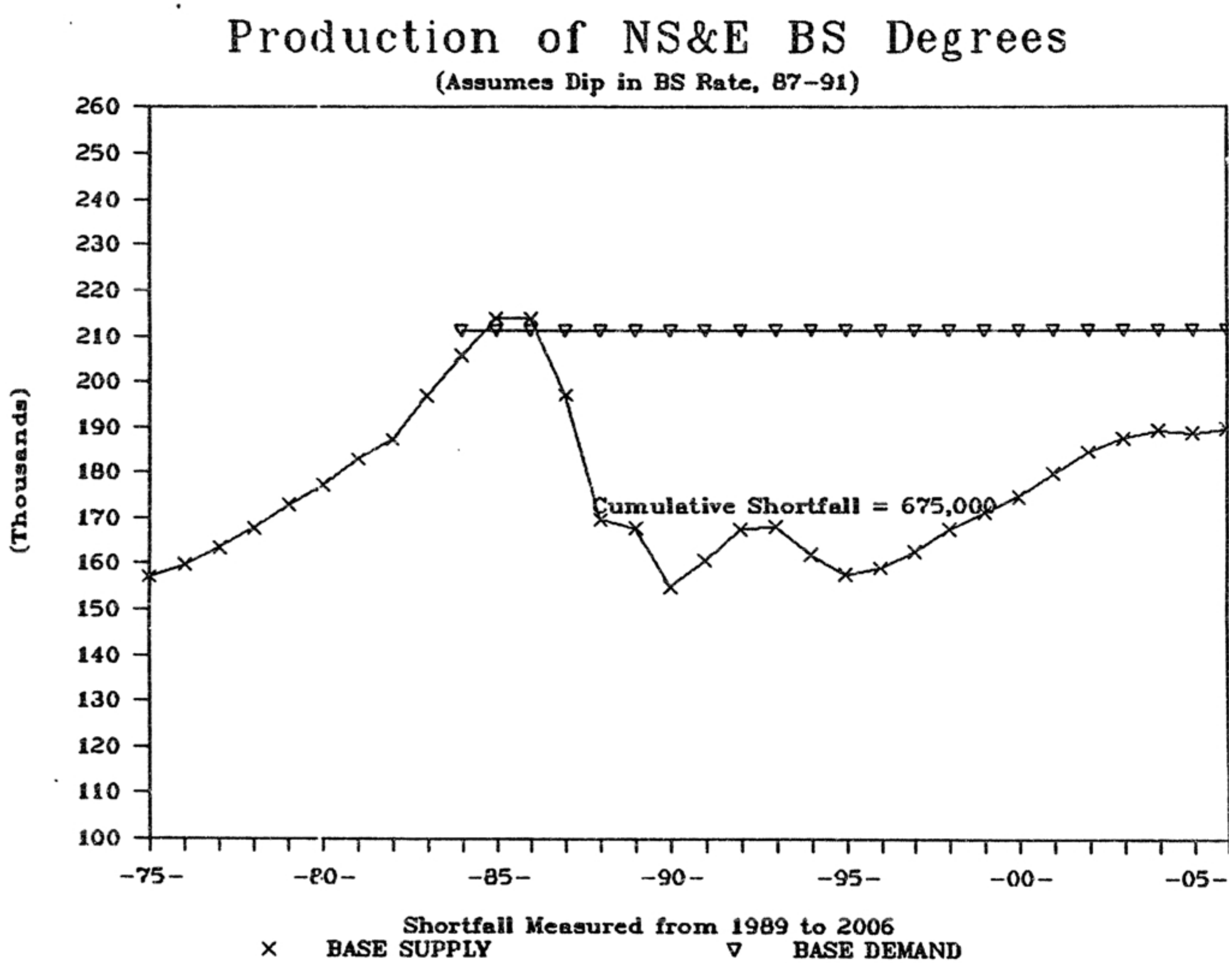

Production of NS&E BS Degrees
(Assumes Dip in BS Rate, 87-91)
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Cumulative Shortfall = 675,000
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Shortfall Measured from 1989 to 2006
BASE SUPPLY
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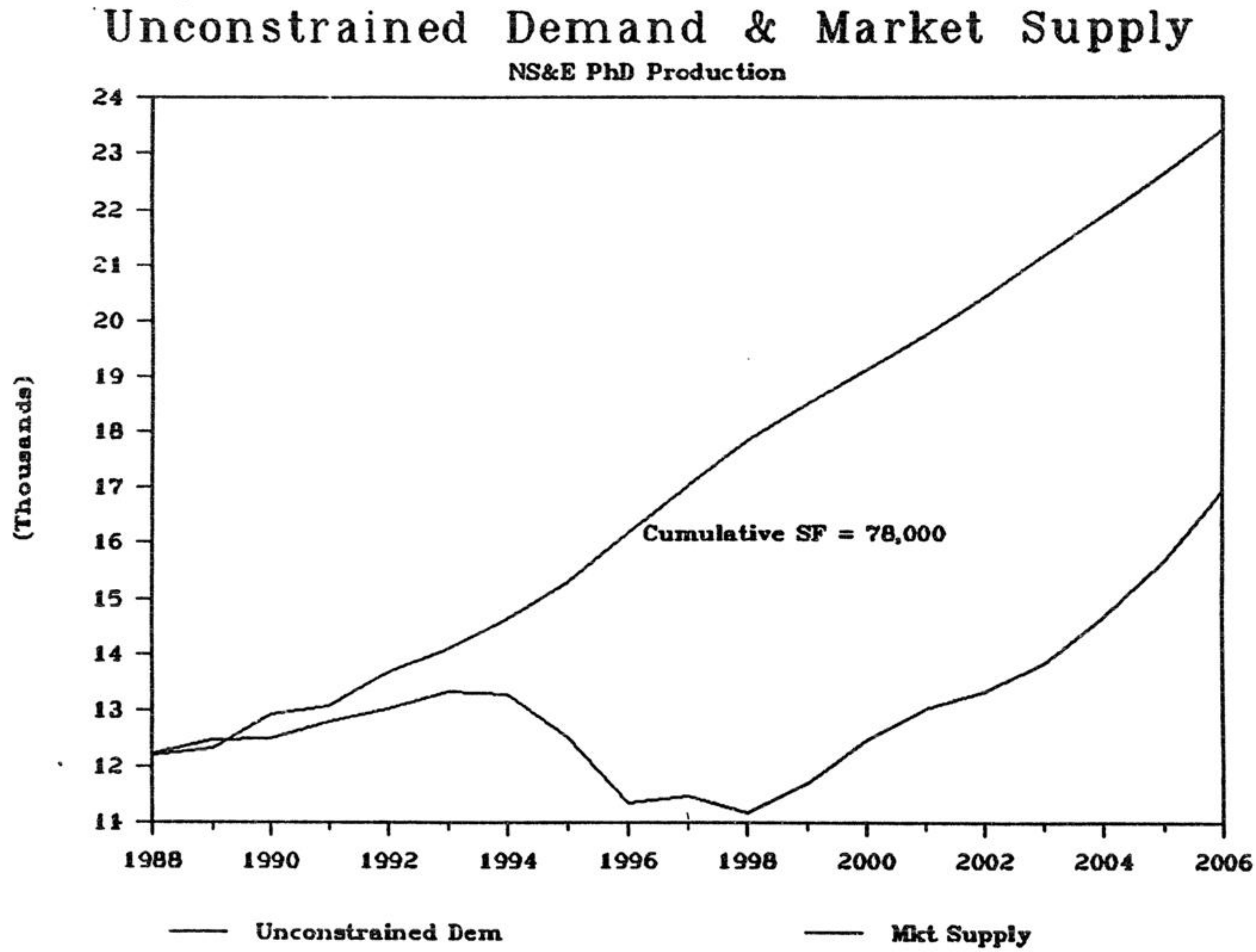
Unconstrained Demand & Market Supply
NS&E PhD Production
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Cumulative SF = 78,000
Unconstrained Dem
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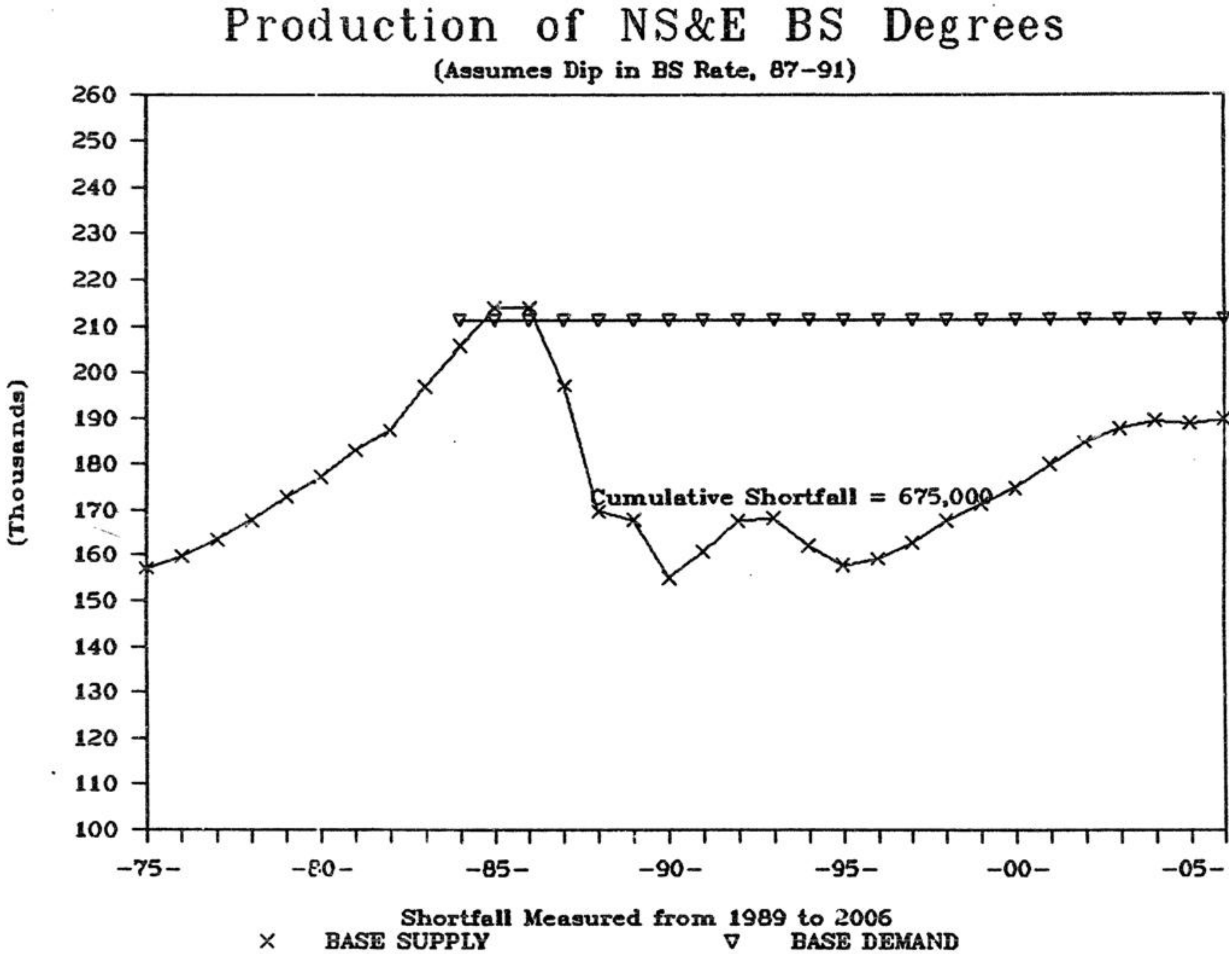
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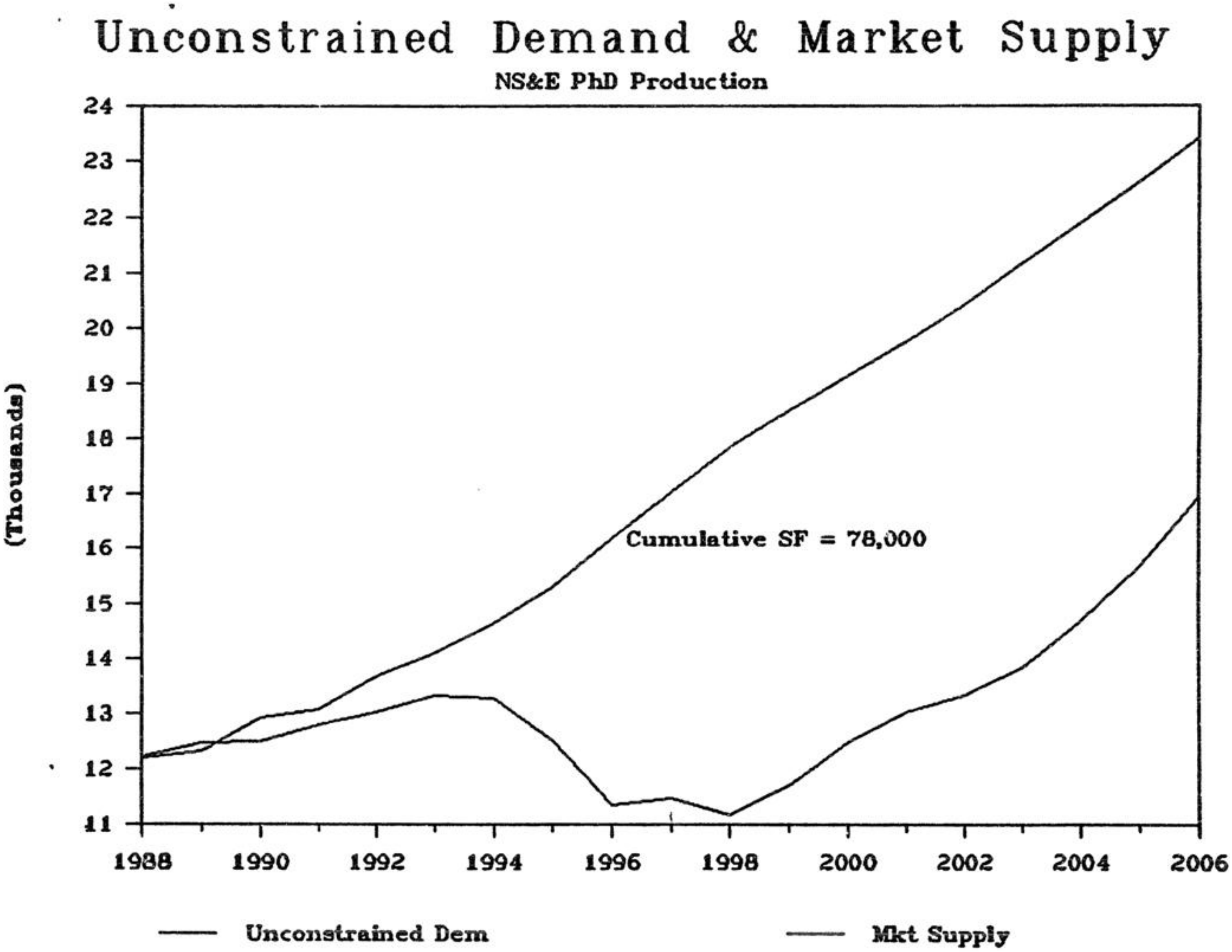
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Cumulative SF = 78,000
Unconstrained Dem
Mkt Supply

Wanted: 675,000 Future Scientists and Engineers

A shortage of technically trained workers is looming, unless more women and minorities can be attracted to science

THE JOBS MARKET for researchers with freshly minted Ph.D.'s is tight right now, creating tough competition for those who want to advance in scientific and technical fields. But if the National Science Foundation's vision of the future is correct, the situation will soon reverse. A "sellers' market" will develop over the next decade, according to NSF, in which companies and universities will be falling all over each other to recruit young scientists and engineers to replace older employees who are coming up for retirement.

That will be good news for those now in the educational pipeline, but it could spell disaster for the U.S. economy. Even though better opportunities should lure able students into science, a shortfall of about half a million scientists and engineers is expected to develop by the end of the century. And this shortfall is looming at a time when overall educational standards in the United States are dismally low in comparison with those of America's major industrial competitors. Says William O. Baker of Bell Labs, the country can no longer operate on the old assumption that "the gifted and talented will see us through."

The crisis that is being widely predicted over the next decade is rooted in an incontrovertible demographic fact: because of low birthrates in the 1960s and 1970s, the college-age population—the raw material for tomorrow's educated workforce—is shrinking. According to the Census Bureau, numbers of 18- to 24-year-olds will bottom out at a little under 24 million in the mid-1990s—compared with a peak of over 30 million in 1980. Currently, a little over 5% of 22-year-old Americans earn B.S. degrees. Unless that fraction is increased, says NSF, there will be a shortage of 400,000 scientists and 275,000 engineers by 2006.

Although the dip in the college-age population will be temporary—the children of the baby boomers will be entering their early 20s in growing numbers in the late 1990s—the nation could still be faced with a shortage of scientific manpower over the long term because of growing proportions of nonwhites in the population. Current new additions to the workforce are mainly women, immigrants, blacks, and Hispanics, groups that have traditionally been grossly underrepresented in science and engineering.

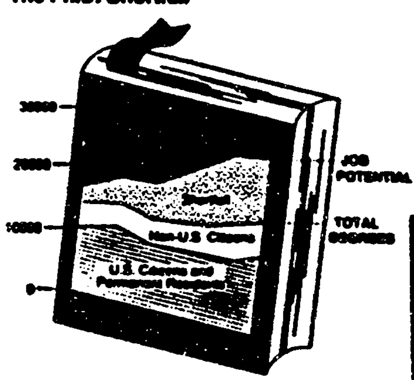
In fact, Jaime Oaxaca of Northrup Industries, a member of a congressionally established task force on women and minorities in science, says recent trends make the NSF's shortfall projections "look super-optimistic." Says Oaxaca: "The dilemma we face is by and large America doesn't believe there's a problem because America's a short-term thinker."

Others are more sanguine. Hilliard Williams, research director at Monsanto Corp., admits that a look at the demographic picture could easily persuade one that "we are headed for a period of immense crisis." But he believes that the fears are exaggerated and that market demand will draw in more people, particularly foreigners, to fill the gap. Aggressive recruitment of women and minorities is essential, he says, but as far as such programs are concerned, "I don't see much of anything having a profound effect in less than 10 years."

Engineer Mildred Dresselhaus of the Massachusetts Institute of Technology, who headed a National Academy of Sciences workshop on women in science and engineering, says that despite spot shortages, the manpower crunch is yet to be felt at higher degree levels. At the moment, she says, students fresh out of graduate school are actually encountering a constricted job market. Industry demand is "soft" because of slow growth in R&D expenditures and academic research funding is tight. But although she believes "demand and supply are pretty well matched now," she predicts "the tide will turn very rapidly" as the rate of retirements accelerates in academia.

On one point, all are agreed: If a long-term shortage of scientists and engineers is to be averted, unprecedented numbers of women and minorities will have to be attracted to technical careers. There are a few bright spots. Asian Americans, for example, are heavily invested in natural sciences and engineering; although they constitute only 2% of the population, in 1986 they garnered 5% of the doctorates in these fields. But overall, recent trends provide scant hope

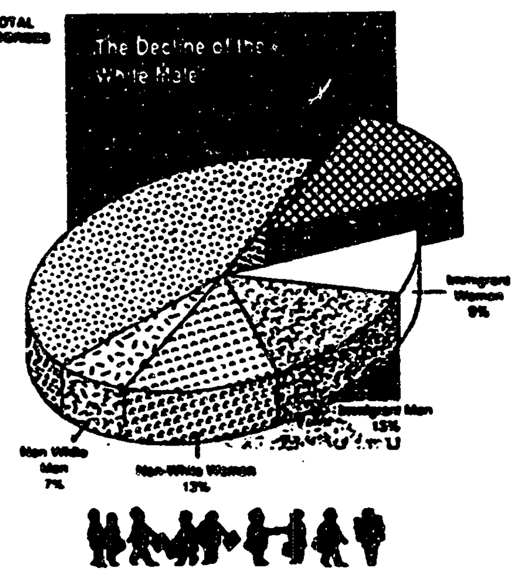
The Ph.D. Shortfall



Source: NSF

The NSF has predicted a shortfall of 675,000 scientists and engineers by 2006 as a result of the dip in the college-age population in the 1990s. This assumes that about 5% of 22-year-olds will get B.S. degrees and 5% of B.S. holders will obtain Ph.D.'s. A shortfall of some 9000 Ph.D.'s is anticipated by 2000, assuming the market causes a rise in salaries. The situation is aggravated by the accelerating pace of retirements from academia—by 2000, about one-third of the current faculty will have to be replaced.

White men now make up 47% of the total workforce and about 80% of the science and engineering workforce of 4.6 million. But they will constitute only 15% of the net number of 25 million people entering the workforce in the last 15 years of the century. By 2010, they will make up less than one-third of the college-age population.



Source: U.S. Department of Labor

that women and minorities will plug the projected gap.

The number of women planning careers in science and engineering appears to have plateaued after peaking in the late 1970s. Female participation in the science and engineering workforce has grown to about 15% from 13% a few years ago. The slowdown is not surprising. Women scientists still suffer higher unemployment, lower pay, and fewer opportunities for promotion at every degree level than do males. According to the Office of Technology Assessment (OTA), "the gender gap in recruitment to and participation in science, reduced by two decades of gains, is in danger of widening again."

Although women account for about one-third of all doctorates in the sciences, they tend to be concentrated in the social sciences and psychology. In fact, the number of Ph.D.'s awarded to women in natural and computer sciences has stayed flat since 1983. A similar pattern prevails at the undergraduate level, with some exceptions—for example, 38% of the freshman class at MIT is now female. The Educational Testing Service reports that only 11% of female SAT-takers, compared with 34% of the males, plan to study the physical sciences in college.

The situation for blacks and Hispanics is, unfortunately, even worse, because both groups continue to lag far behind whites from early elementary school onward. "The participation of blacks and Hispanics in engineering, as well as the physical sciences, shows little sign of substantial increase," says the OTA.

In some respects, the lot of blacks, particularly males, has actually been deteriorating. Blacks, now more than 12% of the population, make up about 2% of the science and engineering workforce. Although various reports claim that they now graduate from high school in roughly the same proportion as whites, the percentage of black high school graduates going on to college dropped from 33% to 26% in the decade ending in 1986. This mainly reflects the dramatic drop in black males going to college: black females on campus generally outnumber black males by two to one.

At the Ph.D. level, the situation is even bleaker. According to the National Research Council, the numbers of blacks earning Ph.D.'s in all fields has dropped by 27% in the past decade. More than half of all black Ph.D.'s are in education. In 1988, according to the NSF, the combined total of Ph.D.'s in the natural sciences and engineering for blacks and Hispanics was a mere 287.

Hispanics, who now make up perhaps 9% of the population, have the worst high school dropout rate of any group and, as with blacks, college enrollment has declined in the past decade. Moreover, only 25% of Hispanics who attend 4-year colleges persist to get their bachelor's degrees. Despite their smaller numbers, Hispanics are getting roughly the same percentages of higher degrees in the sciences as blacks.

Can the pull of market forces lure more women and minorities into scientific careers, as Monsanto's Williams hopes? Even he is discouraged that "the minority community doesn't realize what a gold mine of opportunity sits there today." Industrial competition for minorities and women "is absolutely fierce" and big companies are sometimes offering them higher salaries than white male competitors. But despite that, he says, "the hardest thing in the world to find is a Ph.D. female [or black or Hispanic] chemist."

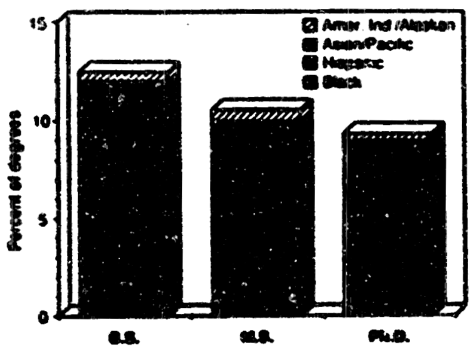
The NSF does not express all that much optimism that the market alone will be enough to fill the gap. Peter House of NSF says the greatest immediate payoff would be from efforts to improve the college retention rate of students who already have an expressed interest in science and engineering. In an April report on future scarcities of scientists and engineers, the NSF says the problem could also be remedied if the 8% of high school graduates who don't go on to higher education, but whose grades and course-taking qualify them as "apparently able," could be induced to go to college. Furthermore, the agency says increased scholarship support would provide quick results, especially at the Ph.D. level. Foreigners won't make up the shortfall, it says, unless there are "significant reductions in barriers to obtaining student visas."

There are enormous numbers of government-, university-, and industry-sponsored programs now operating at all levels of education that are designed to raise the participation of women and minorities in science. But the NSF report says that "it is too late for precollege programs to contribute" to alleviating looming Ph.D. shortages in science.

To NSF director Erich Bloch, it will take 20 years to bring about necessary improvements in precollege education. But even if schools eventually succeed in providing a solid early foundation for all students, there is no guarantee that blacks and Hispanics—or women—are going to gravitate in great numbers toward physics, math, computers, and engineering. Policy-makers seem to have adopted the implicit assumption that these groups should ultimately distribute themselves in the disciplinary patterns favored by white males. But it may be that as the demography of science shifts the landscape too will be altered.

■ CONSTANCE HOLDEN

Minority Progress Stalled

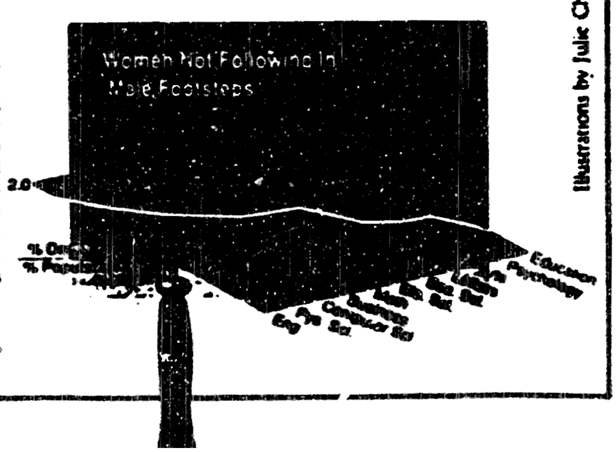


Blacks, Hispanics, and American Indians continue to show high drop-out rates from high school and college, and college attendance has declined over the past decade. Blacks and hispanics make up more than 20% of the population but get only 7% of B.S. degrees and 4% of all science and engineering doctorates. In physical sciences, engineering, math, and computer sciences, proportions of black and Hispanic doctorates each hover in the neighborhood of 1%.

Source: *Educating Scientists and Engineers, Grade School to Grad School*, OTA, 1988

Illustrations by Julie Cherry

Women get almost 40% of B.S. degrees and have been making gains in graduate school. But female interest in engineering seems to have plateaued since 1983. Heavily represented in biology, health sciences, and psychology, they get only 16% of doctorates in the physical sciences, 10% in computer science, and 7% in engineering. Asian women are the only ones who violate the overall pattern: the highest number of B.S. degrees are in computer sciences, math, and biology.



In the inflammatory letter by Nicoll and Russell, I was used as an example of a "'moderate' animal rights advocate" who had supposedly made the statement that "it is pointless to use animals for AIDS research." I made no such statement. There is a great difference between writing off an area of research as "pointless" and a reasoned discussion of its limitations.

The authors went on to describe as "antiscientific and anti-intellectual" my statements that "there is no good animal model for AIDS. There are monkeys which have a disease similar to AIDS but it is caused by a different virus." In fact, this is supported by many others. Note, for example, the *Report of the Presidential Commission on the Human Immunodeficiency Virus Epidemic* (*1*).

> To date, adequate animal models have not been developed for human HIV-related research. An appropriate model is one in which the animal can be infected with HIV and can develop disease similar to that produced by HIV infection in humans. . . .Difficulties with animal models persist. Chimpanzees, for example, can be infected with HIV, but, to date, have not developed AIDS. . . .The lack of appropriate animal models for HIV research makes the application of animal research to humans uncertain. . . .There is also a lack of adequate animal models for vaccine development.

This is not to say that animal research is pointless. But it is to say that the inadequacies of animal models, combined with the extraordinary stresses of isolation, confinement, and manipulation, which are routine in infectious disease research, should encourage a shift toward other methods. Or should the Presidential Commission also be labeled "anti-scientific and anti-intellectual"?

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Post Office Box 6322,
Washington, DC 20015*

REFERENCES

1. *Report of the Presidential Commission on the Human Immunodeficiency Virus Epidemic* (Government Printing Office, Washington, DC, 24 June 1988), pp. 39–47.

Shortage of Scientists

The article by Constance Holden, "Wanted: 675,000 future scientists and engineers" (News & Comment, 30 June, p. 1536), deals with an issue of vital importance to the nation. Holden's discussion of the topic is concise and thoughtful, but misleading in one respect. In the article she states: "White men now make up 47% of the total workforce and about 80% of the science and engineering workforce of 4.6 million. But they will constitute only 15% of the net number of 25 million people entering the workforce in the last 15 years of the century. By 2010, they will make us less than one-third of the college-age population." This statement and the accompanying pie-chart with the caption "The decline of the white male" can be misinterpreted unless they are examined carefully.

The figure of 25 million people is the estimated *increase*, from 115.5 million to 140.5 million, in the workforce between 1985 and 2000 and takes into account not only the number entering but also those who leave. White males, far from disappearing, increase their numbers by almost 4 million. Although their proportion falls from 47% to 41%, they remain the largest group (58 million in 2000). Despite a 10.5 million absolute increase by white women, their representation only rises from 36% to 37% (52 million in 2000). The total of all other groups, increasing by 10.7 million, rises in representation from 17% to 22% (30 million in 2000). The change in makeup of the workforce, while not insignificant, is not as startling as implied by Holden's article.

White males already constitute less than 50% of the workforce. Using the rates of percentage change (−0.4% per year for white males, +0.07% per year for white females), it would take until 2009 for the white male number to be equalled by white females, at which time each group would constitute about 38% of the workforce.

Although white males' dominance of the labor market is declining, it is a slow process and their numbers will remain significant for many generations. It is critical, for a variety of reasons, to increase the number of women and minorities entering the scientific workforce. But no matter how successful we may be in that regard, such efforts will not meet the nation's needs for technically trained people. Graduate fellowships and other incentive programs targeted only at women and minorities will miss the largest pool of potential recruits. The subtitle of Holden's article is "A shortage of technically trained workers is looming, unless more women and minorities can be attracted to science." That recommendation will not suffice. We need to attract more young people to science from all segments of the population.

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*Chancellor,
University of California, San Diego,
La Jolla, CA 92093*

56-061 (231

April 9, 1990

<u>SRS PROJECTION MODEL OF THE U.S. ECONOMY FOR FORECASTING EMPLOYMENT REQUIREMENTS OF SCIENTISTS AND ENGINEERS</u>

I. Why is SRS doing forecasts of S/E requirements?

A. The National Science Board in 1974, expressed concern that better techniques for predicting future demand for S/E personnel were needed so that reliable indices of future demand could be included in the <u>Science and Engineering Indicators</u> reports of the future. SRS was given responsibility for this.

B. Supply projections should utilize dynamic demand projections as an explanatory variable for supply and to assess overall future supply demand balances. We are currently working on just such a supply model and results will be available this year.

C. The public looks to NSF to provide the best projections of requirements and supply of S/E personnel possible with no bias in the assumptions about the future which could impeach their integrity.

II. Differences between SRS and BLS!

A. BLS is only other organization doing projections of S/E personnel within the context of forecasts of the economy and how changes will affect requirements for all occupations and thus changes in relative demand for scientists and engineers compared to other professional occupations. Unlike SRS, they do not attempt to reconcile their projections of individual occupational field requirements with future supply to project potential shortages. Major differences with BLS projections:

1. BLS has small staff responsible for projecting trends for approximately 500 occupations. Attention to S/E fields by SRS staff has resulted in more timely estimates for current S/E employment trends; these trends are identified up to two years before BLS due to quicker turnaround time by SRS to BLS survey results.

2. BLS updates its projections only once every 2 years. However, substantial changes in demand for S/E may occur due to such factors as redirection in Federal funding or the state of the national economy which can seriously impact on outdated projections. We now have the ability to update our projections quarterly, incorporating any changes in leading indicators to assess their impact on the projected requirements for S/E.

3. Economic forecasts are key to reliable projections. In 1980, when we evaluated the economic forecasting models

available to utilize in our projections, we chose the DRI model. As you can see from the Wall Street Journal's evaluation done in 1987 (attached), we made the best choice possible. (BLS also used DRI's macro model for their 1988-2000 projections of the economy) Nevertheless, we incorporated changes in the model to specifically tailor it to producing better estimates of requirements for scientists and engineers and other occupational requirements competing for the supply of talented human resources.

4. To our knowledge, BLS has not analyzed a published short-run projection of requirements (less than 10 years). The SRS modeling system, being linked to the DRI macro model, allows us to do this. Thus, if a recession were to occur, we would be able to examine the short-run impact (1-3 years) on S/E demand using DRI's 3-year business cycle forecasts.

B. Our first projection, for the 1974-85 period, done under Joel Barries' direction, was closer to the actual outcome than BLS's (the only one which can be directly compared to BLS). Using BLS' survey data on actual S/E employment for the basis of comparison, BLS's overall relative error was 8.2 percent of the 1985 S/E stock of S/E jobs. SRS' was 5.5 percent.

Our projection for 1981 to 1987, also done under Joel's direction, shows that there was an overall relative error of only 2.8 percent in our forecast of the 1987 requirements. There was no comparable BLS projection for this period. This is a remarkable accomplishment when you consider that the projection was made during a recessionary period, and we had to forecast the bottoming of the recession in 1982 and the magnitude of the recovery -- which was admirably accomplished by the DRI forecast. As close as it was, over one-half of the 2.8 percent error was caused by Defense outlay cutbacks from the Reagan 1982-87 FYDP of 8.1% real growth rate at the time of our projections to a 2.9% rate implemented in the 1983 FYDP. While our mid-scenario moderated the Reagan growth from 8.1% back to 5.5%, it still resulted in the overestimate of projected 1987 requirements. Had we the resources to have re-run the projections our revised projection of 1983-87 requirements would have been off by only 1.2%.

NATIONAL SCIENCE FOUNDATION

STATEMENT OF

DR. KARL WILLENBROCK

ASSISTANT DIRECTOR

FOR

SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS

BEFORE THE

HOUSE SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES

JULY 31, 1990

Mr. Chairman, I am pleased to appear before you today. This subcommittee is to be commended for holding a hearing on increasing U.S.science and engineering manpower and on the relationship of immigration to this objective.

One of the most important issues facing this nation is the availability of a high quality technical work force. An adequate supply of highly educated scientists and engineers is critical to our economic competitiveness. Our first responsibility, as a Nation, is to increase the numbers of Americans obtaining degrees in the sciences and engineering.

The President's budget for FY 1991 includes an increase in funds to support the education of more U.S. scientists and engineers. NSF is committed to a vigorous program that we believe will meet the challenge of providing America with the scientists and engineers it needs.

However, immigration has, historically, also made significant contributions to our technical talent pool and will continue to do so. By the end of the century, we will be competing with other industrialized nations for a shrinking pool of talent.

In today's global economy, capital and technology easily cross international boundaries and flow to where the human talent is. To compete effectively, the U.S. needs an increase in the number and quality of scientists and engineers. We face many obstacles to achieving this goal:

o The college age population is expected to decline from the 30 million it was in 1982 to 24 million in 1995;

o During this time, the percent of young people from minority groups will increase from 20% to 27%.

Increasingly, women and minorities will constitute a larger percentage of our work force, and these groups, historically, have low rates of participation in the sciences and engineering. To increase the number of scientists and engineers we will have to breakdown the historic barriers that have channeled women and minorities away from technical careers.

If current trends continue, by the end of the century, we will not have enough scientists and engineers to satisfy the needs of our universities, industry, and government. Nor will other nations.

As a group, 29 industrialized and newly industrializing countries which are the major producers of S&E degrees will experience a decline in college age people. Many of these are the very countries which in the past have sent science and engineering graduates with baccalaureate degrees to the U.S. for graduate education.

Approximately half of the full time students in graduate engineering programs in the US are not U.S. citizens, and several of the other disciplines, like mathematics and physics, are not far behind. Foreign students are among the most intellectually able students we have, and they provide an important global perspective to the educational process at our universities. About half of these students remain in the US when they graduate. They contribute to our industries, to our universities, and to our economy and we have grown increasingly dependent on them.

* In 1982, 17% of employed scientists and engineers were foreign born compared to 9.6% in 1972.

* from 1980 to 1988, the number of foreign science and engineering post doctoral fellows working in US universities increased from 5 thousand to 9 thousand.

Recently, the National Academy of Sciences consulted the R&D directors of 20 major high tech companies who said they are "dependent upon foreign talent and that such dependency is growing." Persons born abroad account for:

* 32 percent of US citizens awarded Nobel prizes for scientific achievements since 1945;

* 23 percent of the members of the NAS, and 18 percent of the members of the National Academy of Engineering;

* 20 percent of our science and engineering university faculty; and

* 50 percent of U.S. assistant professors of engineering younger than age 35.

* Currently, 20 percent of the faculty working at 400 US engineering departments earned their Bachelors degrees abroad.

Between 1981 and 1985, 700 foreign engineering and computer students emigrated on the completion of their doctorates. However, in the same period, 4000 new foreign PhD recipients stayed in the US to work, for a net gain of 3300, or 37% of the growth in the US engineering and computer science PHD workforce.

But, this situation may not last. In some countries like Taiwan and Korea have programs to repatriate their S&E nationals from the US, offering them financial inducements, including cash incentives for repatriation, air fares, and other benefits.

A decline in immigration of scientists and engineers has already begun:

* In the last 20 years, science and engineering employment in the United States more than doubled.

* Total immigration grew from close to 400 thousand to nearly 700 thousand.

* However, the INS reports that the small number of scientists and engineers who immigrated to the US has actually declined from 13,300 in 1970 to 10,900 in 1988.

* Scientists and engineers constituted 3.6% of immigrants admitted in 1970, compared to 1.7% of those admitted in 1988.

Under current law, most immigrants come in under family preferences. But scientists and engineers only constitute 1% of those admitted under this provision. In contrast, they constitute 30% of those admitted under the preference which is reserved for skilled workers.

Mr. Chairman, you also asked us to report on the number of foreign born scientists and engineers who leave the U.S.. Unfortunately, no agency of the federal government maintains a count; we can only give rough estimates. The visa status of entering scientists and engineers is a powerful predictor of whether or not they will stay. Immigrants tend to stay. Those who do not have green cards are more likely to return home.

A recent study sponsored by NSF patched together all of the pieces of information we have on immigration and emigration of scientists and engineers from 1981 to 1985. That study found that among foreign born engineering and computer science PhDs living in the US in 1981, 1.3% of those who had become U.S. citizens left by 1985. In contrast, 13.8% of those who had green cards, and 45% of those here on temporary visas left by that year.

Many of those here on temporary visas do succeed in remaining in the US to work. Each year about 18,000 S&E also entered the US on temporary visas. In 1988, 27% of the US engineering Masters degrees and 44% of the Phds went to foreigners here on temporary visas. Of these 62% of the Bachelors and Masters and 50% of the PhDs nevertheless remained here to work.

We estimate that up to 30 percent of science and engineering immigrants leave the United States and continue their careers abroad. Experience shows that about 85% of those who stay in the United States apply for and take U.S. citizenship.

In today's global economy, excluding immigrant scientists and engineers will not protect the jobs of U.S. workers. The Nation already has the benefits of a technologically advanced economy. But retaining that advantage depends on keeping and increasing the pool of trained technical people.

One situation can be addressed directly. Foreigners make up about a third of the post docs at US government laboratories, but virtually all of them are on J-1 visas, which require them to leave the United States upon completion of their work.

Mr. Chairman, there are many indications of the need to increase the quantity and quality of scientists and engineers working in the US. We see immigration as a part of an integrated approach to insuring the availability of the high quality technical workforce we need in both the short and the long term. It complements our efforts to increase the participation of Americans in the sciences and engineering and provides access to some of the best talent on a global basis.

Thank you, Mr. Chairman. That concludes my testimony.

> pipeline:3

Date: ~~<u>20 Aug</u>~~ Dec 91 09:39 EST
To: mcehelsk@nsf.gov
From: jcrawfor@nsf.gov
Subject: 3rd pipeline msg.

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To: JHays
Subject: pipeline and shortfalls
Date: Fri, <u>14 Dec 90</u> 08:09:48 EST
From: Marta Cehelsky (mcehelsk@note.nsf.gov)

Jim: Some points to follow on our telecon last night:

I have completed the COSEPUP memo and you will get it this morning. As you will note, Fred needs to indicate his decision on the last page.

On the other matter, of material or news related to the pipeline controversy, you have the Bob White piece. The BRIDGE, with Alan Fechter's article and Peter's response, is coming to you this morning, as you requested.
(Please call Linda Neuman 357-7613 if you don't get it by this afternoon).

The following have also been critical:

OTA
OMB (Noreen Noonan)

There is also a lot of "noise" from individuals -- an assortment of university officials, professional organization represtatives, etc., at a variety of meetings where the pipeline is discussed, making a point of saying they question or don't believe "the NSF position." AAAS is not exactly in that camp and I believe that Crowley has an open mind, but there are others at AAAS who are more skeptical.

Something you should be aware of: The Fechter issue is not over. Alan made it clear to me when I saw him at the Academy last week that he is preparing another volley for the next issue of the BRIDGE and that he has been getting a lot of supportive letters from what he characterizes as heavy hitters around the country.

What concerns me in all this, as I said to you yesterday, is that NSF not come off in this matter as simply stonewalling. Our critics may be right or wrong, but they are serious people, and some of them are very influential. It would be absurd to maintain that the last word on this subject has been written by us last year. NSF needs to look responsible and responsive.

I think there is an analogy here to the merit review issue and how we have handled it over the last few years. There has never been any question of a radical change in our procedures. But we have taken the position, as an agency, that merit review is a critical issue for us that must be reviewed periodically. We have also taken the position that there is always room for improvement and change in response to new circumstances.

In a similar way, we must look responsive on the pipeline issue and to bring down the noise level. Disagreement with OTA is one thing. But open warfare with the Academy is another story.

I'll be in touch when I'm back in town after the 23rd.

Marta

-------- End of Blind-Carbon-Copy

[183] From: fberntha at nsf4 12/13/90 12:08AM (332 bytes: 2 ln)
To: mcehelsk at nsf15
cc: jawhite at nsf18, jhays at nsf12, kwillenb at NOTE, phouse at nsf15
Subject: pipeline and shortfalls
------------------------------ Message Contents ------------------------------
Jim: Would you "convene" a tiny task force to find out what NSF thinks. Thanks. FMB

90-12-28

SCIENCE, ENGINEERING, AND MATHEMATICS
HUMAN RESOURCES FORECASTING

There is a need for more adequate understanding of science, engineering, and mathematics (SEM) human resources demand and supply in the United States. The principal clients for this information are employers, educators, guidance counsellors, students and the Government.

The process for doing this work is based on several assumptions:

(1) It is impossible to generate a widely credible single numerical estimate of the field by field surplus or shortage of SEM talent. The presentation of a series of closely reasoned scenarios is more credible and useful to the clients of this work.

(2) It is impossible for key operators within social systems to agree on specific numbers that characterize future developments in those systems, but ~~is~~ it may be possible for them to agree on a series of scenarios.

(3) The issue in the SEM human resources forecasts to date, ~~particularly the~~ including PRA's one ~~reflecting a~~ 675,000 short~~age~~fall during the last years of this millennium, ~~is not~~ can relate to the ~~whether or not there will be an~~ overall human resources ~~shortage in these fields~~, ~~but~~ the field by field dynamic interaction of supply and demand and likely results. Nation's strength in human resources. It cannot ~~[illegible]~~ predict ~~[illegible]~~

(4) An important side issue is the so-called "fungibility" question, the degree of difficulty or ease experienced by persons in one SEM field to move to new employment in intellectually adjacent fields.

THE PROCESS

A three-part, on-going project will be instituted to accomplish this.

(1) Since this work is closely related to the Bureau of Labor Statistic (BLS) Occupational Outlook work, BLS will be asked to provide

(a) initial methodological consultations;

(b) certain detailed analyses of their own data to support this work. [This may involve modifications in their existing surveys or additional surveys.]

(2) A group or groups of experts from certain of the client groups--such as industrial employers, educational institutions and associations, students, and parents--will be empaneled to provide (with expert NSF staff support)

(a) statements of questions they would like to see answered,

(b) an indication of the various alternative scenarios they see for future developments of aspects of labor/educational market operations.

(3) A group of analysts in STIA ~~'s SRS Division~~ will then take these questions and scenarios and provide indications of the consequences of each of the scenarios the needs of each major client group, based on the questions they have articulated.

The process is iterative and on-going. When the analysts have completed their work at the end of each iteration in part (3), the results will be presented to the panel(s), who will reexamine the underlying conceptions in their questions and scenarios.

In addition to the main line of this on-going research process, the issue of fungibility will have to be addressed in a related set of studies.

SCHEDULE AND ESTIMATED COSTS

It is anticipated that the process will produce increasingly useful and credible results with each additional iteration. It will be important to complete the first iteration to be completed quickly because of current policy development needs. Three to six months total is contemplated for this first pass, with intermediate products made available to NSF policy-makers on a confidential basis as soon as possible. The schedule and estimated costs will be as follows:

Estimated Costs

ITERATION	ELAPSED TIME	EST. COST PART (1) BLS	EST. COST PART (2) PANELS	EST. COST PART (3) SRS*	EST. COST TOTAL
Iteration 1	4 months	$500,000	$200,000	$100,000	$800,000
Iteration 2	6 months	$600,000	$400,000	$150,000	$1,150,000
Iteration 3	6 months	$650,000	$400,000	$150,000	$1,200,000
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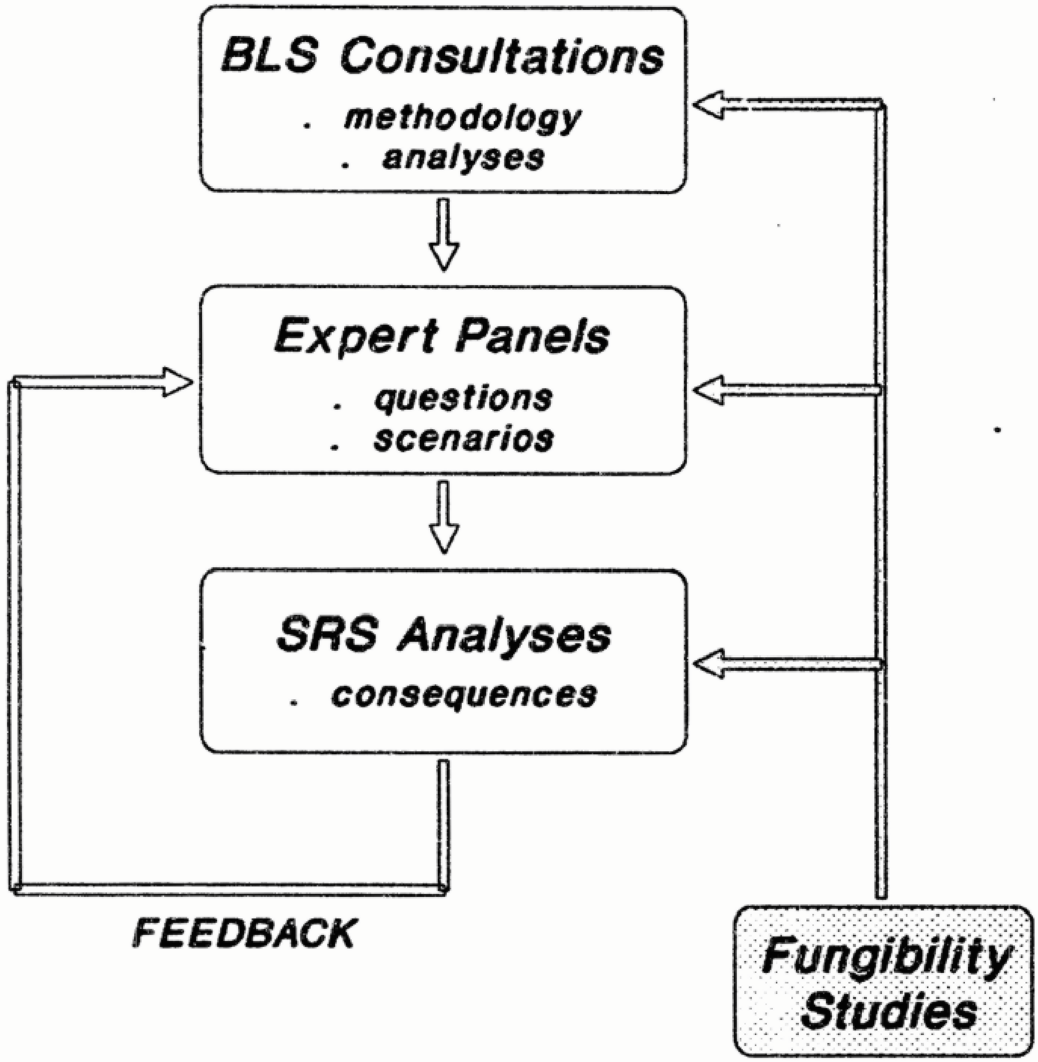
Iteration n	6 months	$700,000	$400,000	$150,000	$1,250,000

THE PROCESS


BLS Consultations
. methodology
. analyses
Expert Panels
. questions
. scenarios
SRS Analyses
. consequences
FEEDBACK
Fungibility Studies

MEMORANDUM

December 7, 1990

TO: F. Karl Willenbrock, Gerard R. Glaser, William W. Ellis

FROM: Leonard Lederman

SUBJECT: Outline of a Program Plan for Determining and Improving the State-of-the-Art on Scientific, Engineering and Technician Personnel Forecasts

Here is the second round of the subject document based on our discussion on Tuesday, December 4. It contains numerous small wording changes plus:

1. The addition of Item III.2 and words to III.1 to take care of Bill Ellis' point of discipline/field/occupation data and information and changing definitions and new fields.

2. The addition of point 5 under IV. Program Elements to take care of the omission we discussed.

3. The addition of consultants, summer interns, supported graduate students under V. Mechanisms #1.

4. The addition of interactive colloquiums reporting results of studies to potential users -- V. Mechanisms, Point 4.

5. A new section VI on Clients/Audiences.

6. The addition of the availability of program staff and outside experts to work for decisionmakers when needed -- V.5 and VI.4.

7. The deletion of "near" and "10 years" to leave time horizon now open ended and the insertion of language promising immediate and continual outputs of utility.

8. The movement of Examples of existing status that provide relevant state-of-the-art information to an appendix (to be added to later) with selected parts of such documents attached to give the reader a more specific example of what is being described.

As you can see, I have not come up with an acceptable short title and would appreciate any suggestions on this.

I believe this addresses the suggested changes called for at our meeting. Please provide your initial feedback by marking up the text, or if any of you feel we should meet and discuss this second draft, let Rose know and she will set it up.

Once we get a text that we are satisfied with, I suggest a discussion with Luther Williams. After any revisions, I think we should discuss the contents with a select group of internal and external knowledgeable people, including program directors, researchers, users and decisionmakers.

Your feedback would be appreciated ASAP and no later than c.o.b. Wednesday, December 12.

Thanks much.

Len

SECOND DRAFT:LLEDERMAN:12/6/90

OUTLINE OF A PROGRAM PLAN FOR DETERMINING AND IMPROVING THE STATE-OF-THE-ART ON SCIENTIFIC, ENGINEERING, AND TECHNICIAN PERSONNEL -- EHR AND STIA

I. **PROBLEM:** There is an insufficient understanding of, and improvement in, the state-of-the-art on scientific, engineering and technician (SET) needs and supply in the future for employers, educators, guidance counselors, students, and government (including NSF program officers) to anticipate potential problems, consider options, and act in the best interest of their constituents.

II. **GOAL:** To provide a significant improvement in the understanding of, and improvement in, the state-of-the-art on SET needs and supply, to point out potential problems, to analyze options for dealing with possible problems (including their advantages and disadvantages), and provide services to federal decisionmakers and other users.

III. **OBJECTIVES:** The objectives of this program are to significantly improve our ability to answer preliminary questions such as the following:

A. Quantitative projections/forecasts/assessments (PFA)

1. What do the various PFA show overall, S and E and T separately, by discipline/field occupation, degree level, and sector/industry?
2. How do the various PFA's deal with changing definitions of, and the new, disciplines/fields/occupations?
3. What different methods, assumptions, scenarios are used?

4. Is it possible to state a consensus? If yes, what would be the ranges?
5. If not, what needs to be done to narrow the differences?

B. Quality Requirements

1. What do we know about changes in SET quality/requirements over time and what explains such changes?
2. What different methods have been used or suggested to deal with quality/requirements determinations and what are the advantages and disadvantages of each?
3. To what extent have technological forecasting/assessments at the industry/product field level been used to forecast future SET personnel requirements and with what results?
4. What factors affect future quality/requirements and the supply of SET personnel adequate to meet them?

C. Quantitative and qualitative results and potential problems and options

1. Can quantitative and qualitative PFA be joined together to show the relationships between them?
2. If so, do the results point to any important potential problems?
3. What options for ameliorating important potential problems exist and what are the advantages and disadvantages of each?

4. What actions might students, teachers, guidance counselors, employers, and government consider given the analysis of options?

IV. **PROGRAM ELEMENTS**

1. Review and describe the state-of-the-art with regard to questions such as those under III and report results to all interested parties.
2. Assess what IV.1 adds up to and what are the most important steps to improvement of the state-of-the-art and communicate results to the research community.
3. Support research that has a high potential for taking the important steps identified in IV.2.
4. Report the results of IV.1, 2, and 3 to potential users, including students, educators, guidance counselors, employers, and government decisionmakers.
5. Assess any potential problems identified under IV.1-3 and options/actions for ameliorating them and provide the advantages and disadvantages of each.

V. **MECHANISMS**

1. The program will be a focused cooperative research and assessment effort involving the internal professional staff, external research performers, panels of experts and potential users of the outputs.
2. A small internal staff (supported by consultants, summer interns, supported graduate students, etc.) will be involved in providing data and information, assessing options and

potential actions, and managing the extramural research.

3. Extramural researchers will submit research proposals that identify and seek to fill important questions/gaps, including literature, data, information, case studies, etc.
4. Results from several related projects will be summarized and presented to potential users in interactive colloquiums.
5. Internal staff and outside experts will be available to work for decisionmakers for short-term assignments.

VI. CLIENTS/AUDIENCES

The diverse clients and audiences for the outputs of this program may be summarized as follows.

1. Decisionmakers in the federal government are the major clients of this program. They will be provided with focused summaries of what is known about the kinds of questions/issues they face, the potential quantitative and qualitative SET potential problems and the options for dealing with them along with their likely positive and negative consequences. Where desirable, program staff/associated outside experts will be available for short-term assignments to work with decisionmakers and their staff (e.g. designing programs, allocating resources, assessing results).
2. Employers will be provided with data and information about the likely quantity and background education/training/ experience of future SET personnel by sufficient occupational detail to assist in their planning and recruitment.

3. Educators will be provided with data and information about the likely future SET skill/educational requirements employers expect to need and the likely demand for SET personnel by industry and occupational field/discipline.

4. Guidance Counselors will be able to use the data and information about the likely future level of new SET jobs, salaries, skill requirements, experience, etc., to provide information to students considering different occupational careers and their educational/experience requirements.

5. Students can use such data and information in considering alternative careers for using their skills and interests and in planning to meet likely educational, skill and experience requirements.

VII. TIMING

While the work described above will be an interactive process with each of the components being pursued simultaneously, major emphasis will shift over time. The following is a preliminary outline of likely emphases over time.

1. The assessment of what is known about the relevant questions, such as those under III and what the important gaps are, are planned for the first 1-3 years and in fact has begun as shown in the appendix.

2. The filling of important gaps will be ongoing from the beginning but concentrated in the 3-7 year period.

3. The explication and analysis of options and actions will take place continually but will be concentrated in the 5-10 year period.

4. Program staff and outside experts will be made available to decisionmakers and their staff whenever needed.

VIII. ESTIMATES OF REQUIRED RESOURCES -- $ AND STAFF

[To be completed later.]

APPENDIX: Examples of existing studies that provide relevant state-of-the-art information.

[Note this is very preliminary and much more material is available that needs to be reviewed. A "Dialog" key word computer search has been completed but the long list of references have not yet been reviewed.]

1. "High School Preparation in Mathematics and Science and Post High School Plans," William B. Walstad (University of Nebraska-Lincoln) and William E. Becker (Indiana University - Bloomington), June 1990 Report to NSF. See Attachment 1.

2. "Scientist and Engineer -- Supply and Demand: A Review," Larry L. Leslie and Ronald L. Oaxasa, November 7, 1990, Draft Report to NSF.

3. "An Investigation Into the Empirical Literature Pertaining to the Science and Engineering Labor Market," Carl W. Ross, Summer Intern, NSF/SRS, August 1987, Report and Abstracts of Econometric Projection Literature. See Attachment 2.

ATTACHMENT 1

Executive Summary

HIGH SCHOOL PREPARATION IN MATHEMATICS AND SCIENCE AND POST HIGH SCHOOL PLANS

by

William B. Walstad

Professor of Economics
University of Nebraska-Lincoln

and

William E. Becker

Professor of Economics
Indiana University-Bloomington

(June, 1990)

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Executive Summary

HIGH SCHOOL STUDENT PREPARATION AND POST HIGH SCHOOL PLANS

An extensive computer search of the major bibliographic and literature retrieval systems in economics, education, and the social and natural sciences was undertaken to determine the relationship between high school student preparation and post-secondary career plans. Our abstracts of nearly 300 studies are available in hard copy and on MS-DOS formatted disks for use with the PFS: PROFESSIONAL FILE program based on key attributes of the studies. The major conclusion of a review of this literature is that the type of secondary school courses taken (and not necessarily the grades received) is the critical determinant of whether a student pursues post-secondary study of mathematics, the natural sciences, or engineering. This finding, however, does not have direct policy implications because the student controls the type of courses taken, and the effort to be invested in courses. At best, policies can provide incentives that encourage (but do not force) high school students to take more mathematics and science courses. Answers to specific questions related to this finding and policy recommendation are the following:

1. How great is the potential interest of students in pursuing careers in the natural sciences and engineering?

The most recent evidence suggests that approximately eighteen percent of all sophomore high school students are interested in pursuing careers in the natural sciences and engineering. Three years later this number falls to about fifteen percent of the high school graduates and to only nine percent by the freshman year of college. For students who complete college, around five percent receive bachelors degrees in the natural sciences and engineering. During high school students flow into and out of the science and engineering pipeline but during the college years there is little inflow. Notable of the recent studies of this issue are the work of Hilton and Lee (1988) with the High School and Beyond data and the Office of Technology Assessment's report (1988) to the U. S. Congress.

2. **What are the various determinants of student interest in and decisions to select science and engineering as a major?**

Variables that are completely outside the control of the student (i.e., exogenous variables) in the decision to select natural science and engineering as a major are many. For example, personal attributes of sex, race and innate ability are obviously beyond the control of the student and are thus exogenous throughout the selection process. Also, factors such as college costs, the availability of financial aid, and the relative wages are beyond the student's control. Even high school course work at the time a student elects a college major is exogenous at that point in time. Decisions made, however, by a student during the high school years do affect post-secondary options; high school courses that are completed by a student influence the decision-making process.

The Office of Technology Assessment's report identifies eleven potential factors that are "most important" in explaining college students' majoring in science and engineering: being in the academic track, taking the most demanding science and mathematics courses, early research participation, intrinsic interest, having good enthusiastic science teachers and counselors, participation in a intervention program, being in a science intensive high school, family socioeconomic status, parents background, race, and sex. The predetermined nature of the schooling items in this list (along with the sample selection problems that result) is not emphasized in this Office of Technology report. Why college cost, financial aid, and relative wages are not included in this list of most important factors is difficult to explain because these are variables that can be altered by policy changes.

There are a number of studies showing that females and nonwhites are less likely to pursue careers in the sciences and engineering than males and whites. The typical reason given for this difference is a lack of interest and confidence in mathematics in high school that is evident in the low enrollment of women and nonwhites in high school upper level mathematics, physics and chemistry courses. For women, this lack of interest and confidence appears to manifest itself in the high school years because researchers (most notably Linn and Hyde, 1989) could not find a "confidence gap" among males and females in the elementary grades. The policy recommendation seems obvious: have teachers and counselors provide a learning environment that demonstrates the usefulness of mathematics and science to women in the pursuit of careers. Chipman and Thomas, however, question whether high school teachers and counselors can affect student interest in mathematics and the sciences. (As argued below, changing the reward structure may produce more pronounced results.)

The external factors provide the greatest means for influencing the flow of natural scientists and engineers. From the early work of Freeman (1976) labor economists have recognized that enrollments in engineering follow salaries in engineering, although it is debatable whether it is starting salaries or lifetime salaries that are the driving force. Most recently, Bishop (1989) has suggested that high school students do not take the more difficult mathematics and science courses because the rewards of a college degree are perceived to be too far into the future (and thus heavily discounted). For those who do not plan to go on to college there is no recognition for high school performance in mathematics and the sciences by prospective employers; thus, why should we expect a fourteen year old who does not plan on going on to college to take geometry, chemistry, and physics? At age 18, if this student has changed his or her mind about pursuing post-secondary education the science and engineering options are no longer available. Policy makers might be wise to consider alternative methods to get employers to base their hiring decisions on high school performance in mathematics and the sciences. To increase the flow of students into careers in the sciences and engineering, financial aid for college needs to be tied to high school performance and specific career plans.

Market wages are currently set in the correct direction to encourage women to enter engineering, assuming they have taken the appropriate courses in high school. Berger's work (in press) shows female starting salaries, as with male salaries, in engineering to be higher than those in the sciences, business, and liberal arts. Only in engineering, however, do female salaries actually exceed those of males. This is somewhat surprising since engineering is male dominated. If this salary differential is sustained we should see an increase in women in engineering.

3. What has been the effect of special programs aimed at increasing the flow of students into the natural sciences and engineering?

Numerous precollege programs have been conducted over the years to increase the pool of scientists or engineers. Typically, the success of these programs has not been rigorously evaluated. There is some indication that local, state and national awards programs aimed at identifying talented youth and encouraging students to study in a particular field have been successful. Winners of scholarships in science fairs have also reported that these events furthered their education and careers. Quick-fix career workshops, however, have not increased the flow of minorities into the natural sciences and engineering.

A basic problem in drawing conclusions from any special program aimed at increasing the flow of students into the sciences and engineering has been that the participants self-selected into the programs and then self-selected into the surveys. As stated by Heckman and Hotz (1989), program evaluators are going to have to begin addressing these selection problems, or alternatively, as suggested by Ashenfelter (1987), truly randomized experiments will need to be conducted.

Executive Summary References

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ATTACHMENT 2

[redacted]

AN INVESTIGATION INTO THE EMPIRICAL LITERATURE

PERTAINING TO THE SCIENCE AND

ENGINEERING LABOR MARKET

By

Carl W. Ross

Division of Science Resource Studies
National Science Foundation, Washington, D.C.

August 1987

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I. INTRODUCTION

Fluctuations in enrollments in science and engineering (S/E) programs at colleges and universities have been a subject of concern for about three decades now. A shortage of S/Es can have serious consequences for the nation's competitiveness while a surplus could be a sign that firms are cutting back on research and development (R&D) spending, and highly trained S/Es will be underemployed. Despite the seriousness of the implications of imbalances in these markets, relatively few comprehensive efforts have been made to project the supply and demand of S/E personnel. The Bureau of Labor Statistics (BLS) does periodic projections of labor supply and demand broken down by sector, but they are based more on extrapolations of demographic trends than on economic relations which describe the behavior of individuals. The National Science Foundation has attempted to generate meaningful projections in the past (see NSF 79-303) but these too, have become dated in terms of the new data and techniques which are now available. More recently, Dauffenbach and Fiorito (1983) have provided comprehensive estimates of behavioral relations and have performed simulations to generate projections based on several demand scenarios. This work has advanced the literature considerably. The vast majority of other work in this area has focussed on fairly narrow aspects of the problem, such as the curriculum choice decision or the decision to enroll in college.

A recent survey of the econometric techniques relavent to this area of study is to our knowledge unavailable. Thus, the main purpose of this paper is to provide an overview of the frequently cited literature which empirically estimates and/or projects some aspect(s) of the labor market for S/Es, with emphasis on key ingredients of the econometric techniques used, and the major findings. The purpose of this study is not to review an exhaustive list of research in this area, but rather to cover a select group of the more technical, recent, and classic works.

The plan for the remainder of the paper is as follows. Section II looks at the demand side of the market, an area which is sparsely covered in the literature. Section III deals with the more prevalent aspects (as treated in the literature) of the supply side of the market. Section IV offers some conclusions. Appendix A contains a short synopsis of estimation in simultaneous equation models, and Appendix B contains short (2 - 6 pages) abstracts of each of the articles cited in this paper.

policy and foreign economic conditions, both of which are totally exogenous to any of the models considered herein.

IV. CONCLUSIONS

The vast majority of the empirical evidence which I have seen and which has been reviewed here supports the hypothesis that S/E labor market behavior can be explained by rational economic behavior and accepted econometric techniques. The received human capital theory of college enrollment and occupational choice has been continuously supported by the data. Most of the econometric work has been directed to better understanding the supply side, presumably because of better data and sturdier theoretical foundations. Nevertheless, more research into the workings of the demand side would be a welcomed addition to the literature.

The evidence seems to indicate that the declining college age cohorts which are due in the late 1980s and early 1990s will not necessarily have a large negative impact on enrollments because enrollment rates will also increase. The reason for these rates increasing is the higher return to college education which accompanies the declining college age (18-21 yrs) population. There are a few caveats to this conclusion however. If enrollment rates increase, who will be the new students opting for college? They are the marginal students who would not have gone had their cohort been larger. Given the intensity of science and engineering programs, these students may not become the scientists and engineers of the future. The proportion of women and minorities attending college may also rise but they may continue to be less prone to enroll in S/E programs. Thus, even if we accept the fact that enrollments will not decline in the next decade, it is still unclear what will happen to the S/E labor force.

The absence of rigorous econometric treatment of the quality of S/Es leaves a hole in the literature and needs to be addressed. The problem of course is data. How does one measure the productivity or quality of a scientist or engineer? A team of molecular biologists might toil for years to discover how a cancerous cell attacks a healthy cell. If their productivity measurement is taken a week before they find the answer, should they get a zero productivity rating? One crude way of measuring productivity of highly trained research professionals in a field is to count the number of articles published in the professional journals, controlling for the increasing number of potential authors - or the rate at which new journals in the discipline are popping up. These are obviously very rough measures for only one aspect of S/E activities.

With respect to methodological chniques, the nested logit model employed by Falaris (1984) deserves more attention than it was given here. A modification of this model might be able to trace a cohort from the decision to enroll in college to the occupational choice decision in one logit model, and thereby simultaneously simplify and sharpen our projection techniques.

The treatment of expectations formation is an area which needs some research as well. While authors have covered several different forms, the disturbing aspect is that the data seem to support all of them, from the static expectations of the early Freeman models to the rational expections of Siow and Stapleton. Some research which examines the different theories of expectations formation with the same data would be a contribution.

Finally is the problem of applying what we know from historical empirical analyses to projection of future markets. With historical data, we can generate parameter estimates of the equations of a model, but to project the dependent variables into the future requires reasonable forecasts of the exogenous variables of the model. Thus at some point, guesswork is necessary. In addition, it is not guaranteed (in fact, it is highly unlikely) that the behavioral parameters of the economic model will remain constant over a long time horizon. The assumption of fixed coefficients can be legitimately made only over a short time period. Variables which are significant determinants of supply or demand may not be hlpful in projecting supply and demand if they themselves cannot be projected.

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EXAMPLES OF SELECTED ABSTRACTS

Ahlburg, D., E.M. Crimmins and R.A. Easterlin, "The Outlook for Higher Education: A Cohort Size Model of Enrollment of the College Age Population, 1948 - 2000", Review of Public Data Use, Vol. 9, 1981, pp. 211 - 227.

Research Questions/Hypotheses

In recent years, speculators have warned that there may be an impending crisis in higher education in the U.S. due to the fact that the baby bust generation is approaching college age. The baby bust refers to the declining birth rates that have occurred since the early 1960s. Those who make these sorts of predictions are implicitly assuming that enrollment rates will remain constant and that increased foreign enrollments will fail to offset the decline in domestic demand for college education.

There is good reason to think that enrollment rates might pick up the slack. It has been shown both theoretically and empirically that the return to college education is inversely related to the number of college students. The larger is the size of one's graduating class (cohort), the smaller are expected and realized salaries, due to the price-adjustment mechanism which occurs when there is excess supply in a market.

The purpose of this paper is to specify and empirically estimate a model of college enrollment rates which incorporates the effect on cohort size on the decision to attend college. The estimated model is then used to make projections of enrollment rates and levels out to the year 2000.

Research Approach

The research approach is actually to estimate four separate, single-equation models - two for males and two for females. For both sexes, the equations are estimated separately for 18-19 year olds and 20-24 year olds.

For males, the graduate and undergraduate enrollment rate is a function of cohort size, real income of the student's father, and the military draft. The cohort size variable is intended to capture the long-run cyclical movement of enrollment rates. The larger the size of one's cohort, the smaller are the anticipated returns to a college education, and the lower will be the enrollment rate. Real income is intended to be a trend variable and we would expect increasing real income to increase college enrollment rates because it represents less of a financing burden on the family. The draft variable captures the short-run, transitory effect of the military draft on enrollment rates. It is set equal to the number of inductees per 1000 males 16 years of age and over for the years between 1960 and 1972, zero otherwise. If a large draft call is expected in the near future, one would expect to see enrollment rates increase.

The model is only slightly different for females. College enrollment rates are a function of cohort size, real income, and a marriage variable. The marriage variable is measured by the percentage of women ever married. It is expected that as this percentage increases, it reflects a favorable marriage market, and college enrollments should drop as women accept more traditional roles. It would be safe to say that none of the editorial board of this journal are strong feminists.

The four equations are estimated by ordinary least squares regression. The model is then used to make projections of college enrollment in five-year intervals out to the year 2000.

The variables and their sources are neatly documented in a footnote to Table 1 in the paper and to repeat it would be redundant. A copy is attached.

Findings

Considering the simplicity, the models display strong explanatory power, with R^2 values ranging from 0.85 to 0.97. The coefficients are generally significant and of the anticipated signs. Both the cohort size and the real income effects are stronger for the younger age groups than for the older, indicating that decisions are made early. Members of the older group are probably already committed to certain career paths, and to change that path would be costly. Hence, they respond less to these sorts of economic decision variables.

In order to project college enrollment rates and hence enrollment levels, the future values of the exogenous variables must be specified. This is easy for cohort size since the future students have already been born. The draft variable is set at zero for the entire projection period, and alternative projections are done with varying hypotheses about the future levels of real income and marriage rates. The rate of growth of real income is projected under the two scenarios of 0.5% and 1.5% per annum over the projection period, while the percentage of women married is allowed to increase, decrease, or remain constant. Under all combinations of scenarios, the enrollment rate increases through to the year 2000, largely due to the favorable (decline) movement in cohort size over the time period. Futhermore, it is only under the worst case scenario of low income growth and high marriage rates that a decline in the <u>level</u> of enrollment is predicted. These projections are less dire than those of other contemporary research.

Appropriateness of Technique

The estimation technique was ordinary least squares which is appropriate if one is willing to assume well-behaved error terms. The Durbin-Watson statistics that were reported indicated the possible presence of positive autocorrelation but I do not think it is a serious case.

The practice of providing projections under various hypotheses about the future paths of the exogenous variables is a good one. When this is not done, projections can be misleading and raise unwarranted fear or bliss.

Reliability of Findings

The single-equation nature of the model imposes some limitations on the richness of the results. One would probably have more confidence in a multi-equation model, which treats other variables (especially the marriage rate) as endogenous.

The data hails from well-respected federal government sources and covers a sizable time frame of twenty-eight years from 1948 to 1976, yielding 29 observations. In this sense, it is better than many other studies.

The enrollment rates used were included both graduate and undergraduate students, which presents a bit of a problem. In using separate age cohorts as exogenous variables, the authors were trying to separate these two groups. However, they could not separate the dependent variable so they did not fully succeed. The decision-making process is much different for an undergraduate than it is for a graduate student.