

Where Do New US-Trained Science-Engineering PhDs Come From?

Richard B. Freeman
Harvard University and NBER
Centre for Economic Performance, LSE

Emily Jin
NBER Science and Engineering Workforce Project

Preliminary
For Discussion Only
February 15, 2003
AAAS

Do PhD science and engineering programs attract students from the best colleges and universities as much as in the past? What types of PhD granting universities and programs rely intensively on foreign baccalaureates for their graduate student body? Are top PhD programs enrolling students from a wider set of institutions than in the past, and if so, is this because students from traditional source undergraduate institutions have selected other careers?

This paper uses data on from the Survey of Earned Doctorates to examine these questions about the baccalaureate origins of new US-trained science and engineering PhDs. It describes the demographic and educational characteristics of new PhDs in science and engineering and analyzes matrices linking undergraduate origins to doctorate degrees from 1966 to 2000. The evidence shows:

1. Huge increases in the proportion of PhDs with foreign baccalaureate degrees and in the proportion of PhDs awarded to US women
2. A decline in the share of PhDs from traditional leading doctorate institutions
3. A decline in the share of PhDs from traditional baccalaureate source institutions.
4. A weaker connection between graduates from top undergraduate institutions and leading PhD programs.

The pattern of PhD production by university -reflects the interrelated decisions of students, PhD granting institutions, and undergraduate institutions, all influenced by government stipend and R and D policies and by the labor market for scientists/engineers and other high level occupations. To the extent that elite undergraduate institutions attract the best students, the drop in their share of PhDs suggests that science has lost some of its attractiveness to the best and brightest, presumably because these students see better job opportunities in other professions.

1. Changed Demography of US trained science and engineering PhDs

PhD graduates from US universities in the early 2000s differ markedly from the graduates three or four decades earlier. The graduates are older than previous cohorts. In 1974, the median age of a science and engineering PhD was 30.0. In 2000 the median age of a science and engineering PhD was 31.7. The graduates come from a more diverse background. In 1966, 71% of PhD graduates were US-born white males;¹ 6% were females; less than 3% were US born minorities; and 21% were foreign born students. In 2000, 30% of PhD graduates were US-born white males; 26% were US born females, 9% were US minorities; and 41% were foreign-born.

Figure 1 documents the increase in the foreign-born shares of US science and engineering PhDs from 1966 to 2001, and decomposes the foreign-born PhDs into those with foreign bachelor's degrees and those with US bachelor's degrees. It shows that the foreign proportion rose

¹ The 71% figure in 1966 for males refers to "non-minority males", which we assume were almost exclusively white.

sharply from the early 1980s to the early 1990s and then leveled off. The increase came roughly equally from students with foreign bachelor's degrees and from foreign born students with US bachelor's degrees.² The underlying data by field show that the foreign-born have become a majority of graduates in some disciplines, including branches of engineering, while increasing in all fields.

Figure 2 shows the increased share of US resident PhDs that went to women from 1966 to 2000 and the share that went to minorities from 1973, when the surveys record detailed minority representation, to 2000. The female and minority shares grow fairly steadily, with only the barest sign of leveling off by the end of the period. Asian and Pacific Island citizens increase their share sharply from negligible figures to 7% of science and engineering PhDs, while blacks and other minorities (American Indian and non black Hispanics) increase their share of US citizen PhDs more modestly. In absolute numbers, the number of US females gaining PhDs increased from 748 in 1966 to 2110 in 1973 to 6,614 in 2000; while from 1973 to 2000 the number of US minority PhDs increased from 450 to 2,374. Over the same 1973-2000 period the number of US white males gaining PhDs fell from 12,518 to 7,829.

These changes in the demographic composition of PhD graduates presumably reflect the differential incentives facing the different groups. Foreign students compare non-US PhD earnings and employment opportunities in their native country to what they could make in the US job market or in their native country with a US PhD. Since earnings for less educated persons are generally lower in foreign countries than in the US, the same US earnings prospects are likely to be more attractive to foreign-born students than to US students, especially if the PhD is their ticket into the US. American students will weigh the career prospects from gaining a science and engineering PhD with other options – medical school, law school, business school, or working as a scientist or engineer without a PhD. In addition, these students may be affected by the quality of their US undergraduate and high school science and engineering education.

Given the very different trends for minorities and women and white men in studying for a PhD, the US job market evidently sent markedly different signals to these different groups about the value of obtaining science and engineering degrees.

² We estimated the number of foreign born with foreign born bachelor's degrees as: the number of PhDs with foreign bachelor's minus the number of PhDs with foreign bachelors who are US citizens. We estimated the number of foreign born with US bachelors' as: Total number of PhDs - the number of PhDs who are US citizens - the number of foreign-born with foreign bachelor's degrees.

2. Who Produces Phds?

Hundreds of institutions grant PhDs in the US's large and competitive higher education market. In 1970, 214 universities granted PhDs in science and engineering. In 2000, 311 universities granted PhDs in science and engineering. Some institutions produce 400-500 science and engineering PhDs per year: UC Berkeley, University of Illinois at Urbana, University of Wisconsin at Madison, University of Michigan, University of Minnesota, MIT, Stanford, for example. Others produce very few PhDs per year: Providence College, University of the Pacific, UC Santa Cruz, Ball State University. A priori, the increase in the number of PhDs from the 1960s to 2000s could have come from increased PhD production at the larger leading universities; proportional increases in degrees among all universities; or increases in the number of degrees from-universities with smaller or less prestigious programs or with newly formed programs.

Table 1 shows that the 1970-2000 growth of PhD production took the form of increased numbers of degrees from smaller and less prestigious PhD granting universities. The columns "by number of doctoral degrees" give the distribution of degrees by the size of the doctoral institution. They show that the proportion of PhDs granted by the ten largest PhD granting institutions fell by 7.8 points from 24.3% in 1970 to 16.5% in 2000; the proportion of the next largest fifteen PhD producers fell by 4 percentage points from 21.5% to 17.7% while the proportion of the next 15 largest producers fell by 1.2 percentage points. The column labeled HH gives one widely used measure of the concentration of output among producers based on the entire distribution of degrees: the Herfindahl-Hirschman index. This index is the sum of squares of the proportions of degrees given by each degree granting institution. It is a standard measure of concentration in industrial organization, used for instance by the US Department of Justice (see www.usdoj.gov/atr/public/testimony/hhi.htm). Analysts of industrial organization consider markets in which the index is between 1000 and 1800 points to be moderately concentrated, and those in which the index exceeds 1800 points to be concentrated. From this perspective, the drop in the index from 1200 to 800 implies that PhD-production went from moderately concentrated to a highly competitive. While applying the standard industrial organization scaling to PhDs may be a stretch, the decline in the HH index with the number of degrees granted increases shows that new degrees came largely from smaller PhD granting universities.³

The columns labeled "by Carnegie classification of institutions of higher education" record degree production in the 125 leading universities defined by their Federal financial support of research and development – research universities; in doctoral universities that grant at least 20 degrees in any field or 10 or more in three fields, and in all other institutions. The proportion of degrees from the research universities falls, while the proportion from doctoral universities and other institutions rises. Finally, the columns labeled "by high quality programs"-classifies universities by the number of PhD programs that attained high rankings in the National Research Council rankings for 1982. They show a decrease in the share of PhD production in universities with higher numbers of high quality programs.

In sum, the increase in science and engineering PhDs in the US largely took the form of expansion of smaller and less prestigious programs. Between 1966 and 2000 the number of PhDs granted in the sciences and engineering increased by nearly 15,000: over 2/3rds of that increase occurred among institutions smaller than the top 40; 82% occurred among universities with few

³ a regression of the HH index on the log of number of Phds gives a coefficient of ---,

high quality programs.⁴ This pattern contrasts with sectors of the economy where large enterprises dominate markets and where increases in production typically come from those large firms (automobiles, steel, software). The difference between higher education and these industries presumably reflects the cost schedule for producing PhDs, in which larger established institutions produce graduates up to some capacity set by faculty, plant, or other characteristics of their existing program.

3. Where Do the Foreign-Born and Women Obtain PhDs?

That growth of PhDs occurred largely at smaller less prestigious PhD granting institutions does not mean that foreign-born or female doctorates flowed disproportionately into smaller less prestigious schools. Some programs may have recruited foreign-trained students to fill graduate classes or to provide research assistance to professors with R and D grants if they could not attract US students. But foreign students may also have enrolled in the most prestigious internationally known US programs. Similarly, the increased number of PhDs granted to women could have occurred largely in the less prestigious and newer programs, or could have come largely in the major prestigious producing programs, as women replaced the declining number of US male PhDs, or could have been proportionately distributed among schools.

To see where the growing number of foreign-born and female PhDs obtained their degrees, we compared changes in the distribution of foreign-born and women among universities between 1966 or 1973 and 2000 with changes in the distribution for the US born men who made up the bulk of PhD graduates in those earlier years. Table 2 summarizes the results of this analysis. The columns in the table labeled “numbers” give the number of PhDs to persons with different demographic characteristics, in total, and in research universities, in the top 40 PhD programs, by size, and in universities with the most highly rated programs and gives the ratio of the numbers in 2000 to 1966. The figures for “white men” are approximations in 1966 when the doctorate surveys did not include race and in 1973 when many persons did not report their ethnicity; as noted in the table. The statistics show that the massive shift in the distribution of

⁴ In our data, there were 11,570 PhDs in 1966 and 25,765 PhDs in 2000, giving an increase of 14,195. The top 40 PhD producers granted 7509 PhDs in 1966 and 12,104 PhDs in 2000. The “high quality” institutions granted 5579 PhDs in 1966 and 8,289 PhDs in 2000. The Carnegie research institutions granted 10,851 PhDs in 1966 and 21,095 so that 30% of the increased number of degrees came outside of that large group. See the numbers in table 2.

PhDs toward the foreign-born and women occurred largely because more of those groups gained PhDs rather than because the number of US males getting PhDs fell massively.

The columns labeled “proportions” record the proportions of the relevant PhD granting populations among the demographic groups or the proportion of the demographic group that earned a PhD in the specified form of institution, as noted-. For 1966 they show that 73.0% of all PhDs went to US men; that 93.9% of those men earned Phds from Carnegie classified research institutions; that 64.3% earned PhDs from the largest 40 PhD granting institutions; and so on. The figures in the final column shows that for all groups the proportion of degrees earned in the top PhD granting institutions fell more/rose less than for groups in total. Comparing these ratios across groups shows sharper drops in the shares for the foreign-born and women, particularly in the high quality institutions. In 1966 when the foreign-born were less likely to get PhDs, they were modestly more likely to get their PhD in a top institution than were US men, while the few US women who got PhDs were as likely to get those degrees from top institutions as were US men. Between 1966 and 2000, the proportions getting PhDs in the top PhD granting universities falls more for women and the foreign-born than for men. The differences are not huge, but they are statistically significant. In 2000, 34.5% of PhDs granted to US men came from “high quality” programs compared to 31.4% of PhDs granted the foreign-born and 27.3% of PhDs granted US women.

The proportion of foreign-born or women PhDs differs among universities, presumably in part because of differences in programs (women are more likely to get PhDs in bio science and the foreign-born are more likely to get PhD in engineering) and in part because of differences in their attractiveness of particular universities to those groups relative to US men. To see whether there is any long run persistence in proportions of PhDs granted the foreign-born or women, we compared the proportion of PhDs granted the foreign-born and US women in 2000 with the proportion of PhDs granted the foreign-born and US women in 1970. Figure 3 summarizes these results with a simple plot of the proportions in both years. For the foreign-born, there is relatively little link between the proportion in a university in 1970 and the proportion in a university in 2000: the correlation coefficient between the two is a modest 0.10. For women, by contrast, universities having relatively high proportion of US women among their PhD graduates in 1970 had relatively high proportions of US women among their PhD graduates in 2000: the correlation is 0.50. In addition, in 2000 there was a significant negative correlation between the share of US women among PhDs granted by a university and the share of foreign-born in that PhD group, of -0.35-, due in large part we suspect to whether a university grants relatively more engineering or biology PhDs.

4. US Baccalaureate Origins of PhDs

Almost all PhD students come from a bachelor’s program and many obtain master’s degrees before undertaking doctorate studies as well. Some bachelor’s programs send large numbers of graduates to science and engineering PhD programs. In the 2000 cohort of new science and engineering PhDs, for example, there were 200-300 graduates from such major institutions as Berkeley, Cornell, Michigan, Illinois, MIT, and Penn State. Other undergraduate institutions send few persons to PhD programs, because they have few graduates or attract students/offer programs that are not conducive to PhD training. Because undergraduate institutions differs significantly, the quality of science and engineering doctorates arguably depends in part on their baccalaureate origins. The greater the number of PhDs from the highly selective

colleges and universities which attract the best students and offer potentially superior education, the more likely will PhDs be drawn from the “best and brightest”. Over time, moreover, -elite universities and colleges have become more selective. The SAT scores of their students has risen relative to the average of college students than in the past, and the dispersion in those scores within selective institutions has fallen⁵. This makes the undergraduate origins a more important indicator of the likely quality of doctoral graduates than in the past.⁶

The National Academy of Sciences and National Science Foundation have gathered data on the undergraduate origins of PhDs from the Survey of Earned Degrees and its predecessor surveys (NSF, 1996; NAS, 1967). The most recent NSF report highlighted the proportion of foreign bachelor’s graduates obtaining science and engineering degrees and the concentration of PhDs from 25 major bachelor’s granting institutions (NSF, 1996); while earlier reports examined the family background as well as undergraduate origins of PhDs (NAS, 1967).

To see how the bachelor’s origins of science and engineering PhDs changed in recent years, we obtained data from the NSF’s Webcaspar database system on the bachelor’s institutions from which -PhDs graduated⁷. We examined the characteristics of baccalaureate institutions along three dimensions: the number of PhDs from their institution; the Carnegie classification of the bachelor’s institution, and the selectivity of institutions according to Barron’s Guide to the Selectivity of Colleges.

Table 3 summarizes the results of our analysis. The columns “by number of bachelor’s going for PhDs” give statistics on the distribution of PhDs by bachelor institution. In these calculations each bachelor’s institution is credited with the number of PhDs graduates from its school in the specified year. For instance, in 2000, 159 persons with a Harvard bachelor’s degree (from earlier years) gained a PhD, so we credit Harvard with 159 PhDs. The data show a modest drop in the proportion of PhDs granted to bachelor’s from the largest undergraduate origin institutions, defined in terms of the top 10, 25, 40 bachelor’s origin four year institutions. Because there are many more undergraduate institutions than PhD granting universities, the baccalaureate origins of PhDs are less concentrated among larger or the more selective institutions than are graduates by PhD-granting institution. The top 175 baccalaureate origin institutions have approximately the same percentage of doctorates as the top 40 doctoral institutions. The Herfindahl-Hirschman index of the concentration of PhDs by their bachelor’s origins falls slightly between 1970 and 2000.

The columns labeled “by Carnegie classification- of institutions of higher education” shows the proportion of US bachelor’s degrees in the 125 leading universities who make up the Carnegie commission’s “research university” category, in other academic institutions covered by the Carnegie classification; and in institutions that Carnegie does not cover. They show a decline in the

⁵ Hoxby reports that the dispersion of SATs within colleges has dropped despite an increase in nationwide, which implies that undergraduates are more tightly sorted into their baccalaureate institutions on the basis of this indicator of ability.

⁶ We use the term likely because we know of no study that shows that productivity of scientists, measured say by their publications or citations, is in fact influenced by undergraduate origins. One way to search for such a relation is to link undergraduate origins to measured productivity in a univariate analysis. Another would be to compare the productivity of graduates from the same PhD program in what amounts to a multivariate analysis conditioning on the quality of the PhD institution.

⁷<http://caspar.nsf.gov/webcaspar>

proportion of PhDs with baccalaureate origins from research universities and other Carnegie classified groups, with a corresponding increase in the proportion of PhDs with bachelor's origins in schools that the Carnegie classification does not cover.

Finally, the columns labeled "by Barron's college ranking" classifies the undergraduate institutions by their ranking in quality by the Barron's group in 2001. This categorization differentiates between the most selective undergraduate institutions (45 colleges); highly selective institutions (87 colleges); very selective institutions (40), and all other institutions. The tabulations show a drop in the proportion of US origin PhDs from 1970 to 2000 in all of the selective institutions.

The decline in the proportion of PhDs from highly selective colleges (or research universities or the largest bachelor's origin institutions) does not mean that these institutions produced fewer science and engineering PhDs over time. As table 3 shows, the number of PhDs with US bachelor's origins increased from 1970 to 2000, so that the proportions from any fixed set of schools would fall even if their numbers of graduates remained constant. In fact, the number of graduates from the colleges in the various Barron's selectivity groups barely changed from 1970 to 2000. In 1970 2,519 graduates from the most selective schools earned science and engineering PhDs. In 2000, 2,832 graduates from these schools earned PhD. The declining proportion of PhDs from the most selective baccalaureate institutions is due to the increased number of PhDs from other four year colleges and universities.

Looking at particular undergraduate institutions, there are some notable changes in the number of bachelor's gaining PhDs. Among top source undergraduate institutions, Berkeley had 295 science and engineering PhDs in 1970 and 279 in 2000 - a modest drop. Cornell had 191 science and engineering PhDs in 1970 and 262 in 2000 - a marked increase. Harvard went from 223 science and engineering PhDs in 1970 to 159 in 2000 and MIT went from 280 in 1970 to 203 in 2000. The biggest decline in a PhD producing undergraduate institution was CUNY City College, which fell from the third largest bachelor's institutions in 1970 with 245 doctoral graduates - 10% more PhDs than Harvard - to just 17 PhDs in 2000. At the other end of the spectrum, Texas A & M graduates earned 171 PhDs in 2000 compared to 83 PhDs in 1970, while UC San Diego undergraduates earned 152 PhDs in 2000, compared to just 1 PhD in 1970. Among smaller schools, Lehigh went from 59 PhDs in 1970 to 39 in 2000 while Harvey Mudd went from 11 PhDs in 1970 to 40 in 2000.

Variation among individual institutions aside, the distribution of PhDs by undergraduate origins changed in the direction of greater dispersion of bachelor's origins among US four institutions, despite the greater concentration of the most able in selective colleges and universities.

5 Bachelor's to PhD Programs

The issue that naturally arises next is the link between specific undergraduate institutions or types of institutions and specific PhD granting universities or types of universities. Perhaps top undergraduate schools send graduates increasingly to top PhD programs and less prestigious undergraduate schools send graduates to lower level PhD programs. Viewed as a matrix of flows from bachelor's institutions to PhD granting universities, have key elements in the matrix changed over time?

To examine the bachelor's institution-PhD institution link, we obtained data from the National Science Foundation on the undergraduate origins of PhDs by doctorate-granting

university for 1970-2000.⁸ For confidentiality reasons, the NSF cannot release data for 5 or fewer people, so it suppresses the information in those cells. To reduce this problem, NSF created an undergraduate origin-PhD university matrix using 5 year windows: 1970-74; 1975-79; etc. rather than single years. Each element in the matrix gives the number of persons from every US bachelor's institution who obtained a science or engineering PhD during those years. For instance, the 1995-1999 matrix showed that 17 University of Chicago bachelor's graduates earned a science or engineering PhD at MIT; that 94 Harvard bachelor's graduates obtained a science/engineering PhD at Berkeley; that 10 Harvey Mudd graduates earned science/engineering Phds at University of California-San Diego, and so on. Even with the five year window, the NSF had to suppress 36% to 47% of the observations because the numbers in particular cells fell below the confidentiality limit. Suppression of data for confidentiality reasons limits our ability to make inferences about PhDs from small bachelor's origin institutions and small PhD programs. For example, in 1970-74 there were no reported graduates from Caltech, getting a PhD at University of Texas, whereas in 1995-99 there are 6 graduates. We do not know whether this was a relatively increase from 0 to 6 or a modest change, from 5 to 6.⁹

This problem notwithstanding, we used the bachelor's- PhD matrices for 1970-74 and 1995-99 to tabulate the proportion of PhDs granted to persons from relatively large or high quality undergraduate origin institutions **and** from large or high quality PhD granting universities. The figures under the label "Percentage of All PhDs" record the percentage of all PhDs, including those trained in non-US undergraduate institutions, in the specified baccalaureate-PhD group. The figures under the label "Percentage of US Bachelor's Origin PhD's" record the percentage of the specified baccalaureate-PhD group relative to US baccalaureate PhDs only.

Lines 1 and 2 show a sharp drop in the proportion of all PhDs and of US bachelor's origin PhDs from large bachelor's origin institutions and large PhD granting institutions. The table gives the figures for the largest 10 and 25 bachelor's origin and PhD granting institutions, but the same pattern can be found in other categorizations. Line 3, which gives the proportion of PhDs from students who did their undergraduate and graduate training in the 125 major research institutions in the Carnegie classification, for instance, also shows a decline in the concentration of PhDs from these groups. Removing foreign baccalaureates from the denominator reduces the magnitude of the trend toward less concentration of PhDs in particular bachelor's-doctorate cells, but does not eliminate the trend. Lines 4-5 show the proportion of PhDs granted to students going to the most selective or to highly selective undergraduate institutions earning PhD at institutions with 10 or more highly rated programs, according to the NRC. The proportion of all PhDs in these groups declines noticeably for all PhDs and more modestly for US bachelor's origin PhDs.

6. Sources for Top PhD Programs

Do top PhD granting universities obtain students from a similar set of undergraduate institutions as in the past or have they widened their range of source institutions? Table 5 shows the undergraduate origins of PhDs at two major private universities, Harvard and MIT, and at two

⁸ We want to thank Teresa Grimes at QRC and Keith Wilkinson at NSF for creating the matrices in useful forms. To minimize the loss of information due to confidentiality, the NSF s

⁹ We know that the number of persons in the suppressed cells ranges from 0 to 5, so we have bounds on the missing observations, which can help in assessing some issues but not in judging changes in small flows..

major public universities, Berkeley and Michigan, in 1970-74 and in 1995-99. It records the number of PhDs granted by each of the institutions; the numbers granted graduates from Barron's most selective, highly selective, and very selective institutions, and the numbers from other US baccalaureate schools and from foreign schools. In addition, the table records the number of PhDs given to graduates from six specific undergraduate institutions.

The data shows a mixed pattern of change. Harvard and MIT obtain fewer science and engineering PhDs from the selective undergraduate schools. Berkeley and Michigan drew more PhDs from those students. An important factor in the decline of PhDs from the most selective undergraduate schools at Harvard and MIT is a sharp fall in the number of their own bachelor's graduates staying on for PhDs. In 1970-74 224 of Harvard's 1575 PhDs went to former Harvard undergraduates. In 1995-99, only 133 Harvard bachelor's graduates obtained science and engineering PhDs at Harvard. At MIT the drop in the number of bachelor's graduates obtaining PhDs at the school is even greater, from 370 to 191. The fall in "own-PhDs" is not limited to those institutions. Taking all PhD-granting institutions we find that the percentage of PhDs granted to persons with a baccalaureate from the same school fell from 14% to 10%, on average.

Overall, the proportion of PhDs in leading US PhD-granting institutions that come from the "most selective" and "highly selective" undergraduate institutions fell from 41% in 1970-74 to 33% in 1995-99. Looking only at US bachelor's origin PhDs, however, the picture is different. Top PhD institutions continue to rely intensively on students from the most selective or highly selective undergraduate institutions. In 1970-74 51% of US bachelor's origin PhDs granted by universities with ten or more top-rated PhD programs came from the most selective and highly selective undergraduate institutions. In 1995-99 55% of US bachelor's origin PhDs granted by universities with ten or more top-rated PhD programs came from the most selective and highly selective undergraduate institutions.

7. Destinations of Top Bachelor's Graduates

Do bachelor's graduates from major 4 year institutions obtain PhDs from top PhD granting universities in the same proportions as in the past, or do they increasingly gain PhDs from the less prestigious growing programs?

To answer this question, we calculated the probability that baccalaureates earned their PhDs from specified types of universities. The numerator in these calculations is the number of persons in the specified bachelor's origin/PhD cell (as in earlier tables). The denominator is the number of PhDs granted to persons with the specified baccalaureate origins, rather than all PhDs. Panel A of Table 6 shows a modest downward trend in the conditional probabilities that graduates from large bachelor's origin schools, research institutions, and selective bachelor's programs obtain their PhD at major or high quality PhD institutes. The drop indicates that graduates from the best bachelor's programs were more dispersed among PhD programs in 1995-99 than they were in 1970-74

Panel B of Table 6 shows the number of bachelor's graduates of selected major universities and elite liberal arts colleges earning PhDs and the proportion who earned PhDs at universities with ten or more highly rated PhD programs. These data show variation among the universities, in the number of PhDs produced in total: sizeable drops in the number of Harvard and MIT graduates getting PhDs, for example, compared to increases in the numbers of Princeton and Yale graduates getting PhDs. There is even greater variation among the liberal arts colleges with the number of PhDs dropping at Amherst while rising at Carleton and Williams and holding roughly steady at high numbers at Swarthmore. In eight of the ten institutions, however, the proportion

obtaining PhDs at Universities with 10 more top programs falls, the exceptions being small liberal arts colleges.

8. Conclusion

This study has shown that the supply of PhDs, once highly concentrated among white men in selective doctorate granting institutions from selective undergraduate institutions, has widened in several ways. The demography of PhDs has changed, with US women and foreign-born persons gaining sizeable shares of PhDs. The concentration of PhDs among universities has fallen, as expansion has occurred largely in smaller and less prestigious universities. The bachelor's origins of PhDs changed, with a huge increase in foreign baccalaureates and with baccalaureates from a wider span of US institutions earning PhDs. There was also noticeable variation in patterns for individual 4 year institutions and doctorate granting universities, presumably reflecting differences in institution policies regarding admission and education, and in differences in the opportunities facing bachelor's from different four year institutions.

The fact that PhD production has become more widely dispersed does not, we caution, mean that the overall quality of science and engineering PhDs has fallen. If the larger established programs had expanded to produce more PhDs (say 800 PhDs per year from Berkeley instead of 500, or 500 from Harvard instead of 300), the quality of their education might have fallen sharply. New and small programs may offer as good or better education as traditional large PhD granting universities during a period of expansion. Similarly, since highly talented students exist at non-selective four year institutions as well as in the elite private and public colleges and universities, it is possible that increasing the range of source bachelor's institutions may have had a similar impact on the quality of PhDs as increasing the number of PhDs from traditional bachelor's sources. Finally, the influx of foreign baccalaureates may have improved the overall quality of new science and engineering PhDs by drawing on a wider pool of talented students. While the implications for the overall quality of the production of PhDs are debatable, the overriding pattern has been for a wider range of bachelor's source institutions and PhD granting universities than in the past.

References and Notes

notes:

The Carnegie Classification of Institutions was used to group types of institutions for this analysis. The Carnegie Commission on Higher Education has periodically (1970, 1976, 1987, and 1994) classified institutions of higher education in the United States by the range of programs and/or degrees offered, enrollment size, and amount of Federal funds received for research. The 1994 Carnegie Classification is used in this report to study the baccalaureate origins of scientists and engineers who recently received their doctorate from U.S. institutions. The changes to the 1994 Carnegie Classification were such that this analysis is not comparable to the earlier data by Carnegie Classifications in the earlier report, *Undergraduate Origins of Recent Science and Engineering Doctorate Recipients*(NSF 92-332

1.

Table 1: Measures of the Concentration of PhDs by Doctoral Institution

Year	# PhDs	By Number of Doctoral Degrees				By Carnegie Classification			By Number High Quality PhD programs			
		% Top 10 (by size)	% Top 11-25	% Top 26-40	HH	research	doctoral	other	10+ Top programs	3-10 Top programs	1-2 Top programs	No Top Programs
1970	18038	24.3	21.5	13.6	123.1	90.3	8.4	1.3	24.9	15.0	22.6	37.5
1975	18778	21.4	19.8	13.8	105.7							
1980	17763	20.2	19.0	13.4	98.3							
1985	18924	20.4	18.1	13.5	96.7							
1990	22841	19.6	18.2	12.8	91.6							
1995	26438	18.3	18.5	12.6	87.1	82.5	12.2	5.3	18.6	14.2	21.3	45.9
2000	25765	16.5	17.7	12.4	79.8							

SOURCE:

National Science Foundation. Various Years. NSF Division of Science Resource Statistics. *Survey of Earned Doctorates*. Data available on WebCaspar.

<http://caspar.nsf.gov/cgi-bin/WebIC.exe?template=nsf/srs/webcasp/start.wi>

Table 2: Numbers and Proportions of Doctorate Recipients in “Top” PhD Programs, by Demographic Characteristic of PhD Recipient and Percentage Change in Numbers, 1966-2000

Doctorate Recipients by	Years			Ratio	Years			Ratio
	1966	1973	2000	2000/1966	1966	1973	2000	2000/1966
US Men:								
% of Total	8,448	12,877	9,014	107	73.0	66.5	34.7	.48
% of US Men								
Research	7,934	11,528	7,520	95	93.9	89.5	83.4	.88
Top 40 by Size	5,439	6,932	4,449	82	64.3	53.8	49.4	.77
High Quality	3,898	4,787	3,114	80	33.7	37.2	34.5	.36
US “White Men”:								
% of Total	8,197	12,518	7,829	95	70.5	64.6	30.1	.42
Foreign-Born:								
% of Total	2,418	4,361	10,744	444.0	20.8	22.5	41.4	1.95
% of Foreign-Born								
Research	2,241	4,002	8,598	384	92.6	91.8	80.0	.86
Top 40 by Size	1,600	2,463	5,001	315	66.2	56.5	46.5	.70
High Quality	1,327	1,930	3,370	254	54.9	44.3	31.4	.57
US Women:								
% of Total	748	2,110	6,614	884	6.4	10.9	25.0	3.91
% of US Women								
Research	676	1,860	4,977	836	90.3	88.2	75.2	.83
Top 40 by Size	470	1,156	2,654	465	62.8	54.8	40.1	.64
High Quality	354	811	1,805	410	47.3	38.4	27.3	.58

SOURCE: tabulated from:

National Science Foundation. Various Years. NSF Division of Science Resource Statistics. *Survey of Earned Doctorates*. Data available on WebCaspar.

<http://caspar.nsf.gov/cgi-bin/WebIC.exe?template=nsf/srs/webcaspar/start.wi>

“White Male” for 1966 and 1973 are estimated. In 1973, 2,972 men did not answer the ethnicity question. Given the proportions minority, we allocated all who did not answer to white men. For 1966 we used the 1973 estimated white male proportion.

Table 3: Distribution of PhDs, By US Baccalaureate Origin Institution,

Year	# PhDs from US Bachelor's Institutions	By Number of Bachelor's Going for PhDs, US Baccalaureates					By Carnegie Classification US Bachelors Only			By Barron's Selectivity Index		
		% Top 10	% Top 25	% Top 40	% Top 175	HH	Research	Other Classified	Not Classified	Most Selective	Highly Selective	Very Selective
1970	18038	12.4	22.9	30.1	59.8	36.0	28.2	9.3	62.5	8.4	11.1	2.9
1975	18778	10.5	19.7	25.7	53.9	38.0						
1980	17763	10.5	19.1	25.6	54.5	27.7						
1985	18924	9.0	17.2	23.0	48.9	21.9						
1990	22841	8.3	15.6	20.6	43.9	19.4						
1995	26438	7.7	14.6	19.8	40.1	15.8	19.2	4.7	76.1	6.1	7.3	2.5
2000	25765	7.8	15.2	20.6	40.8	16.7						

SOURCE:

Carnegie data tabulated from: National Science Foundation. Various Years. NSF Division of Science Resource Statistics. *Survey of Earned Doctorates*. Data available on WebCaspar.

<http://caspar.nsf.gov/cgi-bin/WebIC.exe?template=nsf/srs/webcasp/start.wi>

Barron's data tabulated from:

<http://www.rtnj.org/story.cfm?storyid=4511> and secondarily, from

<http://www.gcc.edu/news/rankings/main/barrons.htm>

NB: Carnegie and Barron's are for 1970-74 and 1995-1999 BUT CANT WE GET THE

INDIVIDUAL YEARS???

**THE YELLOW ARE FOR US ONLY, BUT THE SIZE INCLUDE NON-US. CANT WE GET THAT
ALSO FOR US ONLY**

Table 4. The Percentage of All PhDs and of All US-Baccalaureate PhDs by Undergraduate Origins and PhD Granting Institution

	Percentage of ALL PhDs		Percentage of US Bachelor's Origin PhDs	
	1970-74	1995-99	1970-74	1995-99
1. Top 10 BS Origin Institutions - Top 10 PhD Institutions	5.0	2.8	6.2	4.7
2. Top 25 Origin Institutions - Top 25 PhD Institutions	12.6	6.1	15.7	12.3
3. BS from Research Institutions - PhD Research Institution	27.9	18.6	34.8	31.3
4. Most Selective BS - Top PhD Program	5.2	3.4	6.4	5.7
5. Highly Selective BS - Top PhD Program	4.9	2.7	6.0	4.5

SOURCE:

National Science Foundation. Various Years. NSF Division of Science Resource Statistics. *Survey of Earned Doctorates*. Data available on WebCaspar.

<http://caspar.nsf.gov/cgi-bin/WebIC.exe?template=nsf/srs/webcasp/start.wi>

**Table 5: Numbers of the PhDs with Specified Bachelor's Origins
at Leading Doctorate Universities**

	Harvard		MIT		Berkeley		Michigan	
	1970-74	1995-99	1970-74	1995-99	1970-74	1995-99	1970-74	1995-99
All PhDs	1575	1591	1959	2379	2765	2785	2135	2319
By Barron's Selectivity								
Most Selective	669	573	712	552	423	631	251	319
Highly Selective	209	213	221	185	689	653	605	404
Very Selective	13	32	49	42	53	83	28	62
Other U.S.	684	773	977	1600	1632	1418	1251	1534
Foreign								
By Specific Undergraduate Institutions								
Harvard	224	133	55	55	80	94	44	16
MIT	47	51	370	181	64	80	24	28
Berkeley	55	54	40	65	462	292	28	38
Michigan	30	23	27	19	38	40	367	185
Stanford	26	41	22	36	41	56	12	20
Cornell	52	45	36	33	36	41	29	40
Princeton	42	52	34	31	25	55	17	19

SOURCE:

National Science Foundation. Various Years. NSF Division of Science Resource Statistics. *Survey of Earned Doctorates*. Data available on WebCaspar.

<http://caspar.nsf.gov/cgi-bin/WebIC.exe?template=nsf/srs/webcasp/start.wi>

Table 6: Conditional Probabilities of Baccalaureates from Specified Undergraduate Institutions Programs Earn PhDs at Top PhD Institutions, 1970-74 and 1995-99

A. Proportion from Specified BS Background
Obtaining PhDs at Specified Institution

	1970-74	1995-99
BS from Top 10 BS Origin Institutions Going to Top 10 PhD Institutions	52 %	47 %
BS from Top 25 Origin Institutions Going to Top 25 PhD Institutions	76 %	70 %
BS from Research Institution to PhD Research Institution	99 %	97 %
Most Selective BS to Top PhD Programs	62 %	56 %
Highly Selective BS to Top PhD Programs	44 %	37 %

B. Proportion from Named Institution Obtaining PhDs
at Universities with 10 or More Top Programs

	1970-74	1995-99
Harvard (1005; 826) *	65%	62%
MIT (1144; 989)	71%	57%
Berkeley (1611; 1705)	56 %	48 %
Michigan (1072; 1067)	61 %	39 %
Princeton (433; 581)	57 %	52 %
Yale (411; 561)	61 %	52 %
Amherst (177; 138)	37 %	25 %
Carleton (160; 256)	24 %	28 %
Swarthmore (227; 277)	52 %	44 %
Williams (135; 185)	39 %	39 %

* Total number of PhDs from undergraduate institution in 1970-74 and 1995-99, respectively, including those from universities where the explicit number was suppressed due to small numbers).

SOURCE:

National Science Foundation. Various Years. NSF Division of Science Resource Statistics. *Survey of Earned Doctorates*. Data available on WebCaspar.

<http://caspar.nsf.gov/cgi-bin/WebIC.exe?template=nsf/srs/webcasp/start.wi>

BIBLIOGRAPHY

Hardy, Kenneth R. 1974. "Social Origins of American Scientists and Scholars," *Science*, Vol 185 (August) pp 497-506.

Harmon, Lindsey R. 1978. *A Century of Doctorates: Data Analysis of Growth and Change*. (Washington DC: National Academy of Sciences).

Hill, Susan T. 1992. *Undergraduate Origins of Recent Science and Engineering Doctorate Recipients*. (Washington, DC: National Science Foundation).

Knapp, R.H. and H.B. Goodrich. 1952. *Origins of American Scientists*. (Chicago, IL: University of Chicago Press).

National Academy of Sciences. 1967. *Doctorate Recipients from United States Universities: 1958-1966*. Publication # 1489. (Washington, DC: National Academy of Sciences).

National Academy of Sciences. 1958. National Research Council. *Doctorate Production in United States Universities: 1936-1956, with Baccalaureate Origins of Doctorates in Sciences, Arts and Humanities*. Publication # 582 (Washington, DC).

National Science Foundation. 1996. Undergraduate Origins of Recent (1991-95) Science and Engineering Doctorate Recipients, Detailed Statistical Tables NSF 96-334 (Arlington, VA)

National Science Foundation. Various Years. NSF Division of Science Resource Statistics. *Survey of Earned Doctorates*. Data available on WebCaspar.

<http://caspar.nsf.gov/cgi-bin/WebIC.exe?template=nsf/srs/webcasp/start.wi>