DOCUMENT RESUME

ED 318 387 HE 023 493

AUTHOR Kay, John
TITLE Investing in the Future: The Need for More Graduate-Educated Scientists and Engineers.
INSTITUTION Southern Regional Education Board, Atlanta, Ga.
PUB DATE 90
NOTE 14p.
AVAILABLE FROM Southern Regional Education Board, 592 Tenth St., N.W., Atlanta, GA 30318-5790 ($5.00).
PUB TYPE Statistical Data (110) -- Reports - Descriptive (141) -- Guides - Non-Classroom Use (055)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Demand Occupations; Doctoral Degrees; Employment Projections; *Engineering; Futures (of Society); Graduate Study; Higher Education; *Natural Sciences; *Personnel Needs; *Recruitment; Student Financial Aid; *Supply and Demand

ABSTRACT

Shortfalls in the number of doctoral-level natural scientists and engineers are expected to grow rapidly by the year 2000. Tables show the number of master's and doctoral degrees awarded in engineering, mathematics, physical sciences, and computer and information sciences in 1980 and 1985 by public universities in the United States, in the southern region, and in 15 individual southern states. Factors contributing to the shortfalls in the southern region are outlined, such as limited incentives in luring young scientists and engineers into graduate work, mobility of graduate degree-holding scientists and engineers, and growing demand. Efforts to encourage more people to seek graduate degrees in these fields focus on industry-based programs, special financial aid programs, improving student achievement in these fields in the earlier grades, and building students' confidence in their abilities. A 21-item bibliography concludes the paper. (JDD)

Investing in the Future

THE NEED FOR MORE GRADUATE-EDUCATED SCIENTISTS AND ENGINEERS

SREB
Southern Regional Education Board

Investing in the Future

THE NEED FOR MORE GRADUATE-EDUCATED SCIENTISTS AND ENGINEERS

John Kay

592 Tenth Street, N.W. • Atlanta, Georgia 30318-5790 • 1990 • $5.00

SREB
Southern Regional Education Board

- ***Will the supply of scientists and engineers educated at the graduate level satisfy industry's demand in the year 2000?***
- ***What is the impact of graduate enrollment trends on the availablity of science and engineering faculty in the year 2000?***
- ***What efforts are being undertaken or planned to increase numbers of scientists and engineers with graduate degrees?***

Shortages of college faculty, scientists, and other professionals are expected to grow rapidly between now and the year 2000 and are a concern of educators and public policymakers across the nation. Increasing proportions of individuals now employed in these occupations are approaching retirement. Industry and business changes will involve new technologies and create new jobs requiring scientists, mathematicians, and engineers. Many of these new and replacement positions will require persons with education at the master's or doctoral levels. And, if current trends continue, the supply of scientists and engineers educated at the graduate degree level will not meet the demand.

This paper focuses on natural scientists* and engineers rather than on the larger scientific population, which includes both social and behavioral scientists. While shortfalls across the science population as a whole are expected, the National Science Foundation (NSF) projects that the shortfall of Ph.D.-level natural scientists and engineers alone could reach 8,500 by the year 2006. To meet this challenge, the Southern Regional Education Board and its Commission for Educational Quality have proposed that:

BY THE YEAR 2000—

> ***The percentage of adults who have attended college or earned two-year, four year, and graduate degrees will be at the national averages or higher.***
>
> *Goals for Education*
> **CHALLENGE 2000**
> *Southern Regional Education Board, 1988*

Tracking overall change in graduate enrollment and degree production is important. But this alone does not measure variation in specific fields or progress toward improving quality and access. As SREB's *Goals* report notes:

> ***Progress includes setting quantitative and qualitative targets for graduate enrollments, with consideration of the proportion of minorities and women enrolled, and creating conditions for growth in selected fields.***

*Includes the following disciplines in the natural sciences: physical sciences, environmental sciences, mathematical sciences, agricultural sciences, and biological sciences.

THE SUPPLY OF GRADUATE DEGREES IN SCIENCE AND ENGINEERING

Growing salaries and employment opportunities for *baccalaureate* scientists and engineers will limit the supply of *graduate* scientists and engineers. With few exceptions, individuals who seek graduate degrees in mathematics, science, or engineering earned their undergraduate degrees in these same fields. Today, with ample job opportunities in almost all fields and good starting salaries, there are limited incentives luring young scientists and engineers into graduate work. Add to this the cost and time required to pursue graduate studies, and the prospects for increasing master's and doctoral degree holders in these areas are not good.

Supply is also affected by who is in graduate school. For instance, graduate enrollments can be divided into those students who are United States citizens, non-U.S. citizens who have a permanent resident visa, or foreign students who are in the United States on temporary visas. According to the National Research Council (NRC), United States citizens earned 74.8 percent of all doctorates awarded in 1988. Permanent resident visa holders

Table 1
MASTER'S DEGREES IN ENGINEERING, AND MATHEMATICS, PHYSICAL SCIENCES, AND COMPUTER INFORMATION SCIENCES AWARDED BY PUBLIC UNIVERSITIES SREB STATES AND UNITED STATES 1979/80 AND 1984/85

	Engineering		State Percentage of Regional Total	Mathematics		State Percentage of Regional Total	Physical Sciences*		State Percentage of Regional Total	Computer Sciences		State Percentage of Regional Total
	1979-80	1984-85	1984-85	1979-80	1984-85	1984-85	1979-80	1984-85	1984-85	1979-80	1984-85	1984-85
United States	10,047	13,043		2,201	2,243		3,844	4,228		1,997	3,793	
SREB States	3,020	4,117		707	613		929	1,204		533	1,319	
Alabama	122	122	3.0	26	20	3.3	29	57	4.7	22	109	8.3
Arkansas	136	199	4.8	12	7	1.1	18	26	2.2	4	16	1.2
Florida	245	316	7.7	69	56	9.1	78	80	6.6	16	91	6.9
Georgia	312	430	10.4	63	35	5.7	59	66	5.5	75	128	9.7
Kentucky	128	132	3.2	41	28	4.6	55	53	4.4	17	25	1.9
Louisiana	88	267	6.5	28	45	7.3	46	76	6.3	16	51	3.9
Maryland	89	139	3.4	27	15	2.4	32	47	3.9	29	42	3.2
Mississippi	58	121	2.9	13	14	2.3	15	36	3.0	49	104	7.9
North Carolina	116	226	5.5	56	78	12.7	80	74	6.1	26	51	3.9
Oklahoma	184	267	6.5	17	15	2.4	53	88	7.3	38	37	2.8
South Carolina	133	200	4.9	48	42	6.9	33	63	5.2	11	31	2.4
Tennessee	219	202	4.9	63	42	6.9	45	35	2.9	15	42	3.2
Texas	772	1006	24.4	162	136	22.2	283	387	32.1	174	439	33.3
Virginia	314	388	9.4	68	62	10.1	73	89	7.4	31	135	10.2
West Virginia	104	102	2.5	14	18	2.9	30	27	2.2	10	18	1.4

* Includes master's degrees awarded in the following fields: Astronomy, Astrophysics, Atmospheric Sciences & Meteorology, Chemistry, Geological Sciences, Oceanography, Earth Science, Physics, Planetary Science, General Physical Sciences and other Physical Sciences.

SOURCE: National Center for Education Statistics data tapes earned 5.2 percent of all doctorates that year. Temporary visa holders earned 19.9 percent of all doctorates awarded in 1988, up from 12.1 percent in 1980. In the physical sciences, mathematics, and computer sciences, 29.8 percent of the doctorates awarded in 1988 were earned by temporary visa holders. In engineering the figure was 44.6 percent.

According to the National Science Foundation, the supply of U.S. citizens and permanent resident visa holders who will have earned doctoral degrees in natural science and engineering is projected to rise at a rate of just over 2 percent annually between 1988 and 1993. Supply will then begin to decline and remain below 1988 levels until about 2001. The supply trend for foreign students in this country on temporary visas will follow the same pattern. But, findings of the National Research Council and the National Science Foundation indicate that only about half of the foreign students on temporary visas who earn Ph.D.s in the United States remain in this country as part of the workforce after graduation.

Tables 1 and 2 show the number of master's and doctoral degrees awarded in engineering, mathematics, physical sciences, and computer and information sciences in 1980 and 1985 by public universities in the United States, in the region, and in each of the SREB states.

In the mid-1980s, a majority of all master's degrees awarded in these fields by public universities in the SREB region were produced by only

Table 2
DOCTORAL DEGREES IN ENGINEERING, AND MATHEMATICS, PHYSICAL SCIENCES, AND COMPUTER INFORMATION SCIENCES AWARDED BY PUBLIC UNIVERSITIES SREB STATES AND UNITED STATES 1979/80 AND 1984/85

	Engineering		State Percentage of Regional Total	Mathematics		State Percentage of Regional Total	Physical Sciences*		State Percentage of Regional Total	Computer Sciences		State Percentage of Regional Total
	1979-80	1984-85	1984-85	1979-80	1984-85	1984-85	1979-80	1984-85	1984-85	1979-80	1984-85	1984-85
United States	1,591	1,987		470	452		2,069	2,324		132	152	
SREB States	409	550		114	117		494	560		20	36	
Alabama	22	18	3.3	6	2	1.7	8	10	1.8	0	2	5.6
Arkansas	5	7	1.3	1	1	0.9	8	9	1.6	0	0	0.0
Florida	19	53	9.6	18	19	16.2	51	66	11.8	0	1	2.8
Georgia	35	35	6.4	7	5	4.3	37	37	6.6	0	2	5.6
Kentucky	12	7	1.3	9	2	1.7	11	10	1.8	0	0	0.0
Louisiana	6	13	2.4	3	8	6.8	18	25	4.5	1	1	2.8
Maryland	15	31	5.6	11	15	12.8	35	48	8.6	7	9	25.0
Mississippi	9	7	1.3	1	0	0.0	11	10	1.8	0	0	0.0
North Carolina	18	36	6.5	9	13	11.1	44	53	9.5	1	3	8.3
Oklahoma	54	43	7.8	6	9	7.7	28	19	3.4	1	1	2.8
South Carolina	9	23	4.2	2	6	5.1	36	39	7.0	0	0	0.0
Tennessee	28	28	5.1	7	3	2.6	19	12	2.1	0	0	0.0
Texas	113	145	26.4	22	17	14.5	141	169	30.2	8	10	27.8
Virginia	55	90	16.4	12	17	14.5	34	42	7.5	2	7	19.4
West Virginia	9	14	2.5	0	0	0.0	13	11	2.0	0	0	0.0

* Includes doctoral degrees awarded in the following fields: Astronomy, Astrophysics, Atmospheric Sciences & Meteorology, Chemistry, Geological Science, Oceanography, Earth Science, Physics, Planetary Science, General Physical Sciences and other Physical Sciences.

SOURCE: National Center for Education Statistics data tapes.

a few states. Texas, Virginia, Georgia, and Florida produced large numbers of master's degrees in these fields (about 53 percent of all such degrees in the entire SREB region), but also produced large numbers of graduate degrees across all fields. Texas alone awarded about 27 percent of the total master's degrees in these fields. Georgia awarded a significant number of master's degrees in engineering and computer sciences (about 10 percent of the total in these fields). North Carolina contributed a large percentage of the master's-level mathematicians in the region (about 13 percent), and Oklahoma's public institutions awarded more than 7 percent of the region's master's degrees in physical sciences.

The majority of doctorates awarded in engineering, mathematics, physical and computing sciences by public universities in the SREB region also were produced by a handful of states. In 1984-85, for example, Texas, Virginia, and Florida produced more than 52 percent of all doctorates awarded in engineering. Almost 60 percent of the doctoral degrees in mathematics came from institutions in Florida, Virginia, Texas, and Maryland. Texas, Florida, and North Carolina led the region in educating doctoral-level graduates in the physical sciences. And, while nine SREB states awarded doctoral degrees in computer and information sciences in 1984-85, only two states—Texas and Maryland—produced nearly 53 percent of all the doctorates.

Science and technology planners believe that states with relatively large or fast growing concentrations of both graduate- and undergraduate-educated natural scientists and engineers may be in the best position to attract research and development (R&D) funds, accommodate the human resource needs of high technology industries, and help fuel state economic development.

Table 3
EMPLOYED PH.D. NATURAL SCIENTISTS AND ENGINEERS BY SREB STATE

	1979		1987			
	Total Number	Per 100,000 Population	Total Number	Per 100,000 Population	Percent Change 1979-1987	Percent Change Per Capita 1979-1987
United States	213,093	95	270,217	111	26.8	16.8
SREB States	57,009	78	73,512	89	28.9	14.1
Alabama	2,086	54	2,766	68	32.6	25.9
Arkansas	723	32	1,116	47	54.4	46.9
Florida	4,535	48	5,944	49	31.1	2.1
Georgia	3,344	62	4,356	70	30.3	12.9
Kentucky	1,726	47	1,891	51	9.6	8.5
Louisiana	2,904	70	3,582	80	23.3	14.3
Maryland	8,599	205	11,221	247	30.5	20.5
Mississippi	1,222	49	1,690	64	38.3	30.6
North Carolina	4,941	85	6,559	102	32.7	20.0
Oklahoma	1,907	64	2,558	78	34.1	21.9
South Carolina	1,907	62	2,690	79	41.1	27.4
Tennessee	3,832	84	4,602	95	20.1	13.1
Texas	11,753	85	15,421	92	31.2	8.2
Virginia	6,260	118	7,720	131	23.3	11.0
West Virginia	1,270	65	1,396	74	9.9	13.8

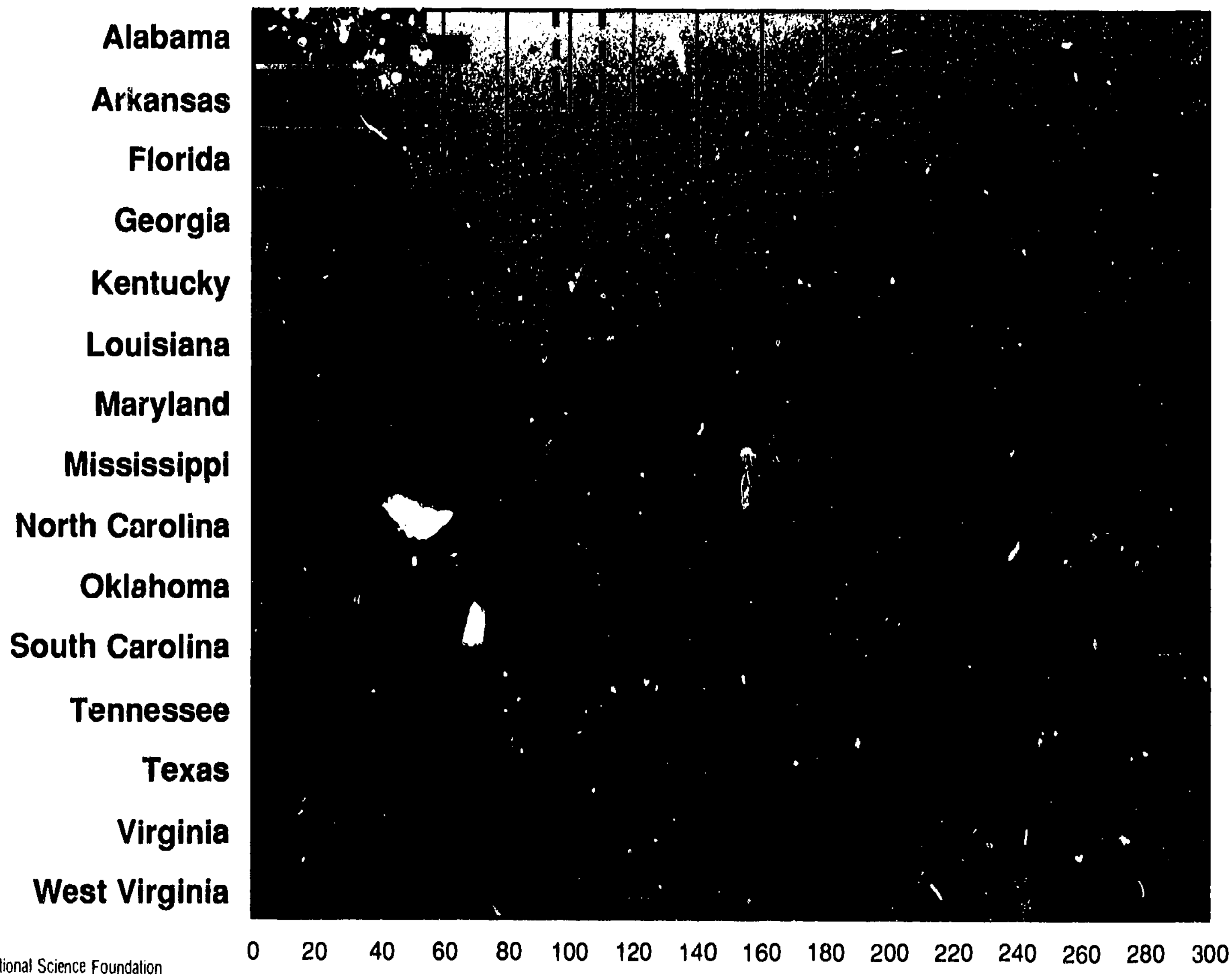
SOURCE: National Science Foundation.

Graduate degree-holding scientists and engineers, however, can be a mobile group. While they may prefer to stay in the state in which they were educated, and certain key industries prefer to be near respected graduate education centers, the graduates go where the jobs are. How then do the SREB states look when we see where graduate-level natural scientists and engineers locate? Data from the National Science Foundation can be used to show how many Ph.D.-level natural scientists and engineers there are per 100,000 population in each SREB state (see Table 3, Figure 1).

In the SREB region in 1979, the average number of Ph.D. natural scientists and engineers per 100,000 population was 78. This rate was only 82 percent of the average for the United States (95 Ph.D. scientists and engineers per 100,000 population).

Worse, by 1987 this percentage had declined to about 80 percent. Maryland and Virginia were the only SREB states in 1987 to exceed the national average. More disturbing is the fact that in 1987, only four SREB states (Maryland, Virginia, North Carolina, and Tennessee) met or exceeded the old 1979 national rate.

Figure 1
EMPLOYED PH.D. NATURAL SCIENTISTS AND ENGINEERS PER 100,000 POPULATION BY SREB STATE, 1979 AND 1987



SOURCE: National Science Foundation

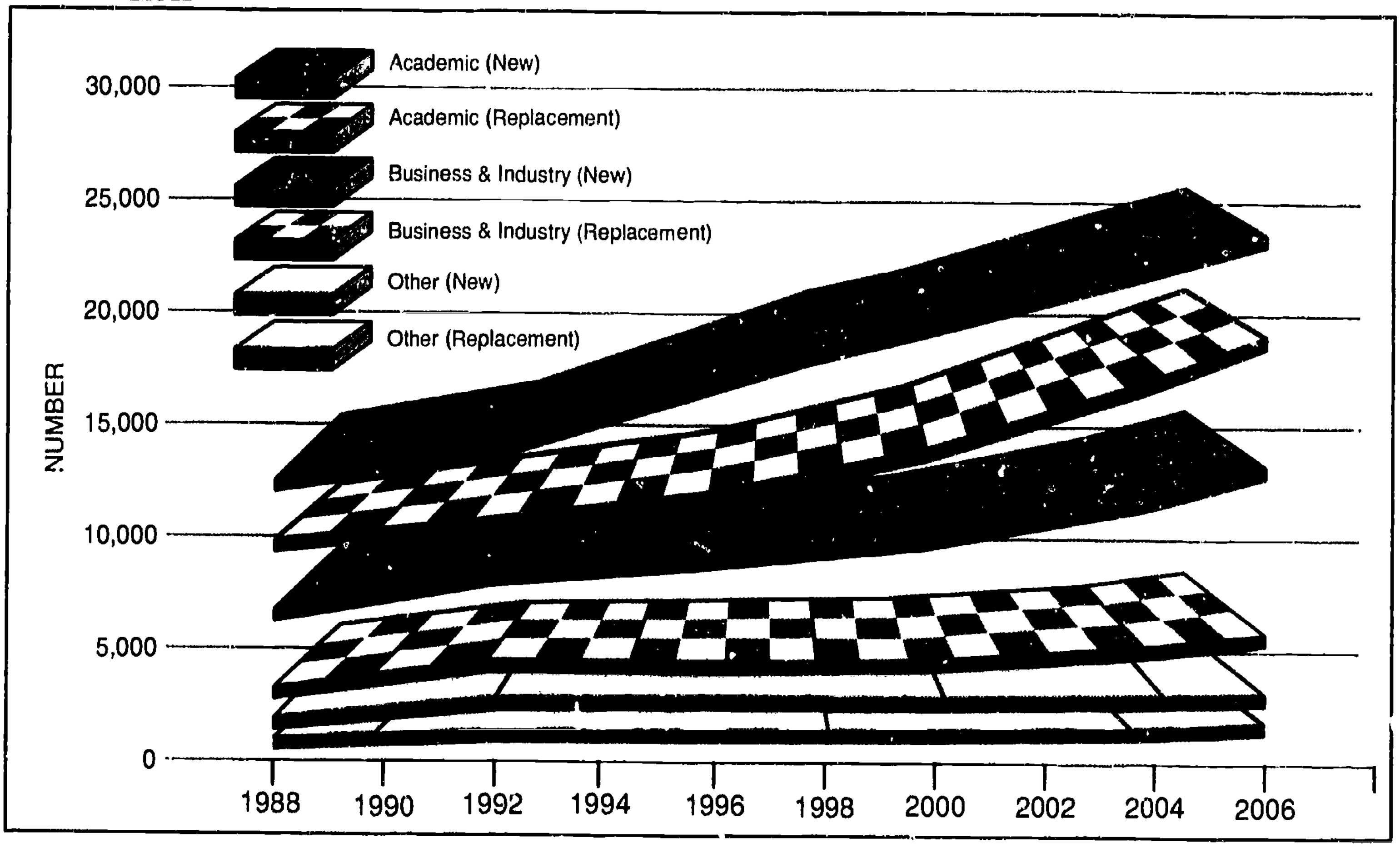
GROWING DEMAND FOR SCIENTISTS AND ENGINEERS

But, as supply is projected to decline, the demand for graduate degree-level scientists and engineers is growing rapidly. Between 1976 and 1986, the employment rate of undergraduate and graduate-educated scientists and engineers in academic, industrial, and governmental employment sectors grew approximately 7 percent annually. This is three times faster than the total growth rate in employment for all occupations in the United States, and twice as fast as the employment growth rate for all professional occupations.*

According to NSF, the rapid increase in science and engineering employment can be attributed to growing R&D expenditures, rapidly changing computer and electronic technology, and the need to improve manufacturing productivity in the United States. Future demand for scientists and engineers is expected to continue growing in response to the increasing use of high technology goods and services in the economy.

Since the mid-1970s, overall demand for doctoral scientists and engineers (as measured by employment growth) increased at an annual rate of about 4½ percent. Industrial employment of these doctoral scientists and engineers grew even more rapidly—an annual rate of nearly 7 percent between 1975 and 1985. Academic employment increased more slowly; the annual rate of growth was slightly over 3½ percent during this same 10-year time period.†

Figure 2
ESTIMATED CUMULATIVE DEMAND FOR NATURAL SCIENTISTS AND ENGINEERS EDUCATED AT THE DOCTORAL LEVEL



SOURCE: "Future Scarcities of Scientists and Engineers: Problems and Solutions," National Science Foundation, September 19, 1989.

Assuming that current market conditions will continue, it is projected that demand for scientists and engineers educated at the graduate level will continue to outpace supply well beyond the turn of the century. This strongly suggests a need to increase numbers of master's and doctoral degrees in these fields.

The National Science Foundation projects that between 1988 and 2006 the demand for Ph.D. natural scientists and engineers will almost double (12,200 to 23,500) in less than two decades. The "unconstrained" demand, as indicated in Figure 2, assumes that current productivity and employment activities of natural science and engineering Ph.D.s will remain relatively constant. New technologies designed to increase work productivity of engineering technicians and scientists, changes in research spending, or unforeseen dramatic increases in salary levels for doctoral scientists and engineers could constrain demand.

Demand consists of both the need to replace positions left by retiring professionals and the need to fill new positions created by growing sectors of the economy. In the business and industry sector, new demand is expected to grow more than 102 percent (3,646 to 7,387), while replacement demand is expected to grow almost 99 per cent (1,422 to 2,835) by the year 2006. Demand for new academics is projected to grow over 85 percent (2,667 to 4,950); replacement demand for faculty is expected to grow about 99 percent (2,895 to 5,772). In other employment sectors, new demand is expected to grow only about 20 percent (796 to 952) and replacement demand is projected to grow from 762 to 1,519—almost 100 percent.

*"National Patterns of Science and Technology Resources: 1987," National Science Foundation. January 1988, p.21.

†National Science Foundation, Ibid. p. 25.

PROJECTED SHORTFALL IN THE SUPPLY OF SCIENTISTS AND ENGINEERS

If undergraduate student interest in the science and engineering fields does not increase, NSF projects a substantial shortfall of scientists and engineers with bachelor's degrees from 1988 through 2006.* This projection is based on the fact that for the last 30 years, the ratio of bachelor's degrees in natural science and engineering (excluding computer science baccalaureates) relative to the number of 22-year-olds in the country, has remained fairly constant at about 4 percent. As the number of 22-year-olds goes down, it is expected that those earning undergraduate degrees in natural science and engineering will also decline dramatically. Using the average production of bachelor's degrees in natural science and engineering between 1984-86 as a proxy for future demand, NSF estimates that the shortfall in the cummulative supply of bachelor degree holders will be between 440,000 and 675,000 through the year 2006.

With more jobs to fill than there are new graduates at the bacclaureate level, industry and business can be expected to raise starting salaries to compete in a tight market. Opportunities in government and industry both here and abroad for those who earn baccalaureate degrees in science and engineering, therefore, are likely to outweigh incentives for entering graduate programs. For many, the return on investing in graduate education may not seem to justify the loss of current income and time necessary to earn a master's or doctoral degree.

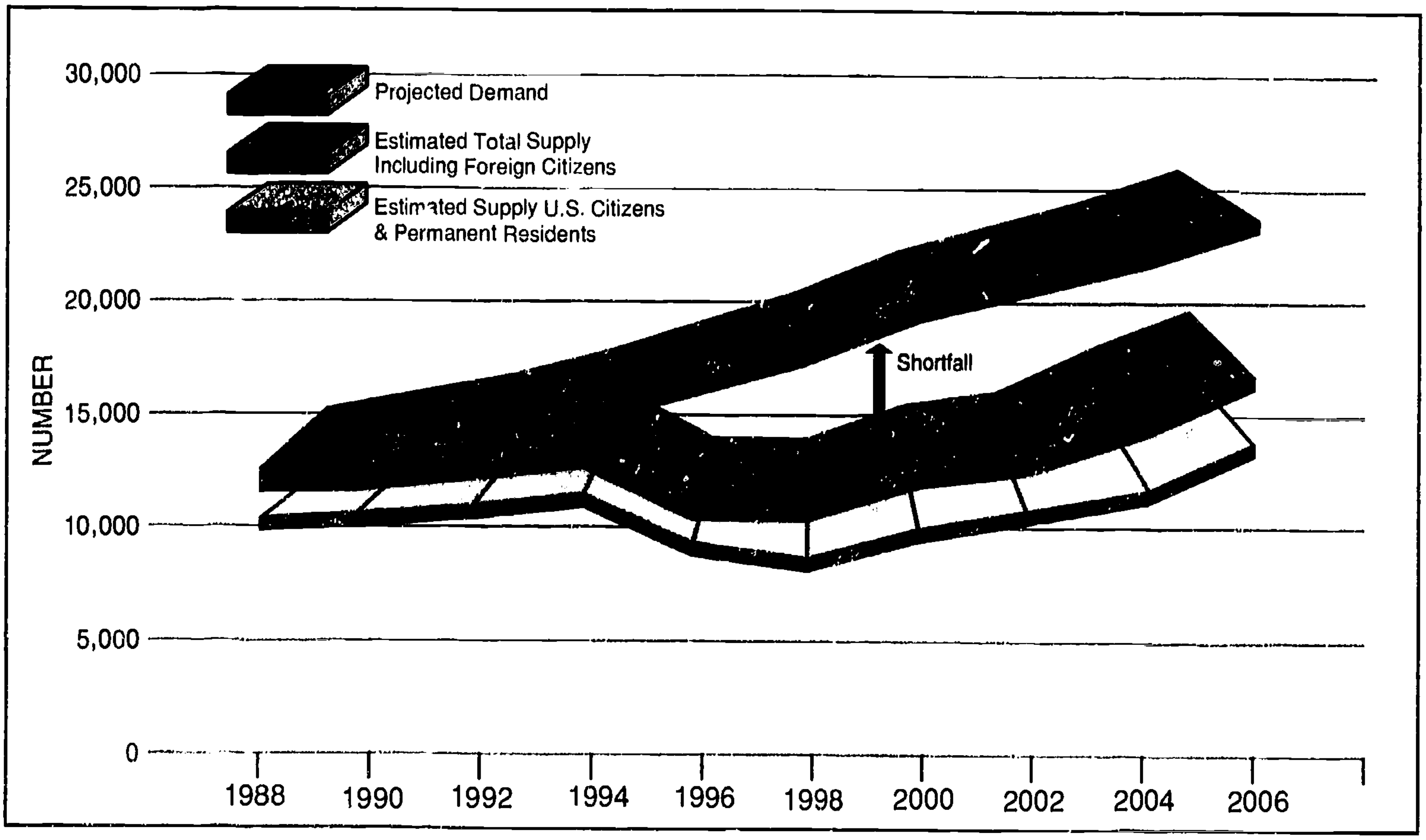
Keeping in mind that the production of Ph.D.s in science and engineering is related to the available pool of candidates with bachelor's degrees in those fields and that current incentives to enter graduate school appear inadequate, serious shortfalls of Ph.D.-level scientists and engineers are expected.

*"Future Scarcities of Scientists and Engineers: Problems and Solutions," National Science Foundation, Division of Policy Research and Analysis, (working draft), September 19, 1989, p.8-9.

The National Science Foundation estimates that about 17,000 natural scientists and engineers newly educated at the doctoral level will be produced in the year 2006. This projection includes all the foreign students who earn doctorates in the United States, including those not expected to remain in the country. If the number of foreign students who are likely to return to their home countries is subtracted (about 2,000), the projected supply drops to 15,000. As noted earlier, demand for Ph.D. scientists and engineers will approach 23,500 by 2006 (see Figure 3).

A shortfall of approximately 8,500 Ph.D. natural scientists and engineers can be expected in the year 2006. This shortfall will be shared by industry, government, and higher education, but higher education may suffer the most, given its typically less competitive salary structure.

Figure 3
PROJECTED SHORTFALL OF PH.D. NATURAL SCIENTISTS AND ENGINEERS



SOURCE: "Future Scarcities of Scientists and Engineers: Problems and Solutions," National Science Foundation, September 19, 1989.

INVESTING IN THE FUTURE

Obviously, then, unless more is done to attract qualified students into graduate science and engineering programs, supply will not keep pace with demand.

Given the projected shortages of those with advanced scientific and technical degrees, efforts should be taken to encourage more people to seek graduate degrees in the engineering, mathematics, physical science, and computer science fields. Committing resources to expand graduate education in these fields should be viewed as an essential investment in the future.

States with strong faculties of research-oriented Ph.D.s, supported by growing graduate student enrollments, are expected to be in the best positions to attract the largest shares of public and private research dollars and offer continued support to all industries, particularly high technology industries.

Motivating talented, baccalaureate degree holders to pursue graduate education in these fields will require innovative and larger financial aid incentives.

Public and private sectors willing to share the cost of investing in America's human resource capital will share the rewards of that investment. Industry can play a significant role. One innovative program, already established by Hewlett-Packard, matches graduate student stipends of $7,000 to $8,000 a year with $50,000 in four-year corporate grants and loans. This provides students with approximately $20,000 a year for four years while in graduate school. Students who agree to teach at a university for three years upon completion of their Ph.D. program are not required to pay back the loan portion of the financial aid package and also receive $50,000 in Hewlett-Packard equipment for their academic department.* States can stimulate and support such industry initiatives by setting policies and providing incentives for industry-based programs. Examples would be state matching grants and tax incentives.

Special financial aid programs, funded by universities and foundations, can help increase minority presence in graduate science and engineering programs and help alleviate expected faculty shortages. The Minority Achievement Program and the Minority Academic Careers initiative, established at Rutgers University, offer students fellowship or loan support for up to four years. Through the Minority Achievement Program, minority students who enter targeted degree programs receive fellowship packages worth up to $17,000 per year. With the Minority Academic Careers Program, students receive $5,000 in tuition remission and loans of up to $10,000 per year. Students who teach four years at a college or university in the state upon completion of their doctorates are not required to repay their loans. One shortcoming of these programs is the maximum four-year financial support period, which, for many, does not allow enough time to complete their doctoral degree programs.

This shortcoming may have been overcome in Florida with the McKnight Doctoral Fellowship Program. Beginning in fall 1990, twenty-five African-American citizens will receive up to $5,000 in tuition and fees and an annual stipend of $11,000 toward the pursuit of a Ph.D. at a participating Florida university. The Florida Endowment Fund provides the first three years of funding; the institution provides the fourth and possibly a fifth year of support. The program focuses on mathematics, business, and engineering, but is not limited to these fields.

One of the more comprehensive plans for reducing the shortfall of Ph.D. natural scientists and engineers has been developed by the National Science Foundation and recommended to the president. The NSF plan calls for:

- 1,040 new natural science and engineering fellowships for U.S. citizens each year;
- $20,000 per year, up to four years, for students in good academic standing;
- Linear expansion to new groups of "freshmen" doctoral students (i.e., 2,080 in 1991, 3,120 in 1992, etc.) up to the year 2001 when *growth* in support would end.

The total cost of this fellowship program would reach a plateau in 2004 at $1.1 billion per year. Between 1989 and 2006, average annual support expenditures would be about $612 million. But, NSF estimates that these expenditures would save government, education, and industry about $1.81 billion annually by reducing the expected higher salaries for scientists and engineers which all employment sectors will be forced to pay if shortages of persons with these technical skills become more acute. The National Science Foundation argues that a program such as this would greatly reduce the projected shortfall of Ph.D. scientists and engineers for the year 2006.

The eventual fate of the NSF proposal is uncertain, but it is not expected to be fully funded because of the strong competition for federal dollars and budget-cutting measures resulting from the Gramm-Rudman-Hollings deficit-reduction law. Because these shortfalls are seen as very serious, some federal agencies have initiated graduate science and engineering fellowship support programs of their own, but budgeted support has been very modest.

*Brian Worani, and Bernard List, "Higher Education Needs Boost," *Dallas Morning News*, April 10, 1989.

WHAT CAN STATES DO?

- Graduate degree-holding scientists and engineers emerge from the end of a pipeline that begins in the earliest grades in school. Attention must be given to insuring that more students in more schools are provided opportunities for the best instruction in science and mathematics. Science and mathematics courses in the schools must be supplied with the best electronic instructional technology available and with teachers who are prepared to use the new technologies effectively.

- As important as improving student achievement in these fields is, equally important is to build the confidence of young students in their abilities and a liking for science and mathematics. Unless students feel good about what they can do and enjoy doing it, they are highly unlikely to choose college programs in science, mathematics, or engineering.

- In the shorter term, states need to begin targeting their efforts. The process should start by setting clear, quantitative, and qualitative goals for where they want to be in terms of producing graduate-level scientists and engineers. Subgoals should be set with respect to minority enrollments.

- To meet the challenge of these goals, states need to encourage and support the efforts of industry and business to increase the supply of graduate-level scientists and engineers. With state-level encouragement, programs such as the Hewlett-Packard effort could be expanded and increased. State actions could include matching grant programs to encourage industry involvement financially, tax incentives for industries that support graduate-level students, and the development of state loan foregiveness programs in return for periods of service as university faculty.

- States can more aggressively bring attention to and support for efforts being considered at the federal level. The National Science Foundation proposal addresses a national need through a national program that would, in the long term, benefit all of our states.

- Florida's McKnight Doctoral Fellowship program is a model that could be adopted by other states, or perhaps more importantly, be developed by several states working cooperatively. This program addresses both the need for graduate-level scientists and the particular need to increase the pool of minority scientists. It also represents a way to bring together the resources and interests of foundations, business and industry, and the states. A major cooperative effort of this type by a group of states might produce a significant increase in the supply side of the issue.

- The costs of reducing the expected shortfall of scientists and engineers will be high, but these costs must be viewed as an investment in our nation's future toward enhancing our international economic competitiveness, improving the quality of life for our citizens, and maintaining our national security.

Bibliography

Abedi, Jamal, and Benkin, Ellen. "The Effects of Students' Academic, Financial, and Demographic Variables on Time to the Doctorate." *Research in Higher Education*, 1987.

Atkinson, Richard C. *Supply and Demand for Science and Engineering Ph.D.s: A National Crisis in the Making.* Speech delivered to the Regents of the University of California, February 16, 1989.

Educating Scientists and Engineers: Grade School to Grad School. Washington, D.C.: Office of Technology Assessment, U.S. Government Printing Office, June 1988.

Engineering Graduate Education and Research. Washington, D.C.: National Research Council, 1985.

"Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook." *Surveys of Science Resources Series.* Washington, D.C.: National Science Foundation, December 1986.

"Foreign Students Account for Most Growth in Graduate Science and Engineering Enrollment." *Science Resources Studies Highlights.* Washington, D.C.: National Science Foundation, February 1989.

"Future Scarcities of Scientists and Engineers: Problems and Solutions." Washington, D.C.: National Science Foundation, Division of Policy Research and Analysis, (working draft), September 1989.

'Human Capital: The Decline of America's Work Force." *Business Week*, September 1988.

Manpower Comments. Commission on Professionals in Science and Technology, Vol. 26, No. 3, April 1989.

Meeting the Needs of a Growing Economy: The CORETECH Agenda for the Scientific and Technical Workforce. Council on Research and Technology.

"National Patterns of Science and Technology Resources: 1987" *Surveys of Science Resources Series.* Washington, D.C.: National Science Foundation, January 1988.

Nettles, Michael. *Financial Aid and Minority Participation in Graduate Education.* Minority Graduate Education Project, Educational Testing Service, 1987.

"Pace of Retirements of Ph.D. Scientists and Engineers Shows Gradual Increase." *Science Resources Studies Highlights*, Washington, D.C.: National Science Foundation, April 28, 1989.

Science & Technology: Trends in the South. Southern Technology Council, January 1989.

Student Financing of Graduate Education: A Report of the 1987 National Postsecondary Student Aid Study. Washington, D.C.: National Center for Education Statistics, March 1989.

Summary Report 1986: Doctorate Recipients from United States Universities. National Research Council, 1987.

Summary Report 1988: Doctorate Recipients from United States Universities. National Research Council, 1989.

Syverson, Peter D., and Robinson, Dawn S. *CGS/GRE Annual Survey of Graduate Enrollment.* Educational Testing Service, December 1987.

Vetter, Betty M. *Look Who's Coming to School! Changing Demographics: Implications for Science Education*, Washington, D.C.: Commission on Professionals in Science and Technology, December 1988.

Vetter, Betty M. *Recruiting Doctoral Scientists and Engineers Today and Tomorrow.* Washington, D.C.: Commission on Professionals in Science and Technology, February 1989.

Woram, Brian, and List, Bernard. "Higher Education Needs Boost." *Dallas Morning News*, April 10, 1989.