

TRENDS IN GRADUATE ENROLLMENT BY DEPARTMENT QUALITY AND CITIZENSHIP, 1993-1998¹

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Here are examined trends in graduate enrollment between 1993 and 1998 by department quality and citizenship. Data sources utilized were the National Science Foundation's *Survey of Graduate Students and Postdoctorates*² and the National Research Council's most recent assessment of research doctorate programs in the United States.³ The purpose of the analysis was to determine, by discipline, if the broad decline in graduate enrollment in the natural sciences and engineering between 1993 and 1998 was evident across all departments regardless of quality rating of degree program. Of particular interest are the trends among U.S. citizens and permanent residents and how these compare with trends for non-citizens (temporary residents).

Enrollment data for doctorate-granting institutions were utilized since the NRC ranked only doctoral programs. However, the two data sources are not completely comparable. While the NRC rated only doctoral programs, the NSF does not collect its data by department or program but by institution. Thus, the NSF data unavoidably includes some data on students in master's degree programs housed in doctorate-granting institutions. This has some effect on the comparisons, largely in engineering and computer science where graduate enrollments reported are the most likely to be in master's programs. Fourteen fields were initially selected for analysis: chemistry, computer science, geosciences, mathematics, physics, chemical engineering, civil engineering, electrical engineering, mechanical engineering, ecology, genetics, neuroscience, pharmacology, and physiology. Taxonomic problems in the five life sciences disciplines – i.e., matching the NRC and NSF field classifications – made it necessary unfortunately to exclude these fields. Thus, the analyses reported here include only the nine disciplines above from the physical sciences, engineering, mathematics, and computer science.

¹ We are grateful to the Alfred P. Sloan Foundation for their generous support of this research.

² National Science Foundation, *Survey of Graduate Students and Postdoctorates*, Webcaspar Database.

³ National Research Council, *Research-Doctorate Programs in the United States Continuity and Change*, 1995. Although the NRC assessment has its limitations as an indicator of quality, there is no alternative or supplement.

Nineteen ninety-three was chosen as the initial year for the analysis because it was the year in which enrollment in most of the sciences and engineering peaked. In addition, it coincides rather well with changes in NSF's treatment of permanent residents in its data.⁴

For each discipline, departments were divided into four tiers based on the NRC ratings.⁵

SUMMARY OF FINDINGS

- Between 1993 and 1998, total graduate enrollment in science and engineering in doctorate-granting institutions declined in most major fields, with the exception of computer science (up 4.9%) and the biological sciences (up 1.1%) as shown in Table 1. Overall, there was a decline of 8.4% in graduate enrollments in doctorate-granting institutions.⁶

Table 1. Total Graduate School Enrollment in Doctorate-Granting Institutions by Selected Fields, 1993-1998

Field	1993	1998	% Change
Chemistry	19,130	17,618	-7.9
Computer Sciences	30,704	32,211	4.9
Geosciences ¹	13,441	10,607	-21.1
Mathematical Sciences	17,916	14,546	-18.8
Physics	13,441	10,607	-21.1
Chemical Engineering	7,411	6,974	-5.9
Civil Engineering	18,087	15,512	-14.2
Electrical Engineering	32,650	28,736	-12.0
Mechanical Engineering	17,476	13,967	-20.1
Biological Sciences	52,496	53,066	1.1
All S&E Fields ²	269,695	247,024	-8.4

¹ Includes earth sciences, atmospheric sciences, and oceanography

² Does not include the health sciences, social sciences or psychology

SOURCE: National Science Foundation, Web Caspar Database, 2001

- This decline was more severe for U.S. citizens and permanent residents. Between 1993 and 1998, the decline in total graduate enrollment in science and engineering for this group was 10.3%, ranging from a decline of 26.5% in mechanical engineering and 24.6% in physics to only a 3.6% drop in chemical engineering. For non-U.S. citizens, the overall decline was 4.2%, ranging from a drop of 25.6% in the

⁴ From 1992 onward NSF has counted permanent residents with U.S. citizens instead of with non-citizens. Also, Chinese students affected by the Chinese Student Protection Act of 1992 were first classified as permanent residents in 1993. The vast majority of these students are in engineering.

⁵ National Research Council, *Research-Doctorate Programs in the United States Continuity and Change*, 1995. Tier 1 - the top rated departments - those having a score of 4.0 and above on the "quality of graduate faculty" scale; tier 2 - those rated between 2.00 and 3.99; tier 3 - those rated less than 2.0; and tier Zero - unrated departments.

⁶ All S&E totals exclude the health sciences/health professions, social sciences and psychology.

geosciences and 20.1% in civil engineering to an increase of 18.8% in computer science.

But how were these declines distributed – relatively evenly across all departments, more concentrated in the top-rated ones, or more pronounced in the lower-ranked ones? The answer might have quality implications if declines were disproportionately in the top-rated departments and thus might elicit some policy concern. *A priori*, the distribution of enrollment changes by quality tier is unclear. One might hypothesize that, in a prolonged slack PhD labor market and with general resource tightness, top departments should have stronger advantages than ever in attracting students and funding so should perhaps gain ground in their share of enrollment. Still, some top departments might voluntarily cut back enrollments somewhat. At the other end of the spectrum, the lower-rated, often newer, departments have more urgent incentives to maintain or increase enrollments and some might do so by accepting marginal students, thus perhaps increasing their market share. Only empirical analysis can permit us to choose between these plausible but competing hypotheses about the dominant factors at work. The results across the nine disciplines are quite mixed.

Top-ranked Departments in Some Disciplines Experienced Greater Decline

The fields of chemistry, chemical engineering, civil engineering, and electrical engineering showed greater declines in enrollments of U.S. citizens and permanent residents at the top ranked schools (tier 1) than at all schools combined (see Table 2). In chemistry, the decline was 17.1% at the top-ranked departments, compared to a drop of 7.8% for all departments. In chemical engineering, there was a decline of 7.3% at the top-rated departments, but only a 3.6% decrease overall. There was a sharp 29.6% drop in enrollments in top-rated electrical engineering departments and a 25.3% decrease overall. In civil engineering, there was a decline of 15.4% at the top-rated departments, compared to a decrease of 12.3% overall

Top-ranked Departments in Some Disciplines Experienced Less Decline

The fields of computer science, geosciences, physics and mechanical engineering, showed the opposite effect (Table 2). Graduate enrollment of U.S. citizens and permanent residents fell less in the top-ranked departments than in all departments. Indeed, in computer science, graduate enrollment *increased* 6.6% at the top departments, compared to a 5.7% enrollment decline in the discipline overall, while in physics there was an overall decrease of 24.6%, compared to a decline of 20.7% for the top-rated departments alone. Similar results were found for the geosciences and mechanical engineering, although the enrollment declines were substantial in all quality tiers within these fields. There was little difference in the magnitude of enrollment change in the top

departments as compared with all departments in mathematics where enrollments of U.S. citizens and permanent residents fell by more than 23% over the five year span.

Table 2. Graduate School Enrollment in Doctorate-Granting Institutions by Selected Fields and NRC Rankings, 1993-1998 (U.S. Citizens and Permanent Residents)

Field	NRC Rankings					
	Tier 1			Total		
	1993	1998	% Change	1993	1998	% Change
Chemistry	2,434	2,018	-17.1	12,638	11,647	-7.8
Computer Sciences	1,413	1,506	6.6	19,742	18,617	-5.7
Geosciences	570	512	-10.2	5,706	5,044	-11.6
Mathematical Sciences	1,304	1,001	-23.2	10,198	7,808	-23.4
Physics	2,063	1,635	-20.7	8,243	6,219	-24.6
Chemical Engineering	852	790	-7.3	4,269	4,114	-3.6
Civil Engineering	1,436	1,215	-15.4	12,035	10,555	-12.3
Electrical Engineering	3,805	2,679	-29.6	20,624	15,396	-25.3
Mechanical Engineering	2,204	1,799	-18.4	11,444	8,410	-26.5

SOURCE: National Science Foundation, Graduate Students and Postdoctorates in Science and Engineering Survey, 1993 and 1998

Note: Tiers for this study were set up as follows: Using the rankings (0-5) published by the National Research Council, Tier 1 includes schools ranked 4.0-5; Tier 2 includes schools ranked 2.0-3.99, Tier 3, those ranked <2.0; and Tier Zero includes all other institutions granting a doctorate who were not ranked by the National Research Council.

Field Differences by Citizenship and Department Rating

Beginning in the 1970s, there has been a steady and heretofore nearly unbroken increase in the number and proportion of foreign citizens studying science and engineering in America's graduate schools. But recently signs have appeared that the supply of international students interested in studying in the United States may not be unlimited. In the recent period of decreasing overall enrollments, this could bring into sharper focus certain policy questions. To wit, are citizen and permanent resident students being displaced from S&E graduate programs by the large foreign presence and better technical qualifications of non-citizen entrants? Or, has the U.S. job market become so strong, especially for individuals with technical skills, that many U.S. citizens are pursuing employment rather than graduate studies leaving not only plenty of room for international students but a pressing need for them? Alternatively, are some of the native-born students who might have pursued graduate education instead going to professional schools? If the U.S. is losing its "best and brightest" from the academic S & E research enterprise, it might be time to reexamine some features of the way the nation carries out its academic research and training for it, including compensation structures. This would be all the more true if non-citizens are becoming less available to fill slots in graduate programs not being filled by citizens.

Here, we document the changes over the 1993-1998 period by citizenship and quality tier (see Table 3 for the data on temporary residents). Our analysis provides evidence across many, though not all, of the disciplines examined that declines in U.S. citizens are no longer being offset by growth in international student numbers as had long been the case. Rather, in most of the fields, both U.S. citizen and non-citizen numbers are down significantly. Among top-rated departments, however, there are more disciplines where increases in international students have partially offset declines in U.S. students. All the instances of such partial “replacement” by international students are in engineering disciplines or computer science, none of the science disciplines show this pattern.

- In chemistry, geosciences, mathematics, and physics, as well as chemical, civil and mechanical engineering, both U.S. and non-citizen enrollments fell significantly between 1993 and 1998.⁷ U.S. citizen numbers declined more in mathematics, physics and mechanical engineering while non-citizens declined more in chemical and civil engineering. Thus, there was no pattern at the aggregate level in any of these fields indicating substitution of non-citizens for the declining numbers of U.S. citizens and permanent residents.

Table 3. Graduate School Enrollment in Doctorate-Granting Institutions by Selected Fields, and NRC Rankings, 1993-1998 (Temporary Residents)

Field	NRC Rankings					
	Tier 1			Total		
	1993	1998	% Change	1993	1998	% Change
Chemistry	839	755	-10.0	6,434	5,756	-10.5
Computer Sciences	886	1,022	15.3	10,478	12,450	18.8
Geosciences	312	287	-8.0	1,654	1,230	-25.6
Mathematical Sciences	904	752	-16.8	4,588	4,040	-11.9
Physics	1,105	1,023	-7.4	5,180	4,369	-15.7
Chemical Engineering	389	336	-13.6	3,127	2,836	-9.3
Civil Engineering	816	885	8.5	5,980	4,780	-20.1
Electrical Engineering	2,042	2,472	21.1	11,922	13,501	13.2
Mechanical Engineering	891	948	6.4	6,017	5,458	-9.3

SOURCE: National Science Foundation, Graduate Students and Postdoctorates in Science and Engineering Survey, 1993 and 1998

Note: Tiers for this study were set up as follows: Using the rankings (0-5) published by the National Research Council, Tier 1 includes schools ranked 4.0-5; Tier 2 includes schools ranked 2.0-3.99; Tier 3, those ranked <2.0; and Tier Zero includes all other institutions granting a doctorate who were not ranked by the National Research Council.

- The pattern of sizeable declines in enrollments of both citizens and non-citizens also applied to the top-rated departments in most of these disciplines. The exceptions were tier one departments in civil and mechanical engineering where non-citizen enrollments increased (by 8.5% in civil engineering and by 6.4% in mechanical

⁷ All the decreases were greater than 10% with the following exceptions: chemical engineering- U.S. citizens -3.6%, non-citizens -9.3%; chemistry- U.S. citizens -7.8%. The declines exceeded 20% for U.S. citizens in mathematics, physics and mechanical engineering and for non-citizens in geosciences.

engineering), although not by nearly enough to offset declines of more than 15% in U.S. citizen enrollments.

- Electrical engineering and computer science showed quite different patterns. In electrical engineering, total enrollments of U.S. citizens and permanent residents fell by more than 25% while non-citizens' numbers grew by 13.2%, suggesting some replacement of citizens by non-citizens was occurring. Similarly, at the top-rated departments in this field U.S. citizen students declined by 29.6% while non-citizens' numbers increased by 21.1%. In computer science the aggregate decline in U.S. citizen and permanent resident students was much more modest, -5.7%, and increases in non-citizens were more than enough to offset these declines. At top-rated departments, both citizen and non-citizen numbers grew, though the non-citizens increased more (15.3% vs. 6.6%).

Enrollments of First-Year Students

Will the declines in graduate enrollments continue? Enrollments of first-year students should give some indication.⁸ In 1999, the number of full-time graduate students enrolled in science and engineering programs for the first time increased for the third consecutive year.⁹ First-time graduate enrollment in engineering rose 9.2% from 1997 to 1999, but first-time graduate enrollment in the natural sciences did not fare as well. The only discipline that showed an increase from 1997-1999 was computer science, which gained nearly 32% during that time period (Table 4). However, a number of science fields showed increases from 1998-1999, indicating that the signals might be turning positive for increases in total enrollment in the future, although some fields may buck the trend.

⁸ Unfortunately, the NSF does not break out its data on first-year enrollments by citizenship status, and provides only full-time enrollment data.

⁹ In data just released in January 2001 by the National Science Foundation, the number of full-time students enrolled for the first time in graduate science and engineering programs continued to increase. This contributed to the first increase in total science and engineering graduate students after five consecutive annual decreases. However, the 1999 gains in total enrollments were entirely accounted for by students on temporary visas; enrollments of U.S. citizens and permanent residents continued to decline.

Table 4. Full-time, First-time Graduate Students in Doctorate-Granting Institutions in Selected Science and Engineering Fields, 1997-1999

Discipline	1997	1998	1999	% Change 1997-98	% Change 1997-99
Engineering, Total	18,283	18,721	19,971	2.4	9.2
Chemical Engineering	1,434	1,485	1,471	3.6	2.6
Civil Engineering	3,639	3,645	3,589	0.2	(1.4)
Electrical Engineering	5,337	5,488	6,116	2.8	14.6
Mechanical Engineering	2,765	2,866	3,044	3.7	10.1
Chemistry	3,625	3,564	3,540	(1.7)	(2.3)
Physics	2,043	2,020	2,032	(1.1)	(0.5)
Geosciences	1,277	1,296	1,247	1.5	(2.3)
Mathematical Sciences	2,547	2,531	2,475	(0.6)	(2.8)
Computer Sciences	4,548	5,221	5,988	14.8	31.7
Biological Sciences	10,482	10,855	10,448	3.6	(0.3)

SOURCE: NSF WebCASPAR Database System.

Summary

This analysis has explored the recent period of declines in graduate enrollments in nine disciplines in the physical sciences, mathematics, engineering, and computer science with a focus on differences in the top-rated programs compared to others, and differences by students' citizenship status. We found that, among U.S. citizens and permanent residents, enrollment declines were larger at the top-rated departments than at other schools in chemistry, chemical engineering, civil engineering, and electrical engineering. This may be cause for some concern in these fields if the trend continues. But declines at the top departments were smaller than those at other departments in geosciences, physics, and mechanical engineering. In computer science U.S. citizen enrollments at the top-rated departments actually increased while they declined at other schools. In mathematics the rates of enrollment decline at top departments and other departments were nearly identical.

The decline in total graduate school enrollment between 1993 and 1998 was more severe for U.S. citizens and permanent residents than for non-U.S. citizens in the fields of mathematics, physics, and mechanical engineering. However, in chemistry, geosciences, chemical engineering, and civil engineering the decline was greater for non-U.S. students. Only in computer science and electrical engineering did non-citizen enrollments increase while enrollments of U.S. citizens declined. Thus, in most of these S & E fields policymakers need to be aware that both sources of graduate students have been on a downward trend, a new development. Graduate enrollment data for 1998 show the number of full-time students enrolled for the first time in graduate S & E programs increased for the second consecutive year and newly released data for 1999 show continued increases in first-time, first year graduate enrollment in science and engineering. The three years of increased first-time enrollment lead to an increase in total enrollment for the first time after five consecutive annual decreases. These data look

positive for continued increases in total enrollment in the future although there is no sign of an upturn yet in chemistry, physics and mathematical sciences.