces a theoretically sound model of labor markets, their projections only convey to us, information about the extrapolation of trends in occupational employment patterns based on the gusstimates of the BLS analysts.

2.3 <u>The Supply of College Graduates</u>

The basic methodology for projecting the future supply of college graduates [or for that matter, supplies of persons with various levels of educational attainment] has apparently changed little in spite of the criticisms voiced by Alice Rivlin (1961) over a decade ago. The methodology can be described in a nutshell as follows: the projected supply in year t is obtained as the product of the Census projection for an age-specific population (say 18 or 22 year-olds) times a trend projection for the appropriate continuation rate (or rates). Since nearly all of the children who will be entering the higher education sector during the next eighteen years are already born, the Census projections of the pertinent age-specific populations will be extremely accurate. The issues thus come down to an evaluation of the methods that have been used to devise the appropriate continuation rates and to project them into the future.

Various aspects of the current supply projection methodology could be critically analyzed, but in this paper, I shall limit the discussion to three topics: (a) extrapolations via weighted trend lines, (b) compounding of several linear trends, and (c) the economic determinants of continuation rates.

(a) Extrapolations via weighted trend lines: This technique which has been employed in the NSF supply projections can best be analyzed with the aid of an illustrative example. The projected supply of high school graduates in year p, $\hat{Y}_p$, is usually obtained by multiplying the Census projection of an age-specific age class X_p, (usually 17 year-olds, but sometimes a moving average of 17 and 18 year-olds) and the projected proportion $\hat{H}_p$ of the future age class that is predicted to complete high school.

(2.7a) $$\hat{Y}_p = X_p\hat{H}_p .$$

As I argued earlier, X_p is likely to be quite accurate so that attention can be directed to the method used to project $\hat{H}_p$. It is typically assumed that H_t will follow a trend, and in the NSF model, a linear trend.[18/]

(2.7b) $$H_t = \alpha + \beta T_t + e_t$$

where T_t is the trend variable, and e_t is a random error term. If $(\hat{\alpha}, \hat{\beta})$ denote the estimates for the parameters of (2.7b), then $\hat{H}_p = \hat{\alpha} + \hat{\beta}T_p$, and the projected supply of high school graduates $\hat{Y}_p$ is seen to be a non-linear trend extrapolation of the specific age-class X_p.

(2.7c) $$\hat{Y}_p = X_p\hat{H}_p = \hat{\alpha}X_p + \hat{\beta}X_pT_p .$$

The novel feature of the NSF procedure lies in the estimation of (α,β). Ordinary least squares which attaches equal weight to all observations yields one set of parameter estimates $(\hat{\alpha}_0, \hat{\beta}_0)$. The NSF procedure contends, however, that the most recent observations should be given more weight. More precisely, the estimation is based on data only for the last ten years with double weights given to observations for the most recent five years. The parameter estimates $(\hat{\alpha}_1,\hat{\beta}_1)$ in the NSF procedure describe a weighted trend line estimated by generalized least squares, GLS.[19/] No attempt is made to provide either a statistical or theoretical justification for ignoring sample data from the preceding decade or for attaching double weights to the most recent five years of experience. One could, as well, have assigned triple weights to the most recent three years, double weights for the next three years, and unit weights for four years of observations of H_t; let me call this last set of parameter estimates $(\hat{\alpha}_2,\hat{\beta}_2)$.

The historical data on high school graduates as a percentage of the 17 year-old age class, H_t, are presented in Table 2.3 for the period 1948-67. The data for the last ten years, 1958-67, were used to estimate the parameters of a linear trend line, (2.7b), assuming equal weights, double weights for 1963-67, triple weights for 1965-67 and double weights for 1962-64. The results are shown below:

(2.8a) $\hat{Y}_t = \hat{\alpha}_0 + \hat{\beta}_0 T_t = 62.33 + 1.541 T_t$, [equal weights, OLS]

(2.8b) $\hat{Y}_t = \hat{\alpha}_1 + \hat{\beta}_1 T_t = 62.57 + 1.507 T_t$ [double weights, GLS]

(2.8c) $\hat{Y}_t = \hat{\alpha}_2 + \hat{\beta}_2 T_t = 62.67 + 1.475 T_t$ [triple weights, GLS]

The three fitted trend lines were used to predict the percentage of the 17 year age class that would complete high school in 1967-71. The results are tabulated below where the first line gives the actual observed percentage H_t.

Predicted Values of Percentage of High School Graduates $\hat{H}_p$

	1967	1968	1969	1970	1971
Actual, $\hat{H}_t$	76.5	76.7	76.0	75.7	75.9
Projected, H_p					
(2.8a) equal weights	77.73	79.27	80.81	82.25	83.89
(2.8b) double weights	77.64	79.15	80.66	82.16	83.67
(2.8c) triple weights	77.43	78.90	80.38	81.86	83.33

The relative forecast error, $(\hat{H}_p/H_t)$ is less than 1.6 percent in 1967 and is smaller for the weighted regressions (2.8b) and (2.8c). All of the trend lines over-estimate H so that by 1971, there is nearly a 10 percent discrepancy.

I cannot logically explain the reasons for the NSF procedure. It seems to assume that the parameters (α,β) of the linear trend equation (2.7b) are not stable over time. By attaching more weight to the most recent observations, the resulting weighted parameter estimates will presumably give us a better linear approximation to an unknown non-linear trend relationship. If the NSF procedure was intended to capture non-linear trend relationships, the estimation of a weighted linear trend line will unavoidably lead to biased projections.[20/] Finally, there is no reason to suppose that the variance of the error term e_t should be smaller for the more recent observations. In short, the NSF method for projecting future values of $\hat{H}_p$ or any other continuation rate [by extrapolating a weighted <u>linear</u> trend line] has <u>no</u> logical foundation.

(b) <u>Compounding of Several Trend Lines:</u> The methodology for projecting the supply of college graduates differs from that for high school graduates in three respects. First, the projected supply of high school graduates, Y_p, is often assumed to be an exogenous data input. Second, a projection must be developed for the percentage of each high school graduating class who will enroll for the first time in college, ϵ_p. Third, one must estimate the fraction of each freshman class who will complete the four years of college and earn a bachelor's degree, $c_t = 1-\alpha_t$, where α_t is the attrition rate in college. If we let Z_p denote the projected supply of bachelor degrees in year P , we have, 21/

(2.9a) $$Z_p = c_{p-4}\, \epsilon_{p-4}\, Y_{p-4} .$$

where c_{p-4} is the completion rate applicable to the cohort entering in year p-4. Again time series data are used to estimate the parameters of <u>two</u> trend equations.

(2.9b) $$\epsilon_t = a + bT_t + u_t .$$

(2.9c) $$c_t = A + BT_t + v_t .$$

where u_t and v_t are random error terms. The parameters of these trend lines can again be estimated by using the historical series for ϵ_t and $c_t = 1-\alpha_t$.

If the high school completion rate H, the first-time enrollment rate ϵ , and the college completion rate $c=1-\alpha$, are multiplied together, we can compute the percentage of each age class that completes college; this is denoted by β_t .

(2.10) $\beta_t = H_t \epsilon_t (1-\alpha_t)$.

These completion and continuation rates for the period, 1948-67, are presented in Table 2.3.[22/] A few descriptive remarks about these data may be in order. The fraction of each 17 year-old age class completing high school climbed from 54.0 percent in 1948 to 76.7 percent in 1968; since then, H_t has declined slightly. The first-time enrollment rate ϵ_t also exhibited a positive trend rising from 47.7 to 64.0 percent. The percentage of each freshman class who earned bachelor degrees, $1-\alpha_t$, followed a flat U-shaped curve being slightly higher in the early and late years of this twenty year period, 1948-67. Finally, 15.1 percent of all youths who were 17 in 1948 ultimately went on to earn a bachelor degree, and this figure rose to 25.1 percent for those reaching 17 in 1967; see the series for β_t in Table 2.3.

The current methodology fits separate trend lines to each completion and continuation rate. The final supply projection for college graduates Z_p is, however, simply a compounding of these trend lines. Thus, when the three trend lines from (2.7b), (2.9b) and (2.9c) are substituted into (2.10), we get,

$$\beta_t = (\alpha+\beta T_t)(a+bT_t)(A+BT_t) = \psi_0 + \psi_1 T_t + \psi_2 T_t^2 + \psi_3 T_t^3 \ .$$

where $\psi_0 = \alpha aA$, $\psi_1 = [\alpha aB + abA + \beta aA]$, etc. Thus, when the projected supply of high school graduates Y_p is endogenous, [as it is in the NSF model], the projected supply of college graduates Z_p is linked to the population of 17 year-olds four years earlier, via a cubic trend equation. There is no a priori reason to suppose that fitting three separate trend lines and multiplying them together improves the predictive accuracy of a forecast. Indeed, one might do even better by directly fitting a polynomial trend equation to the historical data for β_t, and project bachelor supplies from the size of the 17 year age class as follows:

$$Z_p = \hat{\beta}_{p-4} X_{p-4} \,, \qquad \hat{\beta}_p = \psi_0 + \psi_1 T_p + \psi_2 T_p^2 + \ldots$$

A drawback to this latter approach is that the analyst cannot intuitively interpret the ψ parameters, but he can use his judgement about the plausibility of the parameters of separate trend lines. From the viewpoint of predictive accuracy, one cannot judge in advance, which is the preferred approach.

The methodology for projecting the supplies of advanced degrees, (Masters and Doctorates) is qualitatively similar. In some instances, the supplies of bachelor degrees in specific fields are taken to be exogenous. Some forecasts assume fixed time lags between the baccalaureate and doctorate degrees; I shall comment on this lag in Part III below. The data in Table 2.4 show the number of degrees awarded and the implicit completion rates which assume fixed two and five year lags between bachelor and either Master or Doctorate degrees.[23/] The proportions of each college graduating class who continued on to earn Masters and Doctorate degrees have climbed dramatically. For the classes graduating in the 1960's, nearly 30 percent went on to earn Masters degrees and around 6 percent received doctorate degrees. The naive extrapolations of these trends accounts for earlier projections of 55 to 80 thousand doctorate degrees supplied in 1980. The NSF method which attaches more weight to the most recent data must, by its very nature, generate volatile supply projections; i.e. the forecast of the doctorate supply in 1980 that was developed in 1969, [before the recent levelling off of first year graduate enrollments] will be very different from the projected 1980 supply utilizing the historical data through 1973.

To sum up, a model that projects supplies at all levels of educational attainment, [high school, bacculaureate, masters, etc.] can almost always be reduced to a trend projection of some multiplicative combination of trend lines times the Census projection for the size of age specific populations. Further, the existing models [like NSF 71-20] utilize simple linear trend equations. By appealing to logistic or logarithmic functional forms, I suspect that one could get far better fits to the historical time series.

(c) <u>The Economic Determinants of Completion and Continuation Rates</u>: My principal criticism of the current methodology is that no serious attempts are made to explain the temporal fluctuations in the historical data on completion and continuation rates. The strong upward trend in the percentage of each age class completing high school must surely be due, in part, to the declining opportunity costs of attending high school as more and more of the U.S. population is residing in urban areas, the growth in real family incomes, and the secular rise in teen-age unemployment rates. If we could establish stable empirical relationships between H_t and these variables, it would provide us with a far sounder basis for projecting H_t into the future. The first-time enrollment rate as freshmen ϵ_t, depends on, among other things, the cost of a college education, the impact of military conscription, and again, family incomes.[24/] Although the temporal variations in the college completion rate, $c_t = 1-\alpha_t$, are smaller, they are still substantial. My observations suggest that the completion rate, $1-\alpha$, is systematically related to the size and control of the institution being higher in smaller and private institutions. Further, to the extent that college education represents an investment in human capital, the earnings differential between college and high school graduates should affect both ϵ_t and $1-\alpha_t$.

The naive extrapolations of trends in these rates will yield accurate forecasts of future supplies if and only if the causal variables which generated the historical time paths for these continuation rates just happen to be correlated with the same continuation rates in the future as they were in the past. Such a fortuitious outcome is highly improbable. Instead of devoting more research funds and resources into collecting more reliable and current data to develop better trend equations, it is my considered opinion that far more can be learned by developing sound economic models to identify the causal variables which are responsible for the temporal variations in the pertinent completion and continuation rates.

III

On the Production and Employment of Doctorates

The public sector at both Federal and State levels has clearly assumed the responsibility for promoting the growth of higher education. Increasingly larger shares of general tax revenues have been appropriated to finance the expansion of both public and private colleges and universities. The allocation of these public funds has been uneven, understandably favoring public institutions and to a lesser extent, graduate as opposed to undergraduate study.[25/] Further, the NSF and NDEA fellowship and traineeship programs were expressly intended to expand the supply of one kind of highly trained manpower, namely science doctorates. Expanded support for state universities and the research grants to academia from public agencies and foundations also contributed to the financial aid that was needed to subsidize a growing population of graduate students. As Wolfle and Kidd (1971) pointed out, our decentralized higher education system responded admirably by nearly tripling the annual production of doctorates between 1961 and 1972. The predictions in the late 1950's of a severe shortage of doctorates never came to pass, but predictions and fears, like bad pennies, keep turning up, and the latest vintages foretell of a glut in the market for Ph.D.'s. According to Balderston and Radner, _if_ public policies do not provide the "adequate finance" that is needed to finance an enrichment in the doctorate shares of faculties and reductions in student/faculty ratios, the nation may have to suffer the consequences of a "hole" in the flow to academia of new doctorates in the mid 1980's. Cartter (1971) and others generally agree that we need not worry about unemployed Ph.D.'s, but the danger is what might be called "under-employment". Indeed, Cartter voices the fear that new doctorates in the 1980's will be forced to accept employment in positions well below what they had aspired to as Ph.D. candidates. On this point, I agree with Gannicott and Blaug (1973) who wrote, "... that the concept of an appropriate job for a given level of education is meaningless." [p. 76]. Others, however, disagree with this view. One thing is, however, clear; more public resources are being devoted to refine the projections of doctorate supplies and requirements even though it is unclear how policy-makers, students, university administrators, etc. utilize the information conveyed by these projections.

To place the problem in perspective, I first review the NSF projections of doctorate supplies and requirements in 1980. The NSF projections and others like them are mainly extrapolations of recent trends, modified occasionally by judgments about certain parameters which describe the links between inputs of doctorate faculty (or R and D scientists) and the outputs of student enrollments (or R and D outlays). They do not come to grips with the factors that determine the prior observed equilibria of Ph.D. labor markets or that are likely to determine equilibrium rates of production and employment in the future. In my admittedly non-comprehensive review of the literature, I have come across only three studies, [Breneman (1970A), and (1970B), Freeman and Breneman (1973)] that seriously view the Ph.D. labor market from this latter perspective. In sections 3.2 and 3.3, I sketch the outlines of a model describing the production and employment of doctorates.[26/]

In developing this crude model, it became apparent to me that many facets of the Ph.D. labor market have not been analyzed in any systematic fashion. Finally, it is hoped that the model may help us in evaluating the plausibility of the current projections for a glut in the Ph.D. labor market.

3.1 The Projected 1980 Surplus of Doctorates

Several recent articles and studies have apparently reached a concensus that the Ph.D. labor market in the 1980's will be characterized by substantial excess supplies of Ph.D. scientists seeking appropriate jobs.[27/] In order to illustrate the magnitude of the projected surpluses, I have selected the most recent published doctorate supply and utilization projections developed by the National Science Foundation [NSF 71-20].[28/] Although the NSF study identified five broad fields, I have combined the physical sciences, life sciences, engineering, and mathematics into one category which I call the "hard sciences".

I shall not, at this point, criticize the NSF methodology but direct attention to the numerical results of the NSF projections for 1980 which are shown in Table 3.1. Line 1 presents the utilization [employment which is also equal to the 1969 stock supply] of doctorate scientists as of Jan. 1, 1969. The high and low projections of 1980 utilization, shown in lines 2 and 3, invoke different assumptions about Federal R and D spending, faculty/student ratios, etc. The high and low projected 1980 supplies (lines 4-a and 4-b) were derived by taking the initial 1969 supply, adding the projected production of new doctorates, and deducting losses due to death, retirement, and emigration. An estimate of the maximum surplus is obtained as the difference between the high supply and low utilization projections; this is shown on line 5. Similarly, the difference between the low supply and high utilization give us the minimum surplus shown on line 6.

For all sciences combined, the projected 1980 surplus of doctorates, [the excess of projected supply over demand] varies between 55.9 and 17.4 thousand. If these surpluses are expressed as percentages of their corresponding projected supplies, [indicated by the figures in parentheses on lines 5 and 6 of Table 3.1], they are 19.6 and 5.5 percent. The NSF projections thus imply that at worst, one in every five Ph.D. scientists will be unable to find suitable employment in 1980 that "requires" the training and skills of a Ph.D. The optimistic picture implies that one in every twenty will be "under-employed". The employment outlook is considerably bleaker for the social scientists according to these forecasts.

The historical data on the actual number of doctorate degrees conferred in the academic years ending in 1961-72, as well as the NSF projections of doctorate production rates through 1980, are presented in Table 3.2. First, it will be noticed that there are some discrepancies between actual and projected flows in 1970-72. The NRC doctorate record file indicated a drop of -2.2 percent in the output of Ph.D's in the hard sciences, while NSF projected a modest growth of +3.4 percent. Since the actual data for 1970-72 were not available at the time that the NSF projections were made, the discrepancies represent forecast errors. Second, it will be noted that the growth rate of hard science Ph.D.'s in the period 1970-75 is considerably below the projected growth rate of social science Ph.D.'s. This outcome follows from the NSF methodology of linking doctorate production in year t to first-year graduate enrollments some five to eight years earlier. The data for the period 1967-69 exhibited sharp declines in first enrollments in Chemistry and Physics, while no such break in the trend was observed for the soft sciences.[29] Since the NSF projection methods, place more weight on the most recent experience, (without really trying to explain that experience), we get the results reported in Tables 3.2 and 3.1, namely a much larger increase in the projected supply of social scientists accompanied by a larger estimate for the 1980 surplus. Finally, selected data on doctorate production rates by field are shown in Table 3.3 mainly to show the wide variance in growth rates across fields.

3.2 Investment in a Doctorate Degree

In order to explain previous historical trends and to gain insights into possible future developments, we need a market model for that part of our higher education system which produces Ph.D.'s. A convenient point of departure is an analysis of the individual student's decision on whether or not he should enroll for graduate study. In his excellent paper, Breneman (1970A) initially considered the possibility that the quest for a Ph.D might involve elements of both consumption and investment. However, given the sizeable costs and a commitment to a particular field, the decision to seek a doctorate should, in Breneman's view, be analyzed as an investment in human capital. In the context of a human capital model, the student's decision should depend on the expected costs and returns from his investment in a doctorate degree. However, to the extent that the working conditions for a doctorate recipient differ from those in alternative employments, [in terms of the prestige, recognition, hours, places of work, etc.], the "returns" cannot be mechanically equated to estimates of monetary earnings differentials. There are also compelling reasons to suspect that for many, graduate study may be part of the search for a career as well as elements of consumption -- the sheer joy of learning. A correct calculation of the rate of return to the investment in a doctorate must somehow allocate the costs [of foregone income, tuition, incremental living expenses, etc.] to these joint products of human capital, consumption, and search. Breneman cogently argues that a key variable i in this investment decision is the student's subjective estimate for his probability of success meaning the successful attainment of the Ph.D. degree. If one also believes that the prestige of a doctorate degree is an important element of the "returns", and if an academic post provides more prestige, then the chances of securing an academic position will be another important variable. In this section, I try to combine these considerations into a model of the supply of applicants to graduate schools. The juxtaposition of this supply function and the Universities' demand for graduate students determines the equilibrium flow of first-year graduate students. The supply of Ph.D.'s is then linked to these first-year equilibrium enrollments via a theory of attritions from doctoral programs.

A. The Monetary Earnings Differential: A standard procedure in measuring the returns to education is to calculate the present value of earnings differentials over the working life. Let Y_{Bt} and Y_{Dt} respectively denote the wage earnings of bachelors and doctorates t years after completing the bachelor degree. If the successful completion of a Ph.D. degree entails k years of full-time graduate study, the present value of the earnings differential which accrues to the doctorate is given by,

$$(3.1) \qquad E = \sum_{t=k}^{T} (1+r)^{-t}(Y_{Dt} - Y_{Bt})$$

where r is the discount rate at which future income streams are discounted, and the individual is assumed to retire T years beyond his AB degree. Given the age-earnings profiles, (Y_{Dt}, Y_{Bt}), it is apparent that E will be larger, the lower is the discount rate r, or the shorter is the period of full-time study k.

Estimates of the age-earnings profiles of all doctorates, non-academic doctorates, and male college graduates (bachelor degree holders) for 1960 are presented in the top panel of Table 3.4.[30] If I assume that all workers retire at age 65, the undiscounted lifetime earnings are given by the sums shown in panel 1. [This also assumes that the Ph.D. earns nothing during his period of graduate study, ages 22-25.] The present values of earnings [where bachelors have a longer working life of 43 years vs. 39 for doctorates] at interest rates of 5 and 10 percent are shown on lines 2-a and 2-b.[31]

The earnings of all doctorates exceed the earnings of bachelors, but the difference in accumulated lifetime earnings (at a zero interest rate) is small, +19.3 thousand dollars in 1960. At a 10 percent interest rate, this difference in the present values of lifetime earnings becomes negative, -9.8 thousand, due to the loss of income during the assumed four years of graduate school. If, however, doctorate salaries are measured by the earnings of non-academic doctorates, the differences become sizeable, 115.8 thousand at a zero interest rate and 13.9 thousand at 10 percent.[32/]

The differences shown on lines 4-a and 4-b of Table 3.4 are not the same as the differential in monetary earnings E [defined in (3.1) above] that accrues to the Ph.D. holder. To get E, we must add to the differences in Table 3.4, the present values of the incomes of bachelors over the first four years evaluated at interest rates of 0, 5, and 10 percent; these were 16.3, 15.0, and 14.0 thousand in 1960. Using both the all doctorate and nonacademic doctorate income profiles for Y_{Dt}, I calculated the following earnings differential to the Ph.D. degree:

Earnings Differential E for Alternative Interest Rates*

	r = 0	r = .05	r = .10
All Doctorates	35,577	10,093	4,173
Nonacademic Doctorates	132,082	40,885	17,898

*derived from Table 3.4 using equation (3.1)

These figures indicate the rough orders of magnitude of the monetary returns to the Ph.D. degree. The earnings data, (Y_{Dt}, Y_{Bt}) were geometric or arithmetic mean earnings that mask the wide variances of incomes across fields, individuals, and types of employment. An able engineer with a BS degree might easily earn more over his lifetime than a Ph.D. in agronomy. Further, these calculations were based on the earnings differentials (by education and age) that were observed at one point in time, 1960. The measured monetary return E for any given interest rate r [e.g. E = 10,093 for r = .05] will understate the realized differential in monetary returns E^* if all money incomes rise over time due to inflation and economic growth. More precisely, if (Y_{Dt}, Y_{Bt}) describe the cross-sectional age-earnings profiles, and we want to calculate the present value of the monetary returns to a Ph.D. at an interest rate of r = .05, the appropriate formula is given by,

$$(3.1') \qquad E^* = \sum_{t=k}^{T} (1+r^*)^{-t}(Y_{Dt}-Y_{Bt}), \quad \text{where} \quad r^* = \frac{r-g}{1+g}$$

In this equation, g is the annual compound growth rate of money incomes due to inflation and secular growth in labor productivity. Over the period, 1959-73, the Endicott series on the starting salaries of college graduates in business exhibited an annual compound growth rate of g = 4.75 percent per year, and it is probable that this will continue into the future.[33/] Some writers like Banfield (1970) have asserted that youth s attach a high discount rate to future income streams. If so, the use of adjusted interest rates r^* of 5 and 10 percent give us the right measure for the earnings differential E^* that correspond to personal time preference rates r of 10 and 15 percent.[34/]

The question of whether salary differentials have widened or narrowed is of considerable importance in an analysis of the Ph.D. labor market. The starting salaries of Ph.D.'s who received their degrees in 1950, 1955, and 1960 [as well as an interpolated value for 1963] can be obtained from the NRC Survey.[35/] The NSF Roster of Doctoral Scientists also gives us estimates of the median annual salaries of all Ph.D.'s of all ages. The NSF medians are considerably higher than starting Ph.D. salaries due to the older age of the NSF sample. These Ph.D. earnings data are shown in the first four lines of Table 3.5. The starting monthly salaries for business placements of college graduates, [the Endicott series] were converted to annual salaries and appear in line 3 of Table 3.5. The ratios of bachelor to doctorate salaries for selected dates are presented in lines 4 and 5. Over the period 1955-63, all doctorates earned nearly 50 percent more than bachelors (line 4-a). Line 5 suggests that the relative salary differential has not changed much over time.

B. The Costs: In defining the appropriate concept for the cost of a Ph.D. it is useful to distinguish between "outlays" and "economic" costs. The full economic costs of the investment in a Ph.D. include tuition, fees, travel, extraordinary living expenses[36/] and the opportunity cost of foregone income during the period of graduate study. From the student's viewpoint, his private economic costs may be less than the full social economic costs by the amount of any scholarships, fellowship stipends, or income from part-time employment (such as through research and teaching assistantships) that he earns during his period of "full-time" study. Educators and graduate deans are often concerned about the out-of-pocket outlays that are needed to sustain a full-time graduate student. These "outlays" include tuition, fees, travel, and all living expenses.

All of the cost items that enter into both outlays and economic costs vary across fields of study, institutions, and individuals. In panel A of Table 3.6, I have assembled some of the background data on tuition and room and board costs.[37/] In deriving the data appearing in panel B, I invoked the following assumptions:

1. Tuition is the arithmetic average for public and private universities. This is in rough conformance with the ratio of graduate student enrollments in the two types of institutions.
2. Living expenses for graduate students, (who are older and more likely to be married), are assumed to be 50 percent higher than the room and board expenses shown in panel A.
3. Roughly 20 percent of living expenses are extraordinary expenses that would not have been incurred if the individual had not elected to attend graduate school.
4. The calculations for both outlays and economic costs assume that the student receives no financial aid and earns no part-time income.

The last two columns of Table 3.6 were included for the curious who might want to conjecture about the reasons for different growth rates in these cost components.

According to my constructed estimates, the annual "outlays" that must be incurred in the quest for a Ph.D. have roughly doubled between 1959 and 1973. Tuition now accounts for 40 percent of the outlays. The private economic cost [which equal the full economic costs given no financial aid] are dominated by the opportunity cost of foregone income accounting for around 87 percent of the economic cost in 1973.[38/] At a 5 percent interest rate, the present value of the economic costs for a student contemplating four years of full-time, unsubsidized graduate study, would have been 21.9

thousand dollars in 1959 and 43.3 thousand in 1973. These economic costs can be compared to the monetary returns in 1960 of 10.1 thousand for all doctorates [at r = .05] and 40.9 thousand for nonacademic doctorates. It is evident from these illustrative figures that the return to the investment in a Ph.D. for an unsubsidized student whose representative earnings stream is that of all doctorates, is below 5 percent. However, if he elects to enter nonacademic employment with its 20 percent higher salaries, the rate of return is just below 10 percent.[39/] These "representative" calculations again conceal the wide variance across individuals. Tuition at private universities is three times that at public although the differential seems to be narrowing.

A comparison of the private economic costs to the monetary returns yields very different rates of return. A survey of graduate student finances in Spring 1965 revealed that 43 percent of the 477,535 graduate students received some stipends.[40/] Weiss (1971) found that the net earnings of graduate students [defined as stipends and income from spouse or part-time employment less tuition] were positive and varied between 39 and 64 percent of the full-time earnings of comparable bachelor degree holders who did not pursue a graduate degree. He found that the median income of graduate students in 1966 was $5,900. When Weiss deducted the net student earnings from economic costs, the rate of return to the investment in a Ph.D. climbed from 6.67 to 12 percent. It is evident from these results that the size and availability of fellowships and part-time income have substantial effects on the profitability of an investment in the Ph.D. in terms of monetary rewards.

C. The Probability of Success: Not all who embark on the quest for a Ph.D. succeed. Our casual observations tell us something about the magnitude of the proportion π of each entering graduate class that ultimately completes all of the requirements for the degree. Rodney Stark (1966) compiled the records of several cohorts of graduate students at Berkeley. The completion rates of these cohorts from the Stark data are shown below:

Percentage Distribution of Degree Earned by 1966: Berkeley*
(for cohorts entering in 1951, 1954, 1957)

Department	No. in Sample	Percentage who earned: Ph.D.	Master	No Degree
Political Science	82	7.3	31.7	61.0
English	81	11.1	33.3	55.6
Chemistry	125	75.2	11.2	13.6
History	74	21.6	21.6	56.8

*taken from Breneman (1970A), Table 2, p. 9

What surprised me about the Stark data, was not the proportion π who earned the Ph.D. but the fact that aside from Chemistry, over half of each entering class went away without even a Masters degree which in many departments that I have observed is awarded in lieu of a certificate of attendance. A study of 3,450 Woodrow Wilson Fellow by Mooney (1968) is even more startling. Only 34.4 percent of these presumably able and adequately financed students completed the requirements for a Ph.D. degree.[41/] A discussion of the determinants of the completion rate π [across fields and institutions] is deferred to section 3.3 below. The issue here is, "How does the student's estimate of π affect his decision to enroll in graduate school?".

Let γ denote the private net economic cost for k years of graduate study.

(3.2) $$\gamma = \sum_{t=0}^{k-1} (1+r)^{-t}(C_t - S_t),$$

where C_t is the full economic cost including the opportunity cost of foregone income, and S_t is the sum of stipends, tuition waivers, and part-time income. If we ignore the attrition risk, the expected net present value of the investment is simply,

(3.3a) $$V = E - \gamma ,$$

where E is defined in (3.1). The model proposed by Breneman (1970A) tacitly assumes risk neutral students who maximize the expected net value, V', adjusted for the probability of completing the degree requirements π .

(3.3b) $$V' = \pi E - \gamma .$$

Clearly V' will vary across students depending on, among other things, ability and the chosen field of study which will affect π , the monetary returns if successful E, and the net economic cost γ. In this model, a student will apply for graduate school if $V' > 0$; i.e., if the net present value of returns is positive implying a profitable investment in human capital. The data in panel B of Table 3.6 provide some illustrative comparisons. A student who received a fellowship covering tuition and living expenses would have incurred a net economic cost of γ = \$15.6 thousand in 1960. Since the monetary return to all doctorates was only E = \$10.1, the investment in a Ph.D. was not a profitable one at a 5 percent interest rate, even if $\pi = 1$. If, however, we compare γ to the income stream of a nonacademic doctorate, E = 40.9, the net present value V' will exceed zero when $\pi > .381$. It should be emphasized that these comparisons (which are based on admittedly crude data) describe the net returns to the "representative" student. The values of (π, E, γ) obviously vary across students. Although V' may be negative for the "representative" individual, it will be positive for some able students who are confident of their ability to earn the Ph.D. or who perceive high monetary return E which exceeds the average return.

D. Non Pecuniary Returns and Search: The attainment of a Ph.D. degree is generally accepted as evidence of scholarly excellence and bestows upon its holder, preference in securing certain kinds of employment as university professors, heads of prestigious research organizations, or jobs involving original, independent research. If prestige, research, and teaching (especially at the graduate level) are desirable attributes (for which most individuals would be willing to forego some monetary [pecuniary] compensation),[42/] competitive labor markets can be expected to establish equalizing wage differentials. The equilibrium wage rates for jobs with more prestige and better working conditions, will be lower by the equalizing differential R which represents the implicit monetary value which the marginal employee attaches to the attributes of the job or occupation. Introspection suggests that for many, academic salaries contain elements of economic rent; i.e. if all universities were cartelized and salaries reduced by X percent, many of us would still choose to remain in academia. This is not implying that the supply of Ph.D.'s to academia is completely inelastic, but rather that in measuring the pertinent supply price (the compensation needed to attract the last Ph.D. into academia), we must include the size of the equalizing differential R for the marginal worker. The difference between the earnings of academic and nonacademic doctorates (the latter earn about 20 to 30 percent more) gives us a rough indication of the non pecuniary returns to academic employment.

The hiring and salary policies of universities and the hetergeneity of Ph.D.'s and jobs are two of the factors that may impede the attainment of a Pareto optimum equilibrium in the Ph.S. labor markets.[43/] Virtually all universities have adhered to a policy of never cutting the nominal salary of an incumbent faculty member. Since roughly two-thirds of all faculty members are tenured, the burden of adjusting to changing market conditions must largely be borne by new doctorates. Further, the matching of individuals and jobs often entails substantial hiring and training costs because of the wide diversity in the traits of Ph.D.'s and the varying demands imposed by specific jobs. High labor turnover in an academic faculty or in a research organization greatly reduces the productivity of the organization. Given existing tenure arrangements and salary policies, new Ph.D.'s may be unable to obtain preferred jobs even though the employing institution (and the new Ph.D.) would be willing to exchange the new Ph.D. at a lower salary for an incumbent. As of Jan. 1, 1969, 59.7 percent of all science doctorates were employed in academia [confer Table 3.1]. If the potential supply of new Ph.D.'s prefer, on average, academic to nonacademic employment, the future availability of academic posts, [measured by the probability of securing such posts] must affect the non pecuniary returns. More precisely, if the likelihood of getting an academic position is reduced, (as it is likely to be in the years ahead), it lowers the "returns" to the Ph.D. degree (including both monetary and non pecuniary returns) thereby reducing the supply of students who will apply for graduate study.

The decision to continue beyond the AB degree may be prompted by a search motive. The inherent instability and uncertainty that surround the transition from school to work, manifest themselves in high labor turnover with frequent job changes and intervening spells of unemployment. Hall (1972) found, for example, that teen-agers typically hold three or four different jobs in a single year. For the non-college bound, the period following high school is characterized by the search for a suitable job. The situation is not qualitatively different for the college graduate. For some individuals, the search for a career may be most economically carried out by enrolling in graduate school. Breneman (1970A) argues that most first-year students are ignorant about the objective chances π of earning a Ph.D. degree. I suspect that even fewer know how they would value the non pecuniary attributes of the kinds of jobs which Ph.D.'s hold. Such information can only be obtained by enrolling in graduate schools. Others who do not find "suitable" employment in their senior year may apply for graduate school either as a way of staying in a "holding pattern" or as a means of switching fields of study. We have only limited empirical evidence on the returns to an investment in graduate education that does not culminate in an earned Ph.D. degree.[44] The cost of a graduate education, (at least for some individuals) should not be treated solely as an investment in human capital, but a part of the cost may be properly viewed as a cost of search.

The economic literature on job search yields two pertinent implications. First, a decrease in the cost of search increases the demand both in terms of the number of searchers and the duration of search. Second, wealthier individuals demand more leisure and attach higher implicit values to non pecuniary attributes of employment which can only be determined by search. The availability of fellowships, TA's, and RA's greatly lowers the cost of search and should thus expand the supply of first-year graduate students. Further, students who do not have to migrate to universities confront lower search costs thereby implying higher first-year graduate student supplies (in relation to bachelor degrees) at the large urban universities. With the secular growth in the real wealth of our economy, I get the impression that more and more students are extending the time between formal schooling and full-time employment. The Vista volunteers, travel to Europe, or a stint in graduate school may all be reflections of an increase in the demand for a more leisurely search for a lifetime career. The wealth hypothesis [i.e. that the value of search is larger for wealthier persons] further implies that at a point in time, the family wealth of graduate students should be larger than that of undergraduates. The search motive thus suggests that other things equal, [specifically the monetary returns E and the cost γ_t], the projected growth in real incomes should lead to an expansion in the supply of first-year graduate students.

The expected net present value, V'', of an investment in graduate education can now be defined to incorporate these considerations. Let H denote the implicit value of search, while Q represents the implicit value of the non-pecuniary attributes of doctorate employments.

$$(3.4) \qquad V'' = \pi(E+Q) + H - \gamma \, .$$

All of the variables determining V'' can vary across individuals. The private cost γ, for example, is to a considerable extent determined by Federal, State, and private university policies concerning the amount and allocation of fellowship, TA, and RA funds; moreover, γ is likely to be smaller, the more able the student. Each graduating senior can, conceptually, be imagined to formulate subjective estimates about the value of search H, the probability of earning a Ph.D. π, the gross returns to the Ph.D. (E+Q), and the costs, γ -- his estimate for γ is likely to be the most accurate. Hence, for each student, there is, in principle some V'', and we could conceptualize a frequency distribution of net present values, $f(V'')$. The population of graduating seniors B who form the potential population of first-year graduate students, and the supply of first year students, G_a, will then be given by,

$$(3.5) \qquad G_a = \int_0^{\infty} f(V'')dV'' \, . \qquad\qquad B = \int_{-\infty}^{+\infty} f(V'')dV'' \, .$$

In this abstract model, only individuals who perceive a net positive value for the investment in graduate education are presumed to enter graduate schools. The effect on G_a of changes in H, π, E, Q, and γ are obvious.

There is some evidence corroborating these obvious anticipated signs. An unpublished study by Ashenfelter (1971) revealed, for example, a close positive correlation between the percentage of college seniors who intended to go on to graduate school, and the real (deflated) Federal outlays per graduate student for fellowships and traineeships; this result is consistent with $dG_a/d\gamma < 0$. The tighter labor markets for new Ph.D.'s, (especially in academia) in recent years, 1970-73, indicate a decline in both the monetary and non-pecuniary returns, (E+Q), to the Ph.D. degree. A fall in (E+Q) should be accompanied by a decline in G_a, and the recent data do, indeed, show a drop in the ratio of first-year enrollments to bachelor supplies, (G_a/B).

The aggregation implicit in the supply model outlined above conceals the ways in which market forces can influence the allocation of graduate students across fields. In the NSF supply model, the supplies of first-year graduate students in each science field are linked to the output of bachelor degrees in the corresponding fields.[45/] An important omission in the model is the impact of the professional schools, [law, medicine, optometry, dentistry, business etc.] on the supply of applicants to the science fields. There seems to be ample room for more empirical research on how the monetary returns, the psychic value of non-pecuniary returns, and the costs of the Ph.D. influence the supply of graduate students, both in the aggregate and to particular fields.

3.3 The University Demand for Graduate Students

A university can be imagined to be a firm that produces several joint products -- bachelor degrees B, masters degrees M, doctorates D, and research X. Some might want to add another "output", service to the community. These "outputs" are produced by combining inputs of undergraduate students U, graduate students G, faculty F, and other resources -- buildings, facilities, administration, and support personnel. The specification of a model describing the behavior of a university is beset by two difficult problems that have not been satisfactorily resolved in the literature. The first, (and simpler of the two), is the identification and estimation of a joint production function which describes how input flows of faculty and students, (F,U,G), are technically transformed into output flows of completed degrees and research, (B,M,D,X). In short, we want to know more about the properties of what Nerlove (1972) called the joint production function of an educational institution.

(3.6) $f(B,M,D,X) = g(F,U,G)$

The second and more formidable problem is the specification of the university's objective function. Advancing the frontiers of knowledge, training tomorrow's leaders, solving pressing national and social problems, are but some of the phrases that appear in alumni magazines to describe the goals of a university. At a more disaggregative, partial level, Breneman hypothesizes a departmental objective function whose arguments include a prestige index for the reputation of the faculty, and the quality of its Ph.D.'s as measured by their placement in quality institutions. If degree recipients and research are properly adjusted for quality,[46/] the arguments of a university's objective function should only include "outputs" and be something like,

(3.7) $W = \Psi(B, M, D, X)$

where increases in any of the arguments enhance the measure of achievement of the university which is denoted by some index W .

In striving to maximize achievement W , the university is constrained not only by the properties of the joint production function (3.6), but also by a budget constraint which might be written as:

$$(3.8) \qquad FP_f + ZP_z = R + E . \qquad [R = R(U,G,X)]$$

where FP_f = the compensation of faculty, ZP_z = the cost of other resources, R = net revenue from tuition and research, and E = endowment income including the "fixed" components of Federal and State grants.[47/] The model is complicated by the fact that each university is a slightly differentiated firm. The "price" of comparable faculty inputs can vary within narrow limits depending on the quality of the institution, of colleagues, of research facilities, and of graduate student inputs. Likewise, the "prices" that can be charged to comparable undergraduates U, may vary, but competition among institutions for these students limits the range of these price (tuition) variations. It is beyond the scope of this paper to attempt to derive the properties of the equilibrium for the university as a whole. I propose, instead, to direct attention to two special cases dealing with the demand for graduate students.

A. The Short-run Trade-off Between Undergraduate and Graduate Degrees: Consider a case in which research output X, other resources and their costs ZP_z, and endowment income E are fixed in the short run. The budget constraint facing the university can be simplified to:

(3.8') $FP_f = R^*(U,G) + K$,

where K is the net revenue from endowments and research contracts less ZP_z, the costs of other resources. The "fixed coefficient" models that are used to project supplies, imply strong separability of the joint production function (3.6), namely, undergraduate inputs U do not affect the output of graduate degrees, and vice versa. The production functions implied by these models are of the form:

(3.6a) $B = (1-\alpha)\ U_1$,

(3.6b) $D = (1-\delta) G_1$,

where for simplicity, I assume only one kind of graduate degree, doctorates D. Thus, in (3.6a), the output of equivalent bachelor degrees B is linked to the lagged input of first-year undergraduates U_1 via the attrition rate α in undergraduate education. Similarly, D is linked to the lagged input of first-year graduate students G_1 via a different doctoral attrition rate δ. This is surely an over-simplification,[48/] but it enables us to see how the budget and production function constraints limit a university's demand for graduate students.

Consider a university that increases its demand for graduate students in an attempt to expand its output of doctorates. It can do this in two ways; (a) offer more stipends to applicants of a given quality or (b) lower the minimum qualifications for admission to the doctoral program. If G and G_1 are measured in equivalent quality units, the revenue function, $R = R^*(U,G)$, will exhibit rapidly diminishing returns...[49] Further, an enlarged doctoral program must be accompanied by an increase in the size of the graduate faculty, F_g, in order to prevent an unwanted rise in the doctoral attrition rate δ. We can define a net marginal revenue, NMR_g, as the difference between the marginal revenue generated by the student, (dR/dG_1), and the incremental cost of the added faculty needed to maintain a constant attrition rate δ.

$$NMR_g = (\frac{dR}{dG_1}) - (\frac{dF_g}{dG_1})P_f \quad .$$

It is probable that NMR_g becomes negative rather quickly when the university hires new faculty to staff the doctoral program.[50] When this happens, the budget constraint is violated, and the university must adopt another means of financing its increased demand for graduate students. The requisite graduate faculty could be obtained by reallocating the incumbent faculty from undergraduate to graduate programs. Such a reallocation must, however, be accompanied by curtailing undergraduate student enrollments U. If this is not done, a lower faculty to student ratio in undergraduate courses must lead either to a higher undergraduate attrition rate α or a lower quality of bachelor degrees; both result in fewer <u>equivalent</u> bachelor degrees.

In the absence of more external funds from endowments, research grants, or public funds, a university's short run demand for graduate students is effectively limited by its budget. The net marginal revenue of a graduate student, NMR_g, eventually becomes negative as (a) larger stipends are offered to attract students, (b) lower quality students are admitted, and (c) more faculty are hired to staff the graduate program. The enlarged doctoral program can only be financed within the university's budget constraint by cutting back on the production of undergraduate degrees.

B. A Digression on the Incubation Period from Bachelor to Doctorate: The NSF model for projecting future supplies of Ph.D.'s is qualitatively similar to the "fixed coefficient" model of equation (3.6b) above. The assumption in (3.6b) of a fixed ratio, $(1-\delta)$, of the output of Ph.D. degrees to the lagged input of first-year graduate students is an over-simplification. The "incubation period" from AB to Ph.D. degree clearly varies across individuals and fields. Let G_t denote the number of first-time enrollments to a graduate program in year t. Some fraction π_2 of them will complete all of the requirements for the degree in two years, another fraction π_3 in three years, etc. The doctorate yield from this cohort will then be the sum of these proportions where J is the upper limit, $(\pi_2 + \pi_3 + \ldots + \pi_J)$. If these completion probabilities are stable over time, the actual number of Ph.D. degrees conferred in year t, D_t, will be a distributed lag of prior first-year graduate enrollments, G_{t-j}.

$$(3.9) \qquad D_t = \sum_{j=2}^{J} \pi_j G_{t-j} = \pi_2 G_{t-2} + \pi_3 G_{t-3} + \ldots + \pi_J G_{t-J} \, .$$

The NSF Roster or the NRC Doctorate Record File could be used to estimate the profile of these completion probabilities π_j. In the time available for this paper, I was unable to gain access to these files. If, however, one assumes that nearly all students enter graduate school immediately after receipt of their bachelor degrees, the biographical data in American Men and Women of Science allow us to infer the length of the incubation period from AB to Ph.D. degrees. A sample of 368 individuals was selected from this source, and data on the time interval between AB and Ph.D. degrees were cross-tabulated by major field and the year in which the Ph.D. degree was conferred. The results are presented in Tables 3.7A and 3.7B.

For the entire sample, the mean length of time from the bachelor to the Ph.D. degree was 8.48 years. One of every nine degrees was awarded to an individual who required fifteen or more calendar years beyond the AB before he completed his dissertation. In this sample of 368 degree recipients, the interval ranged from two years, [one of which was a Ph.D. in forestry awarded to an Indonesian whose previous degree was not easily translated into U.S. terms] to thirty years [for an undergraduate from McAllister who eventually earned his Ph.D. in inorganic chemistry].[51/] The data of Table 3.7A reveal different frequency distributions for the physical and biological sciences vs. the social sciences. Fully 45 percent of the Ph.D.'s in the hard sciences were completed in four to six years. The social science distribution was essentially flat between four to nine years.

The incubation period as well as the probability of eventual completion [i.e. the sum of completion probabilities π_j] should be affected by the same market forces that influence the supply of graduate students. The analysis of section 3.2 suggests the hypothesis that the probability of completion should increase during periods of rapidly rising demands for Ph.d.'s. The percentage of late finishers [ten or more years to earn a Ph.D.] seems to have increased in the 1955-59 and 1965-73 periods, but the sample sizes in Table 3.7B are too small to show statistically significant differences.

Aside from the Stark (1966) study, [reported in Breneman (1970A)], I was unable to get reliable estimates on the probability of ultimate completion, $\pi = \Sigma\pi_j$. I have the impression that π is around .2 to .4 in the social sciences and around .5 to .7 in the physical sciences.[52/] If these guesses are near the mark, the long tails in the frequency distributions of incubation periods, suggest that at any point in time, there is a substantial reserve of "all but dissertation" Ph.D. candidates who could be induced to finish their degrees thereby augmenting the supply of new Ph.D.'s in a period of rising demands. Conversely, in a period of falling demands for Ph.D.'s, we should expect to observe a fall in the ultimate completion probability π (implying a rise in the doctoral attrition rate δ). The vast quantities of data in the NRC Doctorate Record File, and the diversity across fields in the market demands for new Ph.D.'s can be used to develop economic models that can be empirically implemented to test some of these hypotheses. Aside from Breneman (1970B),[53/] the research to date has largely been addressed to projecting future supplies and not to further our understanding about the underlying production function for Ph.D.'s.

C. The Longer Run Determinants of the University Demand: In the long run, a university's demand for graduate students will clearly be influenced by its financial (budgetary) resources and by the market demand for new Ph.D's. Very few universities admit all applicants for their doctoral programs because tuition simply does not cover all of the incremental costs. These costs include not only the direct costs for the higher faculty/student ratios in graduate courses,[54] but also the indirect costs of diverting faculty time away from contributing to the research output and undergraduate teaching of the university. In determining the size of its entering class which together with attrition rates fixes the size of the graduate program, [in terms of graduate enrollment and degree production], each department also considers the hidden costs deriving from the implicit, quasi-contractual, [and sometimes even paternal] relationships that often develop between graduate students and faculties. The process of dropping students from a graduate program is distasteful to many faculty members, and they would rather not admit marginal students even when the student is prepared to pay for the incremental costs.[55]

A university demands graduate students to produce Ph.D.'s who will hopefully contribute to the university's reputation and achievement. The value of more Ph.D.'s, in terms of the university's objective function (3.7), depends critically on the market demand for new doctorates. Breneman (1970A) assumed, for example, that each department behaves as if it had a "perceived demand" for its Ph.D.'s. In his model, a Ph.D. who can only be placed at a two-year community college, detracts from the department's reputation; i.e. he has a negative marginal value. If these are the only kinds of jobs available, the department will simply limit its output of Ph.D.'s either by reducing its demand for new graduate students or by increasing attrition rates.[56]

Information about the job market is often imperfect. Students seek the advice, guidance, and assistance of their principal advisors in finding suitable employment. These faculty advisors are often the channels through which information about the market is funneled back to the admissions committee. Graduate deans are continually surveying degree recipients and compiling data on their employment. Several writers have asserted that these information channels are imperfect, and they call for a national employment service for new Ph.D.'s. The Ph.D.'s and the institutions that employ them are very heterogeneous, and organized national exchanges like the wheat pit do not function well when buyer and seller must determine for themselves, the precise attributes of the other. My impressions are that the existing information channels, at least in the older established doctoral programs, function quite well. The newer programs with little prior experience in producing and placing students, seem to have more difficulty in perceiving current market conditions. For roughly comparable budget conditions, these impressions imply that in response to the recent downturn in the employment opportunities for physicists, the older established doctoral programs in physics should have exhibited sharper reductions in graduate enrollments.[57/] Employment opportunities for new Ph.D.'s in academia and research are thus likely to affect both the university demand for graduate students as well as the supply of qualified applicants. Given current tuition rates and stipend policies for graduate students, the production of advanced degrees, (especially Ph.D.'s), constitutes a drain on the university's financial resources. With a declining market demand for new doctorates, universities will, in all likelihood, contract the size of their doctoral programs because Ph.D.'s in non-research and predominantly undergraduate teaching positions contribute little to the institution's reputation and prestige.

3.4 On Market Equilibrium and Projections of the Ph.D. Labor Market

The current NSF projections of the future supply and utilization of science doctorates predict the development of a serious glut in the Ph.D. labor market. By 1980, some 6 to 20 percent of all Ph.D. scientists are projected to be unable to find suitable employment in academia and in nonacademic research positions. The supply projections are mainly predicated on extrapolations of recent trends in the production of new doctorates. Thus, when first-year graduate enrollments dip, [as they did in 1971 and 1972], these supply projections are drastically revised downward without ever really trying to determine the underlying causal factors that produced the dip. Although surveys of the deans of graduate schools contradict these supply projections,[58/] the trend projections still seem to command the attention of policy-makers.

On the other side, the utilization or requirements projections invoke rather rigid assumptions about the structure of the market demand. The projected academic requirements for new doctorates are based on arbitrary judgemental assumptions about the future time paths of two critical parameters, (a) the students to faculty ratio and (b) the doctorate share of new faculty appointments. The teaching load of American professors is absurdly low when compared to that of Soviet professors in non-research university positions. University professors, especially those with Ph.D. degrees, are expected to produce some research even when they are not explicitly provided with earmarked research grants, the role of academic research is wholly ignored in the current demand projection methodology.

The relative values which a university attaches to the research and teaching outputs of their faculty, will surely influence the equilibrium ratio of students to faculty.[59/] The assumptions about the doctorate share of new appointments also largely neglect market considerations except for ad hoc rationalizations for the particular assumptions invoked for the projections. Ph.D. and non-doctorate faculty inputs are clearly imperfect substitutes. The rational university can be expected to vary the proportions of doctorate to non-doctorate faculty inputs in response to changing relative prices (salaries) and relative productivities where the latter is measured by their respective contributions to the research and teaching outputs of the university.[60/] In fact, these substitutions are also likely to affect the university's demand for graduate students when they are also employed as teaching assistants. I have not come across any empirical studies that attempted to estimate the magnitudes of the elasticities of substitution between doctorate, non-doctorate, and teaching assistant faculty inputs; in fact, I know of no theoretical studies on this topic.

The neglect of market equilibrium is also evident in the methodology behind the doctorate supply projections. Expectations about the salaries and employment opportunities for new Ph.D.'s, as well as the private net costs of an investment in the quest for a doctorate are, from a theoretical viewpoint, important determinants of the supplies of first-year graduate students; these factors are totally ignored in the current projection methodology. Moreover, many of these same variables are also likely to affect the ultimate supplies of conferred Ph.D. degrees via their impact not only on the university demands for first-year students, but also in the departmental practices which influence attrition rates from doctoral programs.

I can only conjecture on the ways in which policy-makers might react to the projected 1980 glut in the Ph.D. labor market. They could try to reduce the future supply of science doctorates by cutting back on fellowship and traineeship funds. They might try to augment the demand for Ph.D.'s by expanding the flows of Federal and State funds to finance more research and development. If universities could be assured of a continued exponential growth in their budgets, it is virtually certain that the academic demands for science doctorates would also expand. The simplest economic models, common sense, and intuition are sufficient inputs that enable us to predict the direction of change of the policy alternatives before us. We know that more Federal and State funds to subsidize graduate education will expand the supply of Ph.D.'s. What we do not know is the empirical magnitudes of the response of the Ph.D. labor market to the various policy alternatives, and the existing information that is conveyed by the scientific manpower forecasts do not tell us these crucial magnitudes.

The available projections of doctorate supplies and utilizations tacitly assume that whatever has happened in the recent past, will continue to prevail into the next decade or two. The projection methodology simply assumes away the fundamental facts of market equilibrium. The past and future supplies and demands for Ph.D.'s represent the equilibrium outcomes of private and public decisions. It is contended that the available projections give policy-makers an indication of the probable state of the Ph.D. labor market *if* the policies that were followed in the recent past were continued into the future.[61/] But the rational formulation of public policies toward higher education can only be achieved if we, as analysts, are able to identify and quantify how past and future public policy actions affect the equilibrium in the Ph.D. labor market. In spite of these criticisms which have been voiced by earlier writers, public agencies continue to demand more scientific manpower forecasts that differ only in the refinement of the available statistics and in insignificant alterations in the basic methodology. The pressing need for more manpower projections of essentially the same ilk, [backed by the funding to produce these projections], seems somehow to have gotten the priorities reversed.[62/] Forecasts that can be potentially useful in guiding the formulation of public policies, must be based on a sound economic model of the market for Ph.D.'s. Such a model would provide policy-makers with empirical estimates of the relationships describing the behavior of universities and other institutions (mainly research organizations and government) that employ science doctorates, as well as the behavior of college graduates who form the potential supply of new Ph.D.'s. The existing projection models that foretell the future of the Ph.D. labor market, do *not* incorporate these behavioral relationships and thus are incapable of providing us with valuable insights about the functionings of the Ph.D. labor market.

FOOTNOTES

1. Market insurance and self-insurance via savings offer two ways of spreading the costs of some random events such as fires, illness, death, etc. Other risks and costs can be affected by allocating resources to protection; e.g. installing sprinkler systems, hiring public and private police protection, buying non-flammable fabrics, etc. F.H. Knight (1921) drew a distinction between "risks" and "uncertainties". According to my interpretation of Knight, risks pertain to situations in which the probability distribution of the random event is stable implying that the event is potentially insurable. Uncertainty, on the other hand, refers to a situation in which the probability distribution is unspecifiable or unstable. It would seem that the random events which scientific manpower forecasts purport to predict, are closer to Knight's concept of uncertainty.

2. This reason applies equally to both public and private demands. An oil company contemplating an investment in another ocean-going tanker must somehow forecast the future returns whether that forecast be explicit or implicit.

3. The six reasons cited here are direct quotations with only one minor omission. The reader is urged to consult the full text, [Freeman and Breneman (1973), pp. 16-18], which presents the authors' arguments for rejecting reasons 1, 2, and 4 as valid justifications for manpower forecasts.

4. Freeman and Breneman (1973), pp. 16-18, contend that students distrust guidance counselors and that college administrators are quite responsive to changing demands for study in different fields. In their view, the objectives sought by reasons 1 and 4 are already being accomplished (without forecasts) by the decentralized decision processes which characterize the U.S. higher education system.

5. This description appeared in G.J. Stigler, <u>The Theory of Price</u> (The MacMillan Co., New York: 1952), second edition, pp. 156-7.

6. Although I appreciate the important distinctions between forecasts, conditional forecasts, and projections, the exposition is facilitated

by referring to all of them as "forecasts". I shall, however, distinguish between requirements or demand forecasts vs. supply forecasts.

7. The magnitude of the decline is evident by examining the data for a specific age class. In the table below, I present the Census data for the actual and projected population of 18 year-olds. The figures are five-year averages for both sexes in thousands:

1950-54	2,120.4
1955-59	2,279.6
1960-64	2,790.8
1965-69	3,620.0
1970-74	3,953.6
1975-79	4,215.2
1980-84	3,936.4
1985-89	3,569.0

It should be remembered that the 18 year-olds in 1989 were already born in 1971 so that these population projections will be extremely accurate.

8. In their review article, Wolfle and Kidd (1971) p. 789 wrote, "For example, Balderston and Radner's work was, to a considerable extent, a test of the sensitivity of Cartter's projections of faculty employment to changes in some of the underlying assumptions."

9. The four structural equations are: (1) new doctorate requirements D_j are equal to the doctorate share of new appointments P_j times total new faculty appointments N_j, $D_j = P_j N_j$, (2) total new faculty appointments are equal to the change in the stock demand for faculty plus replacement of faculty who retire. It can be written,

$$N_j(t) = [F_j(t) - F_j(t-1)] + \delta F_j(t-1) = F_j(t) - \sigma F_j(t-1),$$

where $\delta = .02$ is the retirement rate and $\sigma = 1-\delta$. (3) the stock demand for faculty is equal to the projected student enrollment in the j-th sector S_j divided by the student/faculty ratio R_j, $F_j = S_j/R_j$, and (4) student enrollment in the j-th sector is equal to the allocative proportionality share k_j times total student enrollment.

$$S_j(t) = k_j(t)S(t) \ .$$

10. If the assumed trends in the allocative shares of students, $k_j(t)$, are substituted into (2.2b), we get,

$$W(t) = W^0 - \beta t = .0225 - .0001227t.$$

Thus, $W(t)$ declines from .0225 in 1970 to .0200 in 1990. In interpreting equation (2.4), it should be remembered that in the "no change" projection, P_j and R_j do not vary.

11. I have only shown the parameters for the "adequate finance" case. The "intermediate" projections assume target values for the doctorate share of new hires, P_j, which, by 1990, will equal the observed 1967 percentage of associate professors in each sector who held doctorate degrees.

12. According to the Digest of Educational Statistics, [(1972), Table 88, p. 75], resident degree credit enrollment in all institutions of higher education as a percentage of the 18-21 population, climbed from 4.01 percent in 1899-1900 to 51.89 percent in Fall 1970. The Digest figures of 7,545 thousand enrolled in Fall 1970 differs from the Cartter projection for 1970 of 6,303 thousand [(as reported in Table 3-1 of Balderston and Radner (1971), p. 18]. The discrepancy is probably due to the use of full-time equivalent students in the Cartter projections. The Cartter student enrollment projections imply that college student enrollments as a percentage of the 18-21 population will rise from 43.3 percent in 1970 to 60.4 percent in 1990.

It is my understanding that the current version of the NSF projection model incorporates a feedback effect. Using a Phillips curve type adjustment model, the projection for first-year graduate enrollments is lower, the larger is the excess supply of doctorates. Hence, the projected academic requirements for new doctorates affects projected student enrollments in the "market" version of the NSF model.

13. Disaggregation serves a useful purpose when the behavior and/or parameter values for the disaggregated sectors are substantially different. The principal difference among the six sectors is in the doctorate share of new appointments P_j. A disaggregation between undergraduate vs. graduate enrollments would, I suspect, have been far more efficient in describing the prior "demands" or requirements for new doctorates.

14. The most recent BLS projections are reported in, "College Educated Workers, 1968-80" BLS Bulletin 1676. Projections for 1975 appear in "Tomorrow's Manpower Needs", BLS Bulletin 1606. The BLS methodology is described in Appendix A of Bulletin 1606, Vol. IV.

15. In actuality, the methodology is more complicated. For some occupations such as auto mechanics, dentists, etc. for which time series data are available, occupational requirements are directly estimated by relating employment in the occupation to various explanatory variables such as vehicle registrations, disposable income, frequency of repairs or visits to dentists, etc. I am also skimming over the difficult empirical issues of comparable data and consistent occupational definitions.

16. With fixed technical coefficients, the prices of products that are more labor intensive will rise faster when the wage rate of labor is increased. The higher relative prices for labor intensive goods will prompt consumers to demand fewer of those goods thereby reducing the aggregate demand for labor. This principle was demonstrated by Friedman (1962) in his "Theory of Distribution with Fixed Proportions".

17. The ratio of the projected requirement to actual employment in the j-th occupation, $(\hat{E}_{.j}/E_{.j})$ is simply the product of the corresponding ratios for industry employment and occupational ratios. If there are N industries, we have,

$$\frac{\hat{E}_{.j}}{E_{.j}} = \sum_{i=1}^{N} k_i \left(\frac{\hat{r}_{ij}}{r_{ij}}\right)\left(\frac{\hat{E}_{i.}}{E_{i.}}\right)$$

where k_i is the i-th industry's share of employment in the j-th occupation. The relative error in the projected occupational ratios, $(\hat{r}_{ij}/r_{ij})$ is found to be four to five times the relative error in projected industry employment, $(\hat{E}_{i.}/E_{i.})$.

18. The linear trend is the simplest functional form, but one could posit polynomial trends, exponential trends, or logistic trend equations.

19. The NSF procedure is equivalent to invoking the following assumptions about the variance of the error term: (a) $E[e_t^2] = \infty$, for all t prior to the last ten years of the sample data, (b) $E[e_t^2] = \sigma^2$ for the first five years included in the admissable sample, and (c) $E[e_t^2] = 0.5\sigma^2$ for the most recent five years. Finally, it is tacitly assumed that the random errors are serially independent; i.e. $E[e_t e_{t+j}] = 0$ for all $j \neq 0$. Given these assumptions, the parameters are estimated by Aitken's generalized least squares to get a weighted trend line.

20. One way to see if the relationship has shifted is to estimate it for subperiods. I fitted the linear trend (2.7b) for two five year subperiods where $T_t = 1$ in 1958 and 10 in 1967. The ordinary least squares trend lines were:

$$H_t = 63.07 + 1.010T_t \qquad [1958\text{-}62 \text{ period}]$$
$$Y_t = 66.27 + 1.060T_t \qquad [1963\text{-}67 \text{ period}]$$

The samples are too small to apply significance tests, but it seems that the intercept α shifted in the most recent five year period. The linear equation is one of many trend relationships that could have been fitted to the time series data. One could have experimented with logarithmic trends, logistic trend equations, etc. But as I shall argue in section (c) below, trends can only describe a time series and do not "explain" the time path of the variable in question.

21. It is assumed here that students go directly from high school to college, and the production period for a bachelor's degree is four years for

everyone. The NSF supply pr. ..tions do allow for delays in starting college and in the time required to earn the degree. However, these lags are reported to be stable over time, and neglect of them here does not affect the principle that is being analyzed here.

22. The Digest only reported data from the biennial surveys. Data for the odd years were taken from Social Indicators published by the Bureau of the Census. First-time enrollments (Digest, Table 90) include returning veterans as well as students who do not go directly from high school to college. The completion rate, $c_t = 1-\alpha_t$, was calculated as the ratio of bachelor degrees in year t, Z_t, divided by first enrollments four years earlier, E_{t-4}; $1-\alpha_t = Z_t/E_{t-4}$. The data of Table 2.3 apply to both sexes. The NSF methodology computes separate rates for males and females.

23. The fifth column of Table 2.4 presents the ratio of doctorate degrees awarded in year t divided by bachelor degrees awarded in year t-5. A three-year moving average of bachelor degrees awarded in years t-4, t-5, and t-6 was used in the denominator of the ratios appearing in the sixth column. Since the number of bachelor degrees awarded exhibited a fairly smooth upward trend over this period, the two ratios of doctorates to lagged bachelors are not appreciably different.

24. The cost of a college education has fallen with the rapid expansion of low tuition public colleges and universities. The available cross-section data indicate that the income elasticity of the demand for college education is positive and large. To the best of my knowledge, we do not yet have good empirical studies that estimate the response of first-time enrollment rates to the private costs of college education and family income.

25. The following data on student enrollments (in thousands) by control of institution were taken from the Digest of Educational Statistics, 1972, Table 87.

Year	Total	Public	Private	Public/Private
1952	2,134	1,101	1,033	1.066
1960	3,583	2,116	1,467	1.442
1971	8.116	6.014	2,102	2.861
1971/1952	3.80	5.46	2.04	--

Enrollments in the public institutions over the period 1952-71 increased at an annual compound growth rate of 9.3 percent while that of the private institutions was only 3.8 percent. Further, Table 88 of the Digest revealed that graduate students constituted 10.1 percent of total enrollment in 1952, and 11.9 percent in 1970. The shift toward more graduate study is thus considerably less than that toward more publicly financed higher education.

26. I have borrowed heavily from Breneman (1970A) and strongly recommend it to the reader.

27. In their review article, Wolfle and Kidd (1971) summarized several projections of doctorate supplies and requirements including those by Cartter, NSF, Balderston and Radner, and others. The caveat that projections are not forecasts, is reiterated in this article. However, the authors write: "The agreement among these three studies indicates that the projected faculty requirements given in Table 3 can be taken as a reasonable base for estimating the future academic market for new doctorates." A skeptic would ask if these were "independent" studies and would question their underlying projection models before accepting the "reasonableness" of the estimates.

28. It is my understanding that NSF is revising these projections by re-estimating trend equations in the light of more recent data on first-year graduate enrollments, supplies of doctorates, Federal R

and D spending, etc. The inventory of doctorate scientist utilization is also being up-dated, and the methodology attempts to incorporate a feedback in which first year enrollments are related to the supply/ utilization projections.

29. Further evidence on the sensitivity of this methodology can be found in Lincoln E. Moses (1972). Moses using a similar technique but having the advantage of more recent time series data on bachelor degrees and first graduate enrollments in Physics, developed his own projections of the output of Ph.D. physicists which were (not surprisingly) considerably below the earlier projections by the Office of Education and by Cartter.

30. The data for doctorates represent geometric means of annual incomes from all sources for six cohorts of Ph.D.'s who responded to the NRC survey; confer "Careers of Ph.D.'s", NRC (1968). The NRC questionnaire asked each respondent to report his 1963 annual income and to report (based on recollection) his income in 1960, 1955, and on back to 1935. In developing Table 3.4, I assumed that cohort 6, (degree recipients in 1960) was, on average, 30 years of age. The income for 35 year-old Ph.D.'s was taken to be the geometric mean for cohort 5 (degrees conferred in 1955), etc. Annual earnings for the intervening ages (e.g. 32 or 58) were calculated from log-linear interpolations and extrapolations. I also assumed that in his first four years of employment, (ages 26-29), annual earnings increase at 4 percent per annum, and jumps by 10 percent upon receipt of his degree. The income data for "bachelors" are the annual incomes of white males with exactly four years of college education as reported in the 1960 Population Census. I wish to express my thanks to Prof. Sherwin Rosen who supplied these data to me.

31. The annual equivalent income streams appearing on lines 3-a and 3-b of Table 3.4 are simply the constant income levels that would have generated the present values shown on lines 2-a and 2-b. Lines 4-a and 4-b simply show the difference in lifetime earnings.

32. The "always nonacademic" group earns roughly 20 percent more than all doctorates due largely to the fact that the always nonacademic doctorates are more likely to be in engineering, chemistry, physics, and some of the biological sciences.

33. Technological advances and an increasing ratio of capital to labor are the two most frequently cited explanations for the secular growth in real per capita income. The permanent rate of inflation cannot be predicted, but growth rates for money incomes of 3 to 8 percent seem plausible. In deriving (3.1'), I tacitly assume that relative incomes [e.g. ratios like (Y_{Dt}/Y_{Bt})] will be unaffected by inflation and growth.

34. The importance of this adjustment for the secular growth in money incomes was recognized by Weiss (1971) who used data for 5,868 scientists to estimate the monetary returns to the Masters and Ph.D. degrees. In a sense, the distinction between r and r^* is akin to the distinction between real and nominal interest rates.

35. The NRC data on starting Ph.D. salaries pertain to individuals who have just received the degree. They are thus not representative of the starting pay on the first appointment immediately following full-time graduate study.

36. Since living expenses will be incurred irrespective of the decision to invest in a Ph.D., only the extraordinary incremental living costs arising out of having to live in specific localities, should be included in the full economic costs.

37. The data were taken from Table 128 of the Digest of Educational Statistics, 1972. The same table presents data from the survey on tuition and room and board expenses for four and two year colleges. I have limited the data shown in Table 3.6 to universities.

38. The Endicott data on starting salaries are higher than the 1959 Census data on earnings of white male college graduates, 22-24 years of age. Similar discrepancies are also observed for 1949 and 1969. If I had used the Census figures for foregone income, it would have reduced the economic costs by around 15 to 20 percent.

39. Weiss (1971) estimated the internal rate of return to the Ph.D. degree for an unsubsidized student with no outside income at 6.67 percent. Confer Weiss (1971) for comparisons with other estimates of the rate of return.

40. The data reported in Table 98 of the Digest do not indicate the size of the stipend. The sample is a head count with 45.5 percent of all graduate students being 29 years of age or older. The percentage holding stipends fell with age, but this may be due to a contemporaneous correlation with larger fractions of older students being part-time graduate students; only 26 percent of part-time students held stipends. Some 66 percent of full-time students received stipends. There was very little difference between public and private universities, this may, in part, reflect different ratios of full to part-time students.

41. The Mooney sample included Fellowship recipients in 1959-61. His cut-off date of 1966 may partially account for the low completion rate. It will be shown below that only 54.1 percent of all Ph.D. recipients complete the requirements in less than eight years.

42. This does not mean that the Ph.D. is a pre-requisite for these positions. Non-doctorates do hold down important positions on graduate faculties and make important contributions to the scientific literature. The value of the Ph.D. in securing such positions is, however, substantial as evidenced by the recent embarrassing confessions by two heads of research organizations in Colorado who admitted that they had fabricated their Ph.D. degrees.

43. A truly optimal (ideal) equilibrium would be one in which given the salaries and attributes of various jobs, no Ph.D. would want to trade positions with any other Ph.D. and no employing institution would want to swap with another. This presumes that the Ph.D.'s involved in these conceptual exchanges possess comparable talents.

44. Weiss (1971) found very low rates of return to the Masters degree, and in some fields, it was even negative. Breneman (1970A) seems to feel that the monetary returns to graduate education are negligible for those who do not complete the Ph.D. degree. The issue here is an empirical one that could, in principle, be settled by a good empirical study on the returns to partial graduate education.

45. The ratio of monetary returns to cost, (E/γ) has exhibited considerable variations across fields. In the 1950's, when fellowship, TA, and RA funds were relatively scarce, medical schools were able to attract the very best of each senior class. As more public funds were allocated to fellowships, it was alleged that the quality of first-year medical students declined. Finally, the previous links between undergraduate and graduate fields seem to be breaking down. Most of us would agree that an AB degree in history is unlikely to qualify a student for admission to a doctoral program in physics. Medical schools would not have admitted history and mathematics majors only a decade ago, but many are now doing just that.

46. The problem of quality adjustments is present in all studies. We must somehow combine Ford Pintos and Pontiacs in constructing a measure of the output of the automotive industry. The problem here is relatively simple since market prices provide a measure of quality differentials. The heterogeneity of individuals who are awarded the same degree, creates a difficult problem in defining the "output" of <u>equivalent</u> degrees. In the model proposed by Breneman (1970A), Ph.D.'s are classified according to a five point scale. By attaching a cardinal measure to the scale, it would be possible to construct a measure of the output of equivalent Ph.D.'s.

47. State appropriations for higher education are often tied to student enrollments (U,G), and the variable part of such appropriations should properly be included in R. The marginal revenue from an increase in undergraduate inputs, $R_u = dR/dU$, should include the "net tuition" [less

scholarships] plus tied appropriations. If fellowship, TA and RA awards to students exceed tuition plus State appropriations, it might happen that the marginal revenue of an additional graduate student, $R_g = dR/dG$, could be negative. Research X that is funded by public agencies, non-profit organizations, or private parties, usually contributes to the university's revenue. If, however, more research is financed out of the "general funds" of the university, $R_x = dR/dX$ will be negative. Presumably, when $R_x < 0$, the research contributes enough to the achievement W to warrant the outlay.

48. The effects of faculty inputs on the outputs, (B,D), are buried in some unspecified relationship of F to the attrition rates (α,δ). Further, more graduate students can affect the output of bachelors, especially if they are used as TA's. The difficulties of measuring equivalent outputs and inputs will be discussed in the text.

49. This conclusion is obvious under the first path since increasingly larger stipends must be offered to attract qualified applicants away from competing institutions. The marginal revenue, $R_g = dR/dG$, would be negative if stipends over and above tuition waivers were needed to attract another student. Under the second path, we must somehow convert students into equivalent quality units. The exceptional cases of students with low GRE scores from poor schools who do well in graduate school [and earn Ph.D.'s], prove the rule that there are trade-offs along the quality dimension. There is, in principle, some number of students with GRE scores of 80 from Ferdonia State who together are equivalent in quality to one student from Reed with a GRE of 95.

50. Senior, tenured faculty are more likely to be assigned to the graduate courses, and the new faculty are often used to replace senior faculty in undergraduate courses. If the expansion is accomplished by hiring tenured faculty, the university incurs a long run obligation that may have serious impacts on future budgets.

51. It should be repeated that the incubation period is measured here in calendar time and <u>not</u> time spent in full-time graduate study. The observations in the right tail of these frequency distributions reflect (a) delays in beginning graduate study, (b) part-time study toward the degree, (c) delays in completing the dissertation after taking a full-time position, etc. Weiss (1971) reports that the variance of the time input needed to earn a Ph.D. (measured in semesters or quarters of full-time registered study) is considerably smaller than the variance in calendar time.

52. It is my understanding that the NSF supply model is based on estimates (by field of study) of the time profiles of completion probabilities, π_j, calculated from the first-year graduate enrollment data assembled by the Office of Education. There are substantial differences in both the mean incubation period and the ultimate completion probability. Women and Blacks tend to take longer to complete the Ph.D. and smaller fractions of them earn the degree.

53. Breneman specified a production function in which the output of Ph.D.'s (in relation to graduate enrollment) was related to the output of terminal Masters degrees, the faculty/student ratio, the proportions of graduate students receiving fellowships, RA's, and TA's, and the AEC rating of the department. He assumed a linear form for this production function and estimated its parameters using cross-sectional data for a sample of Berkeley departments. Breneman's model tacitly assumes that all departments (Chemistry, French, Economics, etc.) confront the <u>same</u> technical production function for producing Ph.D.'s. Further, his data implicitly assume that students are homogeneous both within and across departments. His model is suggestive, and it would be enlightening to urge further research along these lines. The model could, for example, be extended to incorporate micro-economic data on the student inputs, to allow for the allocation of faculty time to research as well as to undergraduate and graduate teaching, etc.

54. The following formula was reported by Breneman (1970B) as the one which was used by the California State University system to determine the number of full-time equivalent (FTE) faculty positions in each department.

$$FTE = \frac{1.0(LD) + 1.5(UD) + 2.5G_1 + 3.5G_2}{38}$$

where LD = lower division enrollment, UD = upper division enrollment, G_1 = first-year graduate enrollment, and G_2 = advanced graduate enrollment. The direct faculty cost per graduate student is 2.5 to 3 times greater than that for an undergraduate, even though the two pay the same tuition. The formula makes no allowance for authorized faculty slots that are supported by internal or external research funds.

55. According to Breneman (1970A), many students interpret their admission to a doctoral program as implicit evidence that in the view of the department's faculty, they possess the necessary qualifications to earn a Ph.D. degree.

56. In his scenario of the Berkeley Chemistry department, Breneman argued that nonacademic appointments were "neutral" with respect to the department's reputation and prestige index U that was presumably being maximized. Hence, the Chemistry department expanded its demand for graduate student enrollments by lowering the attrition rate and the time required to earn the degree. I suspect that many of these nonacademic chemists were employed in research positions that encouraged publications and participation in professional meetings and conferences. If so, their research output would make a positive contribution to the department's prestige. If the nonacademic jobs were <u>not</u> in research, would the Chemistry department behave in the same manner?

57. Moses (1972) pointed out that between 1969 and 1972, the fifteen largest departments reduced their physics enrollments by 30 percent, while physics enrollments in all institutions fell by only 17 percent. It seems reasonable to suppose that the fifteen largest departments are

likely to be the older institutions. No clear inference can, however, be drawn since it might have been the case that the contraction in Federal and public funds was larger for these fifteen departments.

58. In the light of the long incubation periods that are needed to produce Ph.D.'s, it should be possible to assemble fairly reliable data on the inventory of "Ph.D.'s in process". Nearly all of the students who will be receiving doctorate degrees in the next four to six years, either are already in the pipeline or have accepted admission offers to enter the doctoral programs for the coming fall semester. The graduate deans who presumably have such data at their disposal, predict virtually no change in the annual output of Ph.D.'s for the next four to five years.

59. Certain private and one or two public universities point with pride to their track records of employing faculty members who have made significant and original scholarly contributions to the advancement of the sciences and arts. It is not surprising to find that these institutions typically have lower student to faculty ratios because their faculties are making substantial contributions to scientific and literary research. Moreover, to the extent that public agencies and non-profit research organizations are prepared to allocate research funds to the university's budget, these financial considerations will also affect the equilibrium students to faculty ratio.

60. Institutional practices with respect to tenure arrangements and salary policies may prevent a university from implementing some of these substitutions.

61. The validity of even this modest contention can be debated. If there are lags in adjustment, a policy initiated and undertaken in year t may affect doctorate supplies in demands in years t+1, t+2, ...
In this event, the policies prevailing in the recent past may generate time paths for doctorate supplies and demands that are very different from extrapolations of trends on the dependent variables.

62. It is reminiscent of the story of the two rabbis who were studying the question, "Which is more important, the sun or the moon?". After considerable debate, they concluded that it was the moon because it gave light in the night when it was most needed.

Table 2.1

Assumed Parameter Values for the Balderston-Radner Model

	University		Four Year College		2 Year College	
	Public	Private	Public	Private	Public	Private
k = allocative share of students						
1. $k_j = k_j(70)$	.242	.082	.255	.163	.239	.020
2. f_j	-.0017	-.0015	.0012	-.0011	.0031	0
3. $k_j(90)$	.208	.052	.279	.141	.301	.019
R = student/faculty ratio						
4. $R_j = R_j(70)$	16.64	11.26	17.86	14.54	21.64	17.72
5. G_j	.132	.063	.143	.077	.132	.236
6. $R_j(90)$	14.00	10.00	15.00	13.00	19.00	13.00
P = doctorate share of new appointments						
7. $P_j = P_j(70)$	.543	.543	.389	.389	.059	.059
8. H_j	.01785	.01785	.01805	.01805	.01205	.01205
9. $P_j(90)$	.900	.900	.750	.750	.300	.300

Table 2.2A

The Balderston-Radner Projections of New Doctorate Requirements*

Year	Population 18-21 years	Student Enrollment	Faculty	New Doctorate Requirement no change	adequate finance
1970	14540	6303	374.6	7.16	8.82
1971	14870	6755	403.6	11.90	14.69
1975	16307	8197	500.4	10.12	15.32
1980	16790	9537	599.8	6.95	13.90
1985	14992	9228	597.2	-2.73	-2.21
1990	14351	8674	579.5	5.29	15.33

*Notes: The population figures (in thousands) is a four year moving sum of the 18 year-old age class and are thus, unadjusted for death and immigration. Student enrollment, S(t) was taken from BR (1971), Table 3-1. Faculty figures were computed by multiplying the weighted mean faculty/student ratio, 1/R, times S(t). The projected annual requirements for new doctorates were taken from BR (1971), Table 3-3.

Table 2.2B

Decomposition of the "Adequate Finance" Projections

Component	1971	1980	1985	1990
1. Separation rate δ	.02	.02	.02	.02
2. Student Enrollment dS/S	.0717	.0228	-.0301	.0151
3. Student/Faculty ratio dR/R	-.0053	-.0071	-.0061	-.0065
4. Doctorate share, δ(dP/P)	.0008	.0007	.0006	.0004
5. Sum lines 1-4	.0978	.0506	-.0034	.0420
6. WS	141.7	302.1	361.0	376.5
7. New Doc. Req. D(t)	13.9	15.3	-1.2	15.8

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Table 2.3

Continuation Rates from High School Graduation to Bachelor Degree

Year of HS Grad.	H	ϵ	Year of B degree	$(1-\alpha)$	$\beta = H\epsilon(1-\alpha)$
1948	54.0	47.67	1952	58.52	15.1
1949	56.5[i]	45.19[i]	1953	54.97	14.0[i]
1950	59.0	42.71	1954	57.16	14.4
1951	58.8[i]	43.60[i]	1955	61.41	15.7[i]
1952	58.6	44.49	1956	58.48	15.2
1953	59.3[i]	46.73[i]	1957	60.14	16.7[i]
1954	60.0	48.97	1958	58.53	17.2
1955	60.4	49.45	1959	57.65	17.2
1956	62.3	50.53	1960	55.23	17.4
1957	63.0	49.90	1961	55.68	17.5
1958	64.8	51.28	1962	54.10	18.0
1959	63.4	49.93	1963	55.07	17.4
1960	65.1	49.52	1964	54.02	17.4
1961	71.3	51.67	1965	52.92	19.5
1962	69.5	53.54	1966	53.47	19.9
1963	70.5	53.66	1967	56.85	21.5
1964	76.3	53.49	1968	54.43	22.2
1965	75.6	54.10	1969	53.38	21.8
1966	74.9	51.57	1970	60.03	23.2
1967	76.5	53.69	1971	60.99	25.1
Mean	64.99	49.585		56.651	18.32
S.D.	7.11	3.536		2.696	3.08

Symbols:

H = percentage of the 17 year age class graduating from high school.

ϵ = percentage of the high school graduating class who enroll for the first time in college.

$1-\alpha$ = the survival rate defined as bachelors in year t expressed as a percentage of first time enrollments in year t-4.

β = the percentage of the 17 year age class t-4 years earlier who earn a bachelor's degree.

Table 2.4

Bachelor and Advanced Degrees Awarded by All Institutions, 1948-71

	No. of Degrees			Continuation Rates*		
Year	Bachelor B_t	Master M_t	Doctorate D_t	M_t/B_{t-2}	D_t/B_{t-5}	$D_t/\overline{B}_{t-5}$
1948	272311	42449	3989			
1949	366698	50763	5050			
1950	433734	58219	6420	0.214		
1951	384352	65132	7338	0.178		
1952	331924	63587	7683	0.147		
1953	304857	61023	8309	0.159	0.0305	
1954	292880	56832	8996	0.171	0.0245	0.0252
1955	287401	58204	8840	0.191	0.0204	0.0224
1956	311298	59294	8903	0.202	0.0232	0.0232
1957	340347	61955	8756	0.216	0.0264	0.0257
1958	365748	65614	8942	0.211	0.0293	0.0289
1959	385151	69584	9360	0.204	0.0320	0.0317
1960	394889	74497	9829	0.204	0.0342	0.0331
1961	401784	78269	10575	0.203	0.0340	0.0338
1962	417846	84855	11622	0.215	0.0341	0.0343
1963	450592	91418	12822	0.228	0.0351	0.0352
1964	498654	101050	14490	0.242	0.0376	0.0379
1965	538930	112195	16467	0.249	0.0417	0.0418
1966	551040	140555	18237	0.282	0.0454	0.0450
1967	594862	157892	20621	0.293	0.0494	0.0487
1968	666710	176749	23089	0.321	0.0512	0.0507
1969	769683	194414	26189	0.327	0.0525	0.0528
1970	827234	208291	29866	0.312	0.0554	0.0564
1971	877676	230509	32107	0.299	0.0583	0.0572
Sum				5.0680	0.71520	0.68400
Mean				0.2304	0.03764	0.03800
S.D.				0.0534	0.01146	0.01145

*The base for the last column is defined as:

$$\overline{B}_{t-5} = \left(\frac{1}{3}\right)[B_{t-4} + B_{t-5} + B_{t-6}]$$

Table 3.1

Supply and Utilization of Science and Engineering Doctorates
(actual, Jan. 1969 and projected 1980)

Item	Total	Hard Sciences*	Social Sciences
1. Actual 1969 Utilization	158.0	123.0	35.0
1.a Academic	94.3	68.8	25.5
1.b Non-academic	63.7	54.2	9.5
2. High Projected 1980 Utilization	297.4	226.9	70.5
2.a Academic	165.1	116.6	48.5
2.b Non-academic	132.3	110.3	22.0
3. Low Projected 1980 Utilization	269.7	203.7	66.0
3.a Academic	163.5	115.1	48.4
3.b Non-academic	106.2	88.6	17.6
4. Supply Projections			
4.a High	335.6	248.3	87.3
4.b Low	314.8	233.5	81.3
5. Maximum Surplus			
(line 4-a minus line 3)	65.9 (19.6)	44.6 (18.0)	21.3 (24.4)
6. Minimum Surplus			
(line 4-b minus line 2)	17.4 (5.5)	6.6 (2.8)	10.8 (13.3)

Source: NSF 71-20, p. 6 and p. 24

*The hard sciences include physical sciences, life sciences, mathematics, and engineering.

Table 3.2

Doctors Degrees Conferred by Field

(actual 1961-72, projected 1978-80)

Year	All Fields		Hard Science		Social Science		Non-Science	
	No.	change	No.	change	No.	change	No.	change
Actual								
1961	10,411	---	5,047	---	1,829	---	3,535	---
1962	11,507	10.5	5,675	12.4	1,944	6.3	3,888	10.0
1963	12,720	10.5	6,345	11.8	2,082	7.1	4,293	10.4
1964	14,324	12.6	7,142	12.6	2,329	11.9	4,853	13.0
1965	16,302	13.8	8,290	16.1	2,411	3.5	5,601	15.4
1966	17,865	9.6	8,946	7.9	2,708	12.3	6,211	10.9
1967	20,295	13.6	10,003	11.8	3,187	17.7	7,105	14.4
1968	22,834	12.5	11,126	11.2	3,579	12.3	8,129	14.4
1969	25,734	12.7	12,314	10.7	4,051	13.2	9,369	15.3
1970	29,436	14.4	13,603	10.5	4,700	16.0	11,133	18.8
1971	31,772	7.9	14,276	4.9	5,316	13.1	12,180	9.4
1972	33,001	3.9	13,966	-2.2	5,574	4.9	13,461	10.5
Projected (NSF)								
1969	26.2	---	12.18	---	3.66	---	10.40	---
1970	28.4	8.4	12.82	5.3	4.06	10.9	11.54	11.0
1971	31.4	10.6	13.82	7.8	4.53	11.6	13.09	13.4
1972	33.7	7.3	14.29	3.4	4.94	9.1	14.49	10.7
1973	35.9	6.5	14.73	3.1	5.25	6.3	15.90	9.7
1974	38.4	7.0	15.74	6.9	5.65	7.6	16.94	6.5
1975	39.1	1.8	15.90	1.0	6.05	7.1	17.12	1.1
1976	40.4	3.3	16.32	2.6	6.46	6.8	17.56	2.6
1977	41.4	2.5	16.61	1.8	6.86	6.2	17.86	1.7
1978	42.6	2.9	16.97	2.2	7.26	5.8	18.42	3.1
1979	43.9	3.1	17.33	2.1	7.67	5.6	18.87	2.4
1980	45.2	3.0	17.77	2.5	8.06	5.1	19.42	2.9

Source: Actual degrees conferred taken from National Research Council, Doctorate Record File. Projections are from NSF 71-20, Table B-1, p. 26.

Table 3.3

Doctorate Degrees Conferred for Selected Fields

Field	1961	1966	1970	1971	1972	Growth rate* 1961-72
Physics	597	1,049	1,657	1,740	1,635	9.59
Chemistry	1,150	1,580	2,223	2,204	2,011	5.21
Engineering	940	2,283	3,432	3,495	3,475	12.62
Mathematics	332	766	1,218	1,236	1,281	13.06
Health Fields	101	175	300	349	318	10.99
Zoology	265	395	519	572	551	6.88
Psychology	820	1,133	1,883	2,116	2,262	9.66
Anthropology	60	109	225	258	278	14.96
Economics	413	622	971	951	980	8.17
Sociology	167	258	506	583	638	12.96
Geography	50	55	137	158	177	12.18

Source: National Research Council, Doctorate Record File.

*Figures represent the annual compound growth rate between 1961 and 1972.

Table 3.4

Annual Earnings of Bachelors and Doctorates, 1959-60*

Item	Bachelors	All Doctorates	Non-academic Doctorates
1. Annual Earnings at Age:			
22	3032	0	0
26	5224	6197	7588
30	7099	7614	9290
35	8863	9235	11220
40	10318	11240	13634
45	11199	11492	13061
50	10534	12519	14701
55	11626	12755	15802
60	11435	12942[a]	16735[a]
64	11181	13183[a]	17984[a]
Sum 22-64	407,155	426,421	522,926
2. Present Value of Earnings Y.			
2.a at 5 percent	148,914	143,967	174,759
2.b at 10 percent	74,693	64,909	78,634
3. Annual Equivalent Income $\hat{Y}$			
3.a at 5 percent	8083	9794	11,889
3.b at 10 percent	6905	8,855	10,727
4. Differential in Present Value of Earnings[b]			
4.a at 5 percent		-4,947	25,845
4.b at 10 precent		-9,784	3941

*Source: The bachelor figures are the 1959 incomes of White males with 16 years of education from the 0.1 percent sample. The doctorate figures are the geometric means of six cohorts in 1960 taken from: "Careers of Ph.D.'s, Academic vs. Non-academic" A Second Report on follow-up of doctorate cohorts, 1935-1960. (National Academy of Sciences, Publication 1577, Washington, D.C. 1968), see especially Tables 5 and 7, pp. 26 and 31.

a. Calculated by extrapolating the annual compound growth rate between ages 50 and 55 to ages 60 and 64.

b. Calculated from lines 2.a and 2.b.

Table 3.5

Comparison of Annual Earnings of Doctorates and Bachelors, 1950-73

	1950	1955	1960	1963	1966	1968	1970	1973
1. NRC Cohort Data								
1-a All Doctorates	4,975	6,062	7,614	8,644[a]				
1-b Academic	4,525	5,316	6,976	7,983[a]				
1-c Non-academic	5,957	7,324	9,290	10,182[a]				
2. NSF Median Ph.D. Salaries			10,000	11,500	13,200	15,000	16,500	20,890
3. Starting Bachelor Salaries (Endicott, Business)	2,936	4,060	5,256	5,912	6,816	7,868	9,004	9,696
Relative Earnings of Doctorates								
4-a = (1-a)/3	1.694	1.493	1.449	1.462				
4-b = (1-b)/3	1.541	1.309	1.327	1.350				
4-c = (1-c)/3	2.029	1.804	1.768	1.722				
5 = 2/3			1.903	1.945	1.937	1.906	1.833	2.154

Sources: "Careers of Ph.D.'s" NRC (1968) and NSF Roster of Doctoral Scientists and Engineers.

a. Obtained by extrapolating the 1963 salaries back by three years assuming that doctorate earnings increase at 4 percent per additional year of experience.

Table 3.6

University Tuition and Living Expenses

(selected years)

Item	1959	1963	1968	1973	Growth Rate 1963-68	Growth Rate 1968-73
A. Background Data[a]						
1. Tuition						
Public		281	377	552	6.05	8.08
Private		1,216	1,638	2,412	6.14	8.05
2. Room and Board						
Public		745	868	1,147	3.10	5.73
Private		889	1,035	1,376	3.09	5.86
3. Foregone Income[b]	5,064	5,912	7,868	9,696	5.89	4.27
B. Constructed Data						
1. Tuition	590	749	1,008	1,482	6.12	8.02
2. Living Expense	1,084.	1,225	1,427	1,812	3.10	4.89
3. "Outlays"	1,674	1,947	2,435	3,374	4.89	6.75
4. "Private Econ. Cost"	5,871	6.906	9,161	11,620	5.81	4.87
5. Present Value of "private cost" at r - .05 (000)	21.86	22.70	34.11	43.26	x	x

[a]Source: Digest of Educational Statistics, Table 128 p. 113.

[b]Source: Endicott Series on Starting College Salaries for Business Positions.

Table 3.7A

Distribution of Incubation Period from Bachelor to Doctorate Degrees

Years from AB/BS to Ph.D	Total Sample freq.	Total Sample percent	Total Sample cumulative percent	Degree granted since 1960 freq.	Degree granted since 1960 percent	Degree granted since 1960 cumulative percent
Physical and Biological Sciences						
2-3	9	4.95	4.95	3	3.95	3.95
4	29	15.93	20.88	11	14.47	18.42
5	28	15.38	36.26	11	14.47	32.89
6	25	13.74	50.00	12	15.76	48.68
7	17	9.34	59.34	8	10.53	59.21
8	15	8.24	67.58	6	7.89	67.11
9	10	5.49	73.08	1	1.32	68.42
10	11	6.04	79.12	6	7.89	76.32
11	4	2.20	81.32	2	2.63	78.95
12-14	14	7.69	89.01	8	10.53	89.47
15 or more	20	10.99	100.00	8	10.53	100.00
Social and Behavioral Sciences						
2-3	11	5.91	5.91	3	3.26	3.26
4	21	11.29	17.20	5	5.43	8.70
5	17	9.14	26.34	9	9.78	18.48
6	22	11.83	38.17	12	13.04	31.52
7	20	10.75	48.92	15	16.30	47.83
8	18	9.68	58.60	11	11.96	59.78
9	18	9.68	68.28	9	9.78	69.57
10	11	5.91	74.19	4	4.35	73.91
11	11	5.91	80.17	4	4.35	78.26
12-14	14	7.44	87.63	3	3.26	81.52
15 or more	23	12.37	100.00	17	18.48	100.00
All Sciences						
2-3	20	5.43	5.43	6	3.57	3.57
4	50	13.59	19.02	16	9.52	13.10
5	45	12.23	31.25	20	11.90	25.00
6	47	12.77	44.02	24	14.29	39.29
7	37	10.05	54.08	23	13.69	52.98
8	33	8.97	63.04	17	10.12	63.10
9	28	7.61	70.65	10	5.95	69.05
10	22	5.98	76.63	10	5.95	75.00
11	15	4.08	80.71	6	3.57	78.57
12-14	28	7.61	88.32	11	6.55	85.12
15 or more	43	11.68	100.00	25	14.88	100.00

Table 3.7B

Percentage Distribution of the Incubation Period from Bachelor to Doctorate
(classified by broad field and year of doctorate degree)

Year	Years from AB to Ph.D 2-7	8-14	15 or more	No.	Mean	Standard Deviation
Physical and Biological Sciences						
before 1939	91.7	0.0	8.3	12	6.00	2.98
1940-49	57.1	33.3	9.5	21	7.62	4.43
1950-54	65.7	34.3	0.0	35	6.69	3.01
1955-59	44.7	31.6	23.7	38	9.89	5.97
1960-64	58.8	35.3	5.9	34	8.32	5.83
1965-73	59.5	26.2	14.3	42	8.67	5.10
Total	59.3	29.7	11.0	182	8.18	5.03
Social and Behavioral Sciences						
before 1939	47.1	52.9	0.0	17	7.71	3.41
1940-49	65.0	30.0	5.0	20	6.60	3.07
1950-54	40.0	60.0	0.0	25	8.52	3.66
1955-59	50.0	34.4	15.6	32	8.66	5.13
1960-64	33.3	41.7	25.0	24	10.75	5.63
1965-73	52.9	30.9	16.2	68	9.13	5.40
Total	48.9	38.7	12.4	186	8.77	4.88
Combined Sciences						
before 1939	65.5	31.0	3.4	29	7.00	3.30
1940-49	61.0	31.7	7.3	41	7.12	3.82
1950-54	55.0	45.0	0.0	60	7.45	3.39
1955-59	47.1	32.9	20.0	70	9.33	5.60
1960-64	48.3	37.9	13.8	58	9.33	5.83
1965-73	55.5	29.1	15.5	110	3.95	5.27
Total	54.1	34.2	11.7	368	8.48	4.95