The Best and Brightest for Science: Is There a Problem Here?

by

William Zumeta and Joyce S. Raveling
University of Washington

August 2002

Commission on Professionals in Science and Technology
1200 New York Ave., NW, Suite 390
Washington, DC 20005
Tel: (202) 326-7080
Fax: (202) 842-1603
info@cpst.org
http://www.cpst.org

The Best and Brightest for Science:
Is There a Problem Here?

by
William Zumeta and Joyce S. Raveling
University of Washington

August 2002

The authors are grateful to the Alfred P. Sloan Foundation and the Daniel J. Evans School of Public Affairs, University of Washington, for support for the research underlying this article. All judgments and conclusions are the sole responsibility of the authors.

The Best and Brightest for Science: Is There a Problem Here?

We live in an age of breathtaking accomplishments in science and technology and it is increasingly obvious that the nation's economic future is closely linked to our capacity in these fields. Unquestionably, the scientific research and teaching that underlies technological progress is demanding work requiring high intelligence and a long period of education and training. Indeed, it is widely held that real innovation in science depends less on the many "worker bees" in the enterprise than on the presence of a decent sprinkling of the very best minds. Yet, the training period for fully-fledged scientists has grown to 6-8 years in graduate school in most of the natural sciences[1] with another 2-5 years in postdoctoral apprenticeship for the majority. Thus, a young scientist is usually in the mid-thirties before he or she is considered ready to apply for an independent teaching or research post in academe or industry. In academe at least, it is then typically another 6 or 7 years before the no-longer-young scientist is fully established, if successful in achieving tenure.

Most graduate students in the sciences still aspire to academic careers but prospects for traditional faculty careers have declined sharply in recent years. For example, a National Research Council study (1998: 35-45) found that the proportion of life sciences PhDs holding faculty positions 9 to 10 years after receipt of the degree fell from 61 percent in 1973 to 39 percent in 1995. The fraction of PhD life scientists employed in industry grew substantially during the 1980s with the biotechnology boom but leveled off after that. Ominously, the share of all life science PhDs 9 to 10 years out who did not hold permanent full-time jobs in science or engineering had climbed to 20 percent by 1995, up from 7 percent in 1993.

Given these conditions, it is reasonable to wonder how well scientific careers are competing for the best intellectual talent. Young people with sharp analytical minds and college degrees have many attractive options. Most obviously, they can pursue graduate study in one of the major professional fields such as medicine, law or business. Compared to advanced study in the sciences, these fields promise a much shorter period in school or apprentice status (medicine excepted), a far higher probability of successful completion of training, and substantially more lucrative job prospects at the end of it all. Love of science is a powerful motivator to be sure, but at some point the yawning gap in the relative career prospects of the professional path compared to the PhD path must surely become big enough to dissuade distressingly large numbers of highly able students from pursuing careers in science teaching and research.

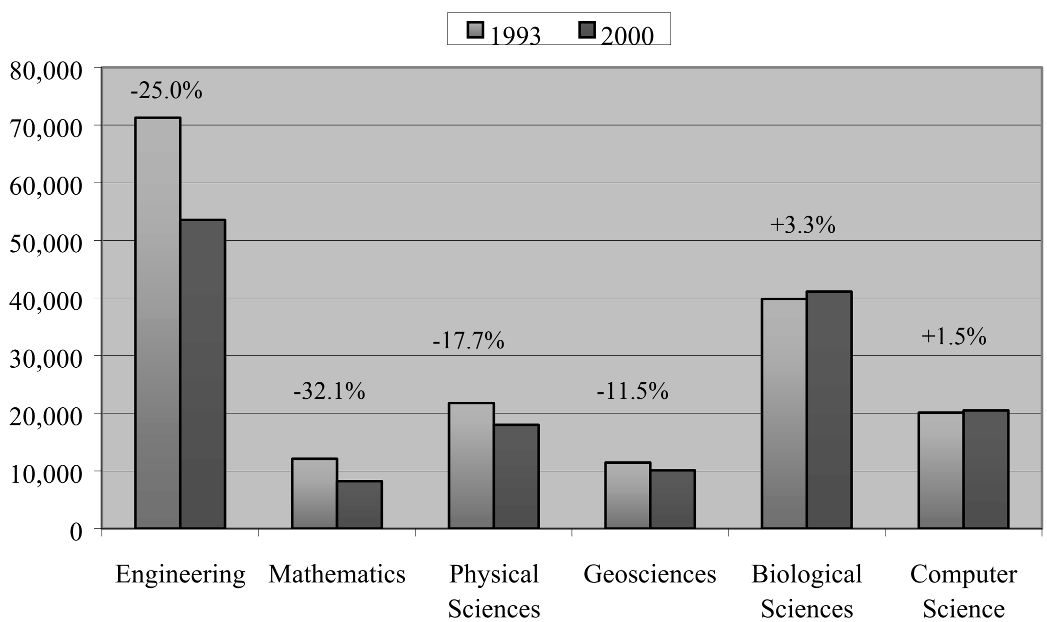
Rather than add to theoretical speculation as to when this point might be reached, the purpose of this article is to present and analyze some recent data bearing on flows of the "best and brightest" U.S. students into graduate study in the natural sciences and engineering. If such flows are decreasing significantly, there are several reasons why this should be of concern. First, after increasing inexorably for many years, enrollments of both U.S. citizens and non-citizens in most S/E fields declined over the 1993-2000 period (Figure 1). In the longer term, it seems clear that, for all their attractiveness, U.S. graduate S/E programs will face increasing competition for

[1] Throughout this article we define the natural sciences to include the biological sciences, the physical and earth sciences, the mathematical sciences, and computer science. In addition, our analyses include the engineering disciplines. Collectively, we refer to all these fields as "science and engineering" or S/E.

international students from other developed countries with similar technological and economic aspirations to ours and from the students' home institutions in the countries from which many of them hail, in particular China, India and Taiwan.[2] More fundamentally, one must wonder how successful the United States can be in the technological age in the long run without a dependable, substantial flow of top home-grown talent through its schools and into the ranks of researchers and eventually scientific, industrial and policy leaders. Here, we will present data from several national sources suggesting worrisome trends in the attractiveness of graduate study in science and engineering to outstanding U.S. students and will suggest some possible policy implications.

Doctorate production and enrollment trends suggest that the attractiveness of the doctoral path is deteriorating. Overall U.S. doctorate output fell by 4 percent in 1999 after 13 straight years of increases, then registered a small increase of 0.8 percent in 2000 (Hoffer et al, 2001). PhD production in the engineering and physical sciences categories (including mathematics and computer science) each fell by more than 10 percent between 1995 and 2000. Life sciences PhD numbers grew steadily for many years before a nearly 5 percent drop-off in 1999 followed by a nearly offsetting gain in 2000. These declines are not surprising in light of the graduate enrollment changes shown in Figure 1. Enrollments of U.S. citizens fell 32 percent in mathematical sciences, 25 percent in engineering and nearly 18 percent in physical sciences over the 1993-2000 period, but made small gains in biological sciences and computer science.

Figure 1. Changes in the Number of U.S. Citizen and Permanent Resident S/E Graduate Students in Doctorate Granting Institutions, 1993 & 2000



Source: National Science Foundation

[2] See Lloyd (1998); McMurtrie (2001). The aftermath of the terrorist attacks on the United States may work to further constrain inflows of international students.

EVIDENCE ABOUT TRENDS IN QUALITY

This is important context but our primary interest here is in quality not quantity. Earlier studies have been limited but have generally indicated that PhD programs in the arts and sciences have enrolled students as good or better than (judging by test scores) those pursuing professional degrees in medicine, law and business (Hartnett, 1987; Bok 1993). Yet, these studies are dated now and concerns about the relative attractiveness of academic graduate studies have, if anything, grown stronger in recent years.

To investigate trends in student quality, we obtained from the Educational Testing Service data on trends in GRE scores by discipline that spanned the universe of U.S. citizen test-takers and intended fields of graduate study for the testing years 1989, 1992, 1995, 1998, and 2000.[3] The main limitations of these data for policy analysis stem from the fact that they are based on individuals' responses on the GRE registration questionnaire as to their intended field of graduate study, not on their actual enrollment behavior. The one follow-up study available of respondents' subsequent enrollment found that about 56 percent enrolled in graduate school in the fall following the year in which they took the test[4] and 82 percent of these enrolled in the same broad field they had indicated on the GRE registration questionnaire (Grandy, 1990). Our analysis uses these broad field categories.

The trends in the science and engineering fields are striking. First, paralleling the already-noted declines in graduate enrollments, the number of U.S. citizen GRE examinees indicating intent to pursue graduate study in the natural sciences or engineering fell from 42,170 in 1992 to 35,373 in 1998, before recovering slightly to just over 36,000 in 2000. This represents a 14.5 percent decline from 1992 to 2000.

Within these totals, the *proportion* of would-be scientists scoring above 750 on the GRE quantitative scale[5] actually increased a bit between 1992 and 2000 (after a larger drop from 1989 to 1992) *but not nearly enough to compensate for the substantial decline in the total number of examinees headed for science and engineering*. Thus, as Figure 2 depicts, the absolute number of very high GRE-scorers (>750) headed for S/E graduate studies declined by more than 700 between 1992 and 2000, or 8 percent. Encouragingly, the graph shows an improving trend in the most recent two-year period after an apparent low point in top-scoring U.S. citizens headed for S/E in 1998. The graph also shows that the declines were sharpest in numbers of top scorers headed for engineering and mathematical sciences, that modest early declines in computer science and physical sciences were reversed by 2000, and that biological sciences showed steady increases throughout the period.

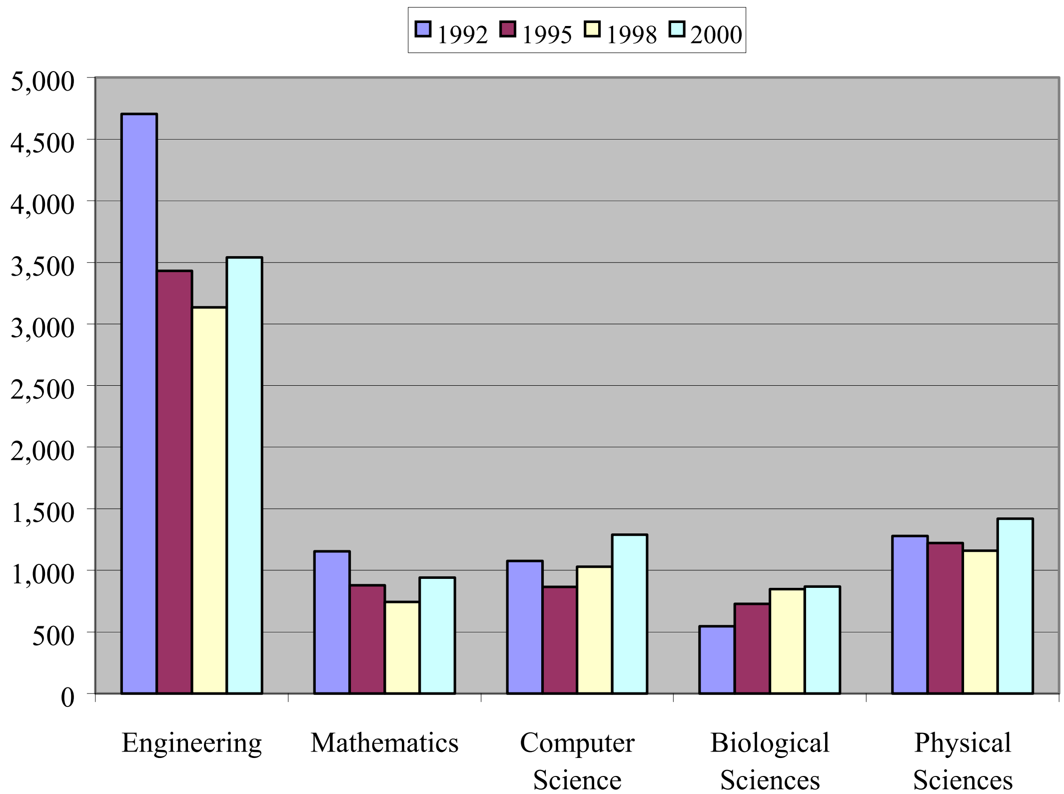
---

[3] ETS testing years begin with October 1 of the prior year and run through September 30 of the named year. We are grateful to Robin Durso, Rebecca Moran and Pankaja Narayanan of ETS for their assistance. Previous analysis along these lines was conducted by Holmstrom et al. (1997).

[4] No doubt some more enrolled in later years.

[5] Since our focus here is on the "best and brightest," we established a high score threshold: the proportion of U.S. citizen examinees (all fields) scoring 750 or above on the GRE quantitative scale was in the 5-7 percent range during the period under study while on the analytical scale the range was 5-8 percent. The proportion scoring above 700 was 11-14 percent for the quantitative scale and 11-17 percent for the analytical scale. The patterns of change over time were generally quite similar regardless of which score threshold was used.

Figure 2. Number of U.S. Citizen GRE Examinees Scoring > 750 on the Quantitative Scale, by Intended S/E Field



Source: Educational Testing Service

As some science and engineering fields lost ground in attracting the "best and brightest" during the 1990s, it is instructive to observe which fields showed substantial gains.[6] Table 1 shows the numbers of very high scorers (750+) among U.S. citizens by intended field of graduate study for the years 1992 and 2000. In addition to engineering and mathematical sciences, behavioral and social sciences and humanities saw significant declines in top quantitative scorers. The fields showing notable increases included biological sciences, applied biology and the residual "other" category. The largest gains came in the "health sciences" (ETS terminology) which increased its number of top scoring recruits by an impressive 87.6% to 878 in 2000. This category is actually dominated by health *professions* such as physical therapy, speech and language pathology, and public health where master's degrees rather than research doctorates dominate graduate studies. These fields draw on life science roots like the biological sciences but provide the attraction of comparatively short graduate training periods and a clear, low-risk and decent-paying professional path for the graduate.

[6] In total, while natural sciences and engineering attracted 8 percent fewer top scoring U.S. students in 2000 than in 1992, all other named fields combined attracted 289 more such students, a gain of nearly 7 percent.

Table 1. Number of U.S. Citizen GRE Examinees Scoring > 750 on the GRE Quantitative Scale, by Intended Field of Graduate Study, 1992 & 2000				
Intended Field of Study	**1992**	**2000**	**Change 1992 - 2000**	**% Change 1992 – 2000**
Engineering	4,706	3,539	-1,167	-24.8%
Mathematical Sciences	1,153	939	-214	-18.6%
Computer Science	1,075	1,289	214	+19.9%
Biological Sciences	545	867	322	+59.1%
Physical Sciences	1,278	1,419	141	+11.0%
TOTAL: Natural Science & Engineering	**8,757**	**8,053**	**-704**	**-8.0%**
Art	93	100	7	+7.5%
Other Humanities	1,013	862	-151	-14.9%
Behavioral Sciences	1,403	1,180	-223	-15.9%
Social Sciences	499	391	-108	-21.6%
Education	623	736	113	+18.1%
Health Sciences	468	878	410	+87.6%
Applied Biology	78	133	55	+70.5%
Other	94	280	186	+197.9%
TOTAL: All Other Fields	**4,271**	**4,560**	**289**	**+6.8%**
Undecided/No Response/Other	2,556	1,078	-1,478	-57.8%
TOTAL NUMBER > 750 SCORERS	**15,584**	**13,691**	**-1,893**	**-12.1%**

Source: Educational Testing Service

Gender and ethnic differences in trends are notable.[7] Between 1989 and 2000 the number of high scoring men headed for S/E graduate studies fell by about 6 percent while the number of such women grew by 23 percent. Significantly, in absolute terms the gains by women almost exactly offset the declines among men. Gains in numbers of high scoring women were particularly strong in the biological sciences (80 percent) and physical sciences (56 percent), while the numbers of such women actually decreased modestly in mathematical sciences and computer science.

A similar pattern occurred with respect to whites compared to other ethnic groups. The number of whites scoring at or above 700 and indicating plans for graduate study in science or engineering dropped by about 2.5 percent between 1989 and 2000. In sharp contrast, the analogous proportions of African-Americans, Hispanic-Americans, and Asian-Americans jumped by 85 percent, 73 percent and 64 percent, respectively. In absolute terms, these gains more than offset the declines in whites. White high scorers declined by 292 over the period while the minority group gains were: Asian-Americans 433; Hispanic-Americans 179; African-Americans 124. Although the absolute numbers are still relatively small, gains by women and

[7] For these analyses we used 700 as the score cutoff for high scorers in order to ensure meaningful numbers in the smaller categories. The analysis focuses on high scorers on the GRE quantitative scale.

underrepresented minority citizens in this rough indicator of preparation for advanced studies in science are encouraging.

WHERE ARE THE TOP STUDENTS HEADED?

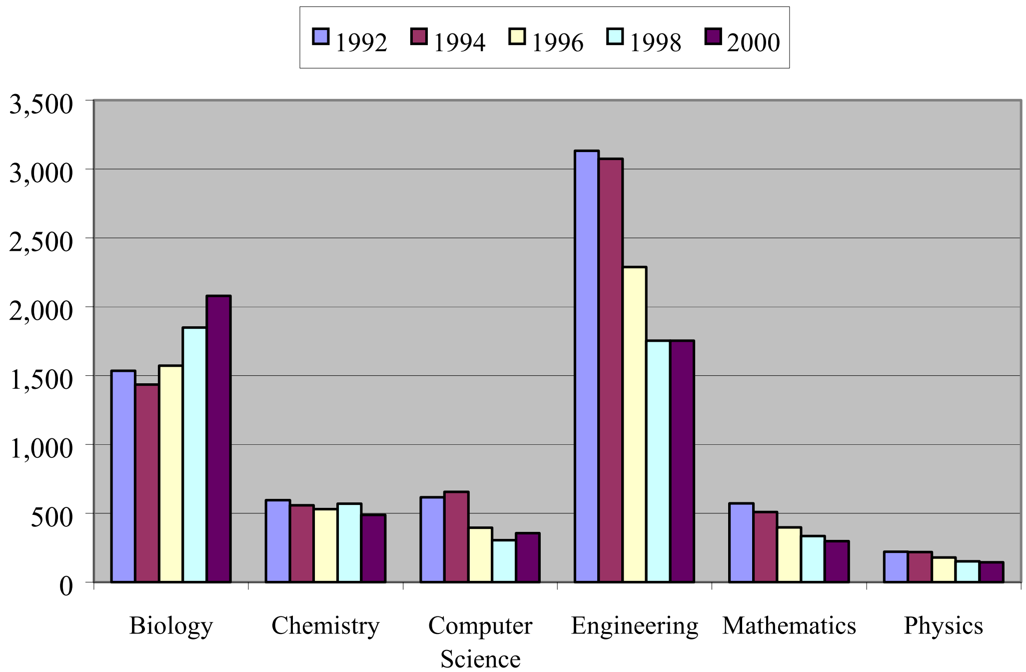
If the number of top U.S. citizens headed for graduate studies in the natural sciences and engineering decreased during the 1990s, what can be said about where these high potential young people went instead? A complete answer would require a comprehensive tracking of several cohorts of bachelor's degree recipients, which was beyond the scope of the present research. It seems likely that, in the unusually hot job market of the 1990s, some who could have pursued S/E careers instead chose to go directly into employment in the Internet economy and elsewhere. Some of these individuals may well turn up in graduate school at a later time. These potential patterns merit study but are not our focus here.

Another plausible possibility is that more top students who might have pursued S/E careers chose graduate professional school studies during the nineties since the training times in most professional fields are relatively short (M.D. training excepted) and predictable compared to the lengthy and uncertain PhD and postdoctoral path to a research career in science. We saw above some evidence from the GRE that, as numbers of top students headed for S/E graduate studies fell, there was a large jump in the number of these students apparently headed for health professions fields with relatively short training times to the usual terminal degree. These are fields that would be logical alternatives to PhD study for high-scoring students with undergraduate science degrees.

We also collected data on pertinent trends in the three largest professional tracks: law, medicine and business. Entrance to graduate professional schools in these fields normally requires a profession-specific test, not the Graduate Record Examination. So, we examined trends in pertinent indicators from the professional school entrance examinations in these fields. We found little evidence of increased flow of top undergraduate science majors to law schools during the nineties.[8] Between 1992 and 2000 the number of Law School Admission Test (LSAT) examinees decreased by about 26 percent and the unduplicated count of applicants to U.S. law schools declined 24 percent while law school enrollments were essentially flat.[9] Mean LSAT scores of examinees and applicants decreased very slightly during this period suggesting it is unlikely that more top students were applying to law school. Finally, the number of undergraduate S/E majors among LSAT examinees dropped by more than 25 percent between 1992 and 2000. As shown in Figure 3, the only undergraduate S/E major producing an increase in LSAT examinees was biology. Mean LSAT scores among science and engineering majors who took the test moved little over this period suggesting little change in the ability of these examinees.

[8] Data about the Law School Admission Test and law school applications and enrollments were provided by the Law School Admission Council. We are grateful to Robert Carr at LSAC for his assistance.
[9] Reports from the Law School Admission Council indicate that applications are rising again, by more than 20 percent over the last two years.

Figure 3. Number of S/E Undergraduate Majors Applying to Law School, 1992 - 2000



Source: Law School Admission Council

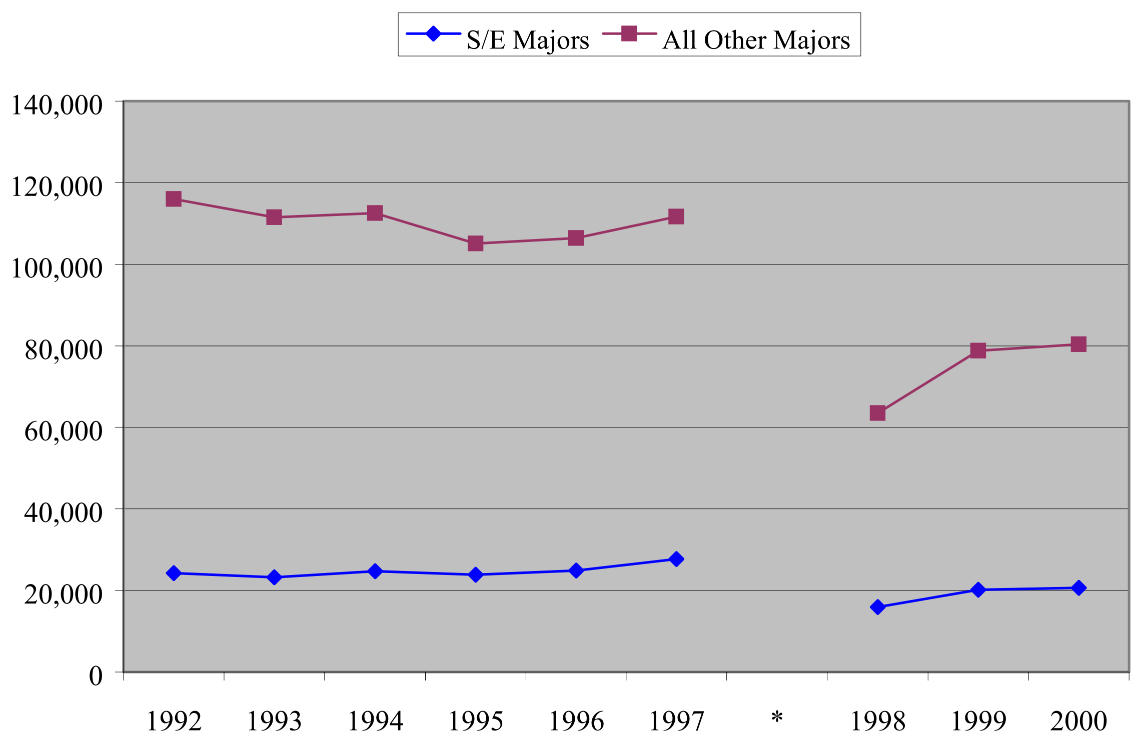
In medicine the story is broadly similar but with a few different twists. U.S. medical school applications rose and then fell during the 1990s, with the latest figures for 2001 falling below the 1992 level, while the number of new MD matriculants was essentially unchanged.[10] Thus there was no consistent groundswell of student demand or increase in capacity for new students in MD programs. The number of applicants with undergraduate S/E degrees increased, along with the total of MD applicants, through 1996 but then fell by nearly 25 percent by 2001. The number of new medical school matriculants with undergraduate S/E degrees declined by 3 percent over the 1992-2001 period. These patterns do not suggest that more top S/E students were entering medical school during these years. On the other hand, Medical College Admission Test (MCAT) scores of applicants and matriculants who were undergraduate S/E majors climbed during the 1990s, which could indicate that the proportion of top students in the pool increased. On a scale of 1-15, the mean score of S/E majors on the MCAT biological sciences scale increased from 9.4 to 10.2 while their physical sciences scale mean climbed from 9.2 to 10.1. Interestingly, non-S/E majors' scores increased comparably.

In the third major professional field, business, there are clearer signs that more top potential science and engineering graduate students were being attracted. Enrollment data in this field are somewhat unreliable but the number of MBA degrees awarded grew by nearly a third, to over 112,000, between 1992 and 2000 according to the National Center for Education

[10] Data about the Medical College Admission Test (MCAT) and medical school applications and enrollments were provided by the Association of American Medical Colleges (AAMC). We thank Collins Mikesell for his assistance.

Statistics. For graduate business programs, the standard test is the Graduate Management Admission Test (GMAT). Figure 4 graphs the trends in GMAT examinees from 1992 through 2000.[11] Total examinees declined a bit over the years 1992-97, while the number with undergraduate majors in the natural sciences or engineering increased modestly, mostly after 1995. The sharp decrease in examinees in 1998 was the result of conversion from paper-and-pencil testing to computerized test administration with fewer test dates. By 2000 it appeared that the number of examinees was recovering with those who were S/E majors increasing by nearly 30 percent from 1998, and preliminary reports indicate a further 12 growth in 2001. The S/E majors' share of all GMAT examinees was 20.4 percent in 2000 compared to 17.3 percent in 1992. Also, the mean scores of S/E majors on both the GMAT's quantitative and verbal scales increased appreciably from 1992 to 2000, from 34.0 to 37.2 (on a 0-60 scale) on the quantitative scale and from 30.6 to 31.8 on the verbal scale.[12] In sum, this evidence suggests that graduate business schools, largely MBA programs, were attracting a larger share of high scoring S/E majors during the nineties.

Figure 4. Number of U.S. Citizen GMAT Examinees by Field of Study, 1992 - 2000



* Conversion to computerized testing in 1998 resulted in 3 fewer GMAT administrations that year then to students scheduling individual appointments at testing centers in subsequent years.
Source: Educational Testing Service

[11] Data about the GMAT and business school applications and enrollments were provided by the Educational Testing Service, the Graduate Management Admission Council, and the Association to Advance Collegiate School of Business. We are grateful to Anne-Marie Marino at ETS for her assistance.
[12] The quantitative and verbal scores of GMAT examinees with non-S/E undergraduate majors also improved over this period but considerably less than the scores of S/E majors.

CHANGES IN POST-GRADUATION PLANS OF SCIENCE GRADUATES FROM TOP COLLEGES

Another way to get at the question of possible changing graduate study and career choices of top science and engineering students is to examine the career choices at the time they graduated from college of cohorts of top students from different periods. To do this, we obtained data from the periodic surveys of seniors conducted by the member schools of the elite Consortium for Financing Higher Education (COFHE). This is a group of 31 highly selective private colleges and universities that cooperate for various purposes including policy-oriented data collection.[13] COFHE provided us with data for analysis on the condition that specific institutions not be identified.

The surveys were conducted in the spring shortly before the seniors' graduation. Our analysis focused on five COFHE institutions with response rates above 50 percent for each of the 1984, 1989 and 1998 surveys. These three years provide a substantial span of time and include one year when the labor market was relatively sluggish following a recession (1984), and two years characterized by similarly strong prosperity and robust labor markets (1989 and 1998). Thus, if consistent trends emerge in the data over the entire period, they cannot readily be attributed to labor market variations.

Our analysis focused on the subset of the roughly 3,500 COFHE senior survey respondents in each year who were U.S. citizens or permanent residents and identified themselves as science or engineering majors.[14] These S/E majors numbered 700 in 1984, 602 in 1989, and 747 in 1998**.**

Table 2 shows the responses of these S/E majors from highly selective colleges and universities as to their plans for the autumn following their impending graduation.[15] Plainly, the proportion of these students headed directly into advanced study[16] declined sharply over time (top row) while the share headed directly into employment after college climbed. Most important for our purposes in this article, the share of these S/E majors from leading schools

---

[13] The member schools are appended. Clearly, the seniors from these schools are not a nationally representative sample but it is reasonable to surmise that the science majors are among the most promising potential scientists and engineers in America. We are grateful to Kathleen Kern Bowman, C. Anthony Broh, and Larry Litten of the COFHE staff for their assistance.

[14] See the S/E field categories shown in Table 2 and further explanation in table footnotes. Students with multiple majors were classified as S/E majors if any one of their majors was in a S/E field.

[15] COFHE has conducted several follow-up surveys of senior cohorts from the 1980's. Unfortunately for our purposes, these surveys were not for the most part designed to establish the validity of the original responses as predictors of what graduates actually do. The most direct evidence came from follow-ups of the 1982 senior cohort (COFHE, 1988; 1995) which found that 90 percent of those who had said they would enroll in a graduate program in arts and sciences in autumn 1982 were so enrolled in February 1983, compared to just 7 percent of those who had said they planned employment immediately after graduation. When those who were not enrolled but said they would enroll in arts and sciences later were resurveyed in 1987, just 25 percent had done so in arts and sciences while another 34 percent had enrolled in a professional degree program. Two-thirds of the rest said they planned to enroll later, three-fifths of these in a professional field. Clearly, professional fields were attractive even to those S/E majors who had initially planned graduate work in arts and sciences.

[16] A large majority of the students headed for advanced study in S/E fields said they planned doctoral rather than master's level graduate work. Master's level study was more common only in business and engineering. Here we have combined those planning master's- and doctoral-level studies.

planning advanced study immediately in a science or engineering discipline fell from around 17 percent in 1984 and 19 percent in 1989 to 12 percent in 1998, or from 117 individuals in 1984 to 90 in 1998. Interestingly, the number headed immediately for MD degrees fell similarly, from around 16 percent in 1984 and 1989 to 10 percent in 1998. Less than 5 percent of the S/E majors planned to pursue advanced studies immediately in fields other than science/engineering or medicine and this proportion changed little over the years examined.

Table 2. Plans of COFHE Senior S/E Majors for Autumn Following Graduation, 1984, 1989, & 1998 Cohorts

	1984 n = 700		1989 n = 602		1998 n = 747	
	n	%	n	%	n	%
Advanced Study	**327**	**46.7%**	**233**	**38.7%**	**207**	**27.7%**
All Science & Engrg.	***117***	***16.7%***	***114***	***18.9%***	***90***	***12.0%***
natural sciences*	58	8.3%	61	10.1%	43	5.8%
mathematics	9	1.3%	10	1.7%	5	0.7%
computer science	8	1.1%	7	1.2%	3	0.4%
Engineering	25	3.6%	20	3.3%	26	3.5%
two S/E fields	5	0.7%	5	0.8%	1	0.1%
Ph.D. / MD	12	1.7%	11	1.8%	12	1.6%
Medicine	***113***	***16.1%***	***96***	***15.9%***	***75***	***10.0%***
Other Fields	***34***	***4.9%***	***21***	***3.5%***	***30***	***4.0%***
Law	8	1.1%	9	1.5%	9	1.2%
Business	6	0.9%	2	0.3%	3	0.4%
all other fields**	20	2.9%	10	1.7%	18	2.4%
Field Undecided	***0***	***0.0%***	***0***	***0.0%***	***2***	***0.3%***
Field Not Specified	***63***	***9.0%***	***1***	***0.3%***	***10***	***1.3%***
Employment	**333**	**47.6%**	**308**	**51.2%**	**445**	**59.6%**
Undecided	**27**	**3.9%**	**53**	**8.8%**	**76**	**10.2%**
Plans not indicated	**13**	**1.9%**	**8**	**1.3%**	**19**	**2.5%**
TOTAL	**700**	**100%**	**602**	**100%**	**747**	**100%**

* Response options within this category varied from survey to survey. Included here are: for 1984, "biological sciences" plus "natural sciences"; for 1989, "natural sciences"; for 1998, "biological sciences" plus "physical sciences."

** In 1984, "all other fields" included fine arts, humanities, other health fields, social sciences, theology/ religion, and "other." In 1989, graduate programs in education, fine arts, other health fields, public policy, social sciences, and "other" comprised this category. In 1998, all 1984 fields were included plus communications/ media, forestry/agriculture, history, psychology, public policy, and social work.

Source: Consortium on Financing Higher Education Senior Surveys, 1984, 1989, & 1998.

Given the strong job markets of recent years and perhaps other social factors at work, some of the reduced numbers of students headed to graduate school immediately after college could simply be opting for a temporary respite from schooling before continuing their studies at a later point. Fortunately, the COFHE senior surveys included questions about lifetime as well as immediate plans for graduate study. In Table 3 we combine responses about these later plans from students whose immediate autumn plans were for employment (or undecided, other or no response) to the numbers who planned immediate graduate work. If these plans for graduate study later in the career are taken at face value, the "losses" over time in S/E majors headed to graduate study in S/E fields (and medicine) suggested by Table 2 seem to be essentially recouped. Comparing 1984 to 1998 seniors, the proportion planning a graduate degree in a science or engineering field (including PhD/MD's) at some time in their career declined less than one percentage point, to 34.3 percent, and the proportion planning MD degrees (excluding PhD/MD's) increased a bit, from 23.3 percent to 25.0 percent.

Table 3. Lifetime* Advanced Study Plans of COFHE Senior S/E Majors, 1984, 1989, & 1998 Cohorts

	1984 n = 700		**1989** n = 602		**1998** n = 747	
	n	%	N	%	n	%
Advanced Study	**635**	**90.7%**	**516**	**85.7%**	**602**	**80.6%**
All Science & Engineering	***246***	***35.1%***	***237***	***39.4%***	***256***	***34.3%***
natural sciences**	102	14.6%	115	19.1%	130	17.4%
mathematics	13	1.9%	18	3.0%	13	1.7%
computer science	39	5.6%	17	2.8%	28	3.7%
engineering	64	9.1%	52	8.6%	57	7.6%
two S/E fields	9	1.3%	12	2.0%	6	0.8%
Ph.D. / MD	19	2.7%	23	3.8%	22	2.9%
Medicine	***163***	***23.3%***	***159***	***26.4%***	***187***	***25.0%***
Other Fields	***161***	***23.0%***	***109***	***18.1%***	***142***	***19.0%***
law	17	2.4%	29	4.8%	21	2.8%
business	93	13.3%	43	7.1%	67	9.0%
all other fields***	51	7.3%	37	6.1%	54	7.2%
Field Undecided	***22***	***3.1%***	***10***	***1.7%***	***15***	***2.0%***
Field Not Specified	***43***	***6.1%***	***1***	***0.2%***	***2***	***0.3%***
No Advanced Study Plans	**65**	**9.3%**	**86**	**14.3%**	**145**	**19.4%**
TOTAL	**700**	**100%**	**602**	**100%**	**747**	**100%**

* "Lifetime" plans combine the number with immediate (autumn following graduation) plans for advanced study with the number reporting plans for advanced study in the future.
** Response options within this category varied from survey to survey. Included here are: for 1984, "biological sciences" plus "natural sciences"; for 1989, "natural sciences"; for 1998, "biological sciences" plus "physical sciences."
*** In 1984, "all other fields" included fine arts, humanities, other health fields, social sciences, theology/ religion, and "other." In 1989, graduate programs in education, fine arts, other health fields, public policy, social sciences, and "other" comprised this category. In 1998, "all other fields" included education, fine arts, communications/media, forestry/agriculture, history, humanities, other health fields, psychology, public policy, social sciences, social work, and "other."

Source: Consortium on Financing Higher Education Senior Surveys, 1984, 1989, & 1998.

But this comparison may well understate the changes in these two key categories due to changes in the sequence and wording of questions on the surveys that evidently led some 1984 respondents planning graduate study to fail to designate a field. In 1984 fully 9.0 percent of respondents said they planned advanced study but did not specify a field, while in 1989 and 1998, when the survey made the field choices more salient, the percentages in this category fell to 0.3 percent and 1.3 percent, respectively. This suggests that, had the questionnaire design in 1984 been similar to that of 1989 and 1998, several percent more of the earlier respondents would have allocated themselves to specific fields, thus accentuating the negative changes in the S/E share over time.

Perhaps more important, we should probably discount somewhat respondents' claims about later plans for graduate study in comparison to their necessarily more specific plans for graduate enrollment the following fall (see note 15). Historically, the pattern of taking a respite from school before embarking on post-baccalaureate study has been much more prevalent in professional fields than in science where top students have generally been encouraged to waste no time in getting started on the long road ahead. Yet the share of these S/E majors indicating no advanced study plans at all jumped from 9.3 percent in 1984 to 19.4 percent in 1998. In sum, we conclude that the decline between the 1984 and 1998 cohorts in numbers of these elite school S/E majors likely headed ultimately for graduate study in science and engineering (and medicine as well) probably falls somewhere between the levels indicated by Tables 2 and 3. This would imply a decrease in the proportion ultimately headed for S/E graduate school in the range between 1 – (.343/.351) = 2.3 percent, and 1- (.120/.167) = 28.1 percent. The previous point about the impact of the changes in survey design suggests that the true decrease may be closer to the latter figure.

Since our primary interest is in the graduate school choices of the most academically promising science and engineering students, we further refined the analysis by examining the post-baccalaureate plans of those S/E majors from the COFHE schools who reported they had achieved an A or A- grade point average in college.[17] There were 214 such students in the 1984 cohort, 197 in 1989, and 207 in 1998. A comparison of the responses of these students to those of the entire set of S/E majors produced some notable observations. The A students from all cohorts were substantially more likely to plan to attend graduate school immediately after graduation but the decline in this propensity was also steeper among the more elite group. Thus, the share of the A students in science headed directly to graduate study after college fell from more than two-thirds in the 1984 cohort (67.8 percent) all the way to well under half the 1998 cohort (43.5 percent).[18] This decline would almost certainly have been larger had the 13.6 percent of the A students in the 1984 cohort who were planning graduate school but failed to specify a field done so. (Just 1.5 percent of the 1998 cohort did not identify their field of graduate study.)

The A students were also more likely than the other S/E majors to report they were headed immediately for graduate school in S/E or medicine and the declines in these categories

---

[17] Interestingly, there was no sign of grade inflation among the S/E students earning the highest grades. The proportion of S/E majors earning A/A- GPAs was stable at around 30 percent.

[18] As shown in Table 2, the comparable figures for all the S/E majors were 46.7 percent of the 1984 cohort and 27.7 percent of the 1998 graduates.

over time were larger as well. In particular, the share of A students planning to go directly to graduate school in a science or engineering field fell from about 25 percent to about 18 percent between the 1984 and 1998 seniors[19] while the proportion headed for MD studies dropped from 25 percent to around 17 percent.

The patterns of change over time in the lifetime plans of the A students were very similar to those of the entire group of S/E majors. The number who reported no plans for graduate study at all was smaller among the A student group but grew similarly over time (from just 2.8 percent of the 1984 cohort to 12.1 percent of the 1998 graduates). The proportion saying they would attend medical school at some point fell a bit but the number who planned to attend S/E graduate school sooner or later changed very little. As with the entire group of S/E majors, the interpretation of these changes depends a good deal upon how we treat the significant numbers in the early cohort who said they planned to go to graduate school but did not indicate a specific field and how much we discount respondents' plans for graduate study later in life compared to the probably more likely-to-be-realized plans for immediate post-baccalaureate study. Taking these factors into account, it appears likely that substantially fewer of these most elite students in the 1998 cohort will ever pursue graduate studies in science or engineering.

Gender differences are worth noting here, particularly as the proportion of women among S/E baccalaureates grows. Men were more likely than women to report they would attend graduate school in S/E, whether immediately or at some point in their career, and the gender differences were slightly larger in the more recent cohort. Thus, 12.7 percent of male 1998 S/E majors said they would go to graduate school in S/E the following fall, compared to 9.5 percent of women. When all plans to attend graduate school in S/E during the career are included (Table 4), 38.1 percent of men among 1998 seniors said they would do so compared to 31.4 percent of women. On the other hand, women in the 1998 cohort were more likely than men to indicate they planned to pursue MD degrees (28.4 percent versus 20.7 percent). Not surprisingly given the field distribution of their undergraduate majors, overall women led in proportions planning advanced study in biological/physical sciences and medicine while men had higher shares planning to continue in engineering, computer science and mathematics. Proportions pointing toward law school were similar (and small) for both sexes while men were more likely to plan graduate school in business and women in other fields. Overall, the proportion of the 1998 cohort with no advanced study plans at all was a bit higher for men, at 19.8 percent compared to 17.0 percent for women. Women who do not pursue graduate study shortly after the baccalaureate may well be more likely than men to be dissuaded from the S/E path by other life events such as marriage and childbirth, however. Notably, the proportions with no plans at all for advanced study were substantially lower, just 6 percent, in the 1984 cohort for both genders.

[19] The comparable figures for all the S/E majors (from Table 2, row 2) were: 1984- 16.7%; 1998- 12.0%.

Table 4. Lifetime* Advanced Study Plans of COFHE Male and Female Senior S/E Majors, 1998 Cohort					
	1998 Men n = 323		**1998 Women** n = 423		**Difference** (male – female)
	n	%	N	%	
Advanced Study	**259**	**80.2%**	**351**	**83.0%**	**-2.8**
All Science & Engineering	***123***	***38.1%***	***133***	***31.4%***	***6.7***
natural sciences**	46	14.2%	84	19.9%	-5.7
mathematics	7	2.2%	6	1.4%	0.8
computer science	21	6.5%	7	1.7%	4.8
engineering	39	12.1%	18	4.3%	7.8
two S/E fields	2	0.6%	4	0.9%	-0.3
Ph.D. / MD	8	2.5%	14	3.3%	-0.8
Medicine	***67***	***20.7%***	***120***	***28.4%***	***-7.7***
Other Fields	***61***	***18.9%***	***81***	***19.1%***	***-0.2***
law	7	2.1%	14	3.3%	-0.2
business	40	12.4%	27	6.4%	6.0
all other fields***	14	4.3%	40	9.5%	-5.2
Field Undecided	***6***	***1.9%***	***9***	***2.1%***	***-0.2***
Field Not Specified	***2***	***0.6%***	***8***	***1.9%***	***-1.3***
No Advanced Study Plans	**64**	**19.8%**	**72**	**17.0%**	**2.8**
TOTAL	**323**	**100%**	**423**	**100%**	

Note: One respondent did not indicate gender and is excluded from this table.
* Lifetime plans combine the autumn advanced study plans with indicated plans for advanced study in the future.
** Response options within this category varied from survey to survey. Included here are: for 1984, "biological sciences" plus "natural sciences"; for 1989, "natural sciences"; for 1998, "biological sciences" plus "physical sciences."
*** For men, "all other fields" included fine arts, humanities, other health fields, theology/religion, and "other." For women, this category included education, fine arts, humanities, other health fields, social sciences, and "other."

Source: Consortium on Financing Higher Education Senior Survey, 1998

We also examined the trends in S/E majors' graduate school plans by ethnic group.[20] These showed generally similar patterns of decline in plans for immediate (next autumn) graduate study. The proportion of underrepresented minority[21] S/E majors headed directly to graduate school in any field fell most sharply, from about 51 percent of the 1984 senior cohort to 22 percent of the 1998 group, but the declines for whites and Asians were also substantial. Within these decreased totals headed for advanced study, all three groups also saw substantial

[20] It is worth noting that growth rates between 1984 and 1998 in the number of S/E majors from the three ethnic categories differed sharply. The number of white S/E major respondents fell from 573 to 496 (-13.4 percent) while the number of Asian-Americans increased by more than two and a half times (from 59 to 153). The number of underrepresented minority respondents was identical in both years, at 68.
[21] Since the numbers of self-reported Black, Hispanic, and Native American respondents were too small for meaningful analyses in each cohort, they were combined to create the underrepresented category.

declines in proportions planning to go directly into graduate work in science or engineering. The 1998 cohort figures were 12.1 percent of whites, 10.5 percent of Asian-Americans, and 8.8 percent of underrepresented minorities, respectively.[22]

If we take the responses about plans for graduate study at a later point at face value, the apparent losses to science suggested above would be recouped among whites and the proportion of underrepresented minorities saying they were headed for S/E graduate school at some point in their career actually increased from about 28 percent in 1984 to nearly 43 percent in 1998.[23] This pattern did not hold among Asian-Americans however. The proportion of this group reporting plans for graduate study in S/E at any time in the future fell sharply, from 41 percent of the 1984 cohort to 27 percent in 1998. This trend may be a source of concern since Asian-Americans were the only ethnic group where the number of S/E majors showed growth.

CONCLUSIONS AND POLICY IMPLICATIONS

To sum up, there are good reasons to think that outstanding students with science backgrounds graduating from U.S. colleges and universities today may be deterred more than in the past from pursuing graduate studies in the natural sciences and engineering (except biology). The postgraduate training period in science is undeniably long and success uncertain, far more so than is true in alternative career routes such as graduate professional training for business or health professions careers, which typically takes only two years. Even medicine, which has long training times (including internship, residency, etc.), has far lower attrition rates en route than PhD/postdoctoral studies in the sciences and chances for appropriate job placement and ample financial rewards at the end are much greater.

What is the significance of these findings? Are there implications for policy? First, we would hasten to point out that our hypothesized linkage between the perceived costs and benefits of graduate study in S/E compared to shorter cycle professional programs and the decisions of high potential students needs to be verified by research that analyzes more directly students' decisions and the precise labor market and other conditions that may have influenced them, cohort by cohort. Still, the several trends shown in the data reported here are quite suggestive of deterioration in the competitive position of S/E graduate studies (and careers) relative to business and health professions with short training periods, a linkage that is very plausible in light of economic theory about individuals' human capital investment decisions. Policy must often be made before all pertinent scientific data are in and the urgency here is enhanced by the unprecedented recent declines in the attractiveness of U.S. graduate programs to international students. These effects may be exacerbated by the aftermath of the events of September 2001 and growing efforts by other nations to attract these students. On the other hand, all the broad S/E fields saw improvement in their attractiveness to very high GRE scorers of U.S. origin between 1998 and 2000 according to our most recent data from the Educational Testing Service. Labor

[22] The proportions indicating immediate plans to attend medical school fell even more sharply for whites and underrepresented minorities, but declined by just one percentage point among the Asian-Americans.
[23] Numbers of cases were very small here however. Also, underrepresented minority students may be less successful than others in persevering with plans to pursue S/E studies after a hiatus as other pressures and inducements intervene.

markets are well known to be both volatile and to a large extent self-adjusting so that strong policy responses to perceived imbalances are often ineffective or even counterproductive.

These considerations suggest a cautious policy approach guided more by long-term concerns than by any perceived immediate imbalances. If we believe that the research capacities represented by the highest caliber PhD-trained scientists and engineers have important collective benefits not fully captured by signals from a labor market that may reflect underinvestment in basic research or poorly designed career tracks for such people, then policies should address these demand-side issues as the first priority. Otherwise, efforts to pump up the supply side will be much like pushing on a string, i.e., students will not respond because they do not see attractive career prospects at the end. Or, worse, students may respond to stronger incentives to enroll in graduate school (i.e., more graduate student financial support) only to be trapped much later by the "logjam" that occurs when PhD-holders who have been postdoctoral apprentices for several years are unable to find permanent research or teaching posts. This last seems to be what has happened in the biological sciences where postdoctoral numbers have burgeoned yet graduate enrollments continue to grow (see National Research Council, 1998). Eventually, we would expect this untenable imbalance to affect the willingness of top students to begin graduate studies in these fields. In the other natural sciences and engineering postdoctoral numbers are significant but not nearly so large and have not grown at nearly the rate as in the life sciences. Limited attractive job opportunities appear already to have taken their toll on interest in some of these fields among top students, as our data suggest.

If the root of the problem of attracting adequate numbers of top students into science and engineering research careers lies on the demand side of the equation, then the solution must begin here as well. It is beyond the scope of this article to make a case that investments in R & D with a public good component should be increased and it is clear that our government will not support a policy of funding most PhD-trained scientists to do research, as some others have done in the past. Whatever their ultimate merits, such policies would surely work to increase the attractiveness of S/E graduate studies to top students who are now making other choices.

More realistic would be a policy of modest but visible new federal support – ideally designed to leverage university and other support as well – for a significant number of competitive *research assistant professorships*. These would be available only on a highly competitive basis to proven, experienced postdoctoral scholars. Some of these would otherwise have no place to go but another postdoctoral or similar apprentice position in the absence of sufficient faculty or professional-level nonacademic research posts to keep up with the growth in qualified and long-seasoned would-be postdoctoral "graduates." These new positions should be designed to be as competitive, autonomous and attractive as junior faculty posts at research universities and should have similar periods of appointment (say, a three year term with one renewal possible). The main benefits would be: first, to keep more of the best young people already trained doing science *on their own initiative* (as postdoctoral appointees normally cannot do) during what are often their most productive and innovative years; and, second, if the program were sizeable enough and visible enough, to help expand the pool of "good" jobs available perceived by outstanding young people at the point of choosing between graduate S/E studies and other pursuits. Such a policy seems to us a good bet to produce benefits greater than its costs.

Finally, our findings provide at least some positive news regarding policies now in place to overcome historic obstacles to equal participation in S/E graduate studies and careers by women and members of underrepresented groups. The data on high GRE scorers show significant gains in the numbers from these groups headed for S/E even as the number of top whites and males has fallen.[24] Certainly top talent from these growing sectors of the labor force must be encouraged and provided a full range of opportunities to develop fully. The data suggest that policies to this end may be having an impact.

We hope this policy analysis effort using existing national data files will encourage further investigation designed to both better understand and better respond in the public interest to the early career choices of our most able young people. They are after all among our most crucial resources in this age of rapid scientific and technological advance across the globe and economic and social developments intimately linked to such progress.

---

[24] The COFHE survey data also showed a large gain in the number of female and Asian-American S/E majors between the 1984 and 1998 cohorts but no such gain in the number of underrepresented minorities.

REFERENCES

Bok, D. (1993). *The Cost of Talent: How Executives and Professionals Are Paid and How It Affects America*. New York: Free Press.

"Changes to the GRE General Test: CGS Interviews Dr. Robert E. Thach, GRE Board Chair." (2001, October). *Council of Graduate Schools Communicator* XXXIV(8), 3.

Consortium on Financing Higher Education (1995, August). "The Class of '82: The First Decade." Unpublished report.

_________________ (1988, September). "Five Years Out: Revisiting the COFHE Class of 1982." Unpublished report.

Grandy, J. (1990). *Comparison of Expected with Actual Field of Graduate Study: An Analysis of GRE Survey Data*. ETS Research Report 90-17. Princeton, New Jersey: Educational Testing Service.

Hartnett, R. T. (1987, September/October). "Has There Been a Graduate Student 'Brain Drain' in the Arts and Sciences?" *Journal of Higher Education* 58(5), 562-585.

Hoffer, T., Dugoni, B., Sanderson, A., Sederstrom, S., Ghadialy, R., and Rocque, P. (2001). *Doctorate Recipients from United States Universities: Summary Report 2000*. Chicago: National Opinion Research Center.

Holmstrom, E. I., Gaddy, C.D., Van Horne, V. V., and Zimmerman, C. M. (1997, October). *Best and Brightest: Education and Career Paths of Top Science and Engineering Students*. Washington, DC: Commission on Professionals in Science and Technology.

Lloyd, M. (1998, July 17). "India's Brightest Technology Graduates Begin to Stanch the Brain Drain." *Chronicle of Higher Education*, A52.

McMurtrie, B. (2001, November 16). "Foreign Enrollments Grow in the U.S. but So Does the Competition from Other Nations." *Chronicle of Higher Education*, A45-A47.

National Research Council. Committee on Dimensions, Causes and Implications of Recent Trends in the Careers of Life Scientists. (1998). *Trends in the Early Careers of Life Scientists*. Washington, DC: National Academy Press.

Stricker, L. J., and Rock, D. A. (1993). *Examinee Background Characteristics and GRE General Test Performance*. GRE Board Report No. 89-07R. Princeton, New Jersey: Educational Testing Service.

Syverson, P. (2001, March). "Number of New Doctorates Decreases for First Time Since 1985." *Council of Graduate Schools Communicator* XXXIV(2), 6-7.

Zumeta, W. and Raveling, J. S. "The Best and Brightest for Science: Is There a Policy Problem Here?" (2001). In M.P. Feldman and A. N. Link (Eds.). *Innovation Policy in the Knowledge-Based Economy*. Boston, Dordrecht and London: Kluwer Academic Publishers, pp. 121-161.

Appendix

Consortium on Financing Higher Education (COFHE) members include:

Amherst
Barnard
Brown
Bryn Mawr
Carleton
Columbia
Cornell
Dartmouth
Duke
Georgetown
Harvard
Johns Hopkins
M.I.T.
Mount Holyoke
Northwestern
Oberlin
Pomona
Princeton
Rice
Smith
Stanford
Swarthmore
Trinity College
University of Chicago
University of Pennsylvania
University of Rochester
Washington University
Wellesley
Wesleyan
Williams College
Yale