

DOCTORAL EDUCATION AND
THE FACULTY OF THE FUTURE

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GENERATING DOCTORAL DEGREE CANDIDATES AT LIBERAL ARTS COLLEGES

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Liberal arts colleges are an important source of PhD candidates. While these colleges award about 11 percent of all undergraduate degrees in the United States, almost 17 percent of all PhDs awarded to American students are to graduates of liberal arts colleges. The most recent data suggest that about 5.3 percent of all graduates from the best liberal arts colleges eventually earn a PhD, while only 2.2 percent of all graduates from the best universities do. There is also a substantial difference across liberal arts colleges, with the best colleges producing PhD candidates at three times the rate of lower-ranked colleges.

How is it that some liberal arts colleges are consistently more successful than other institutions at producing graduates who go on to earn a PhD? The answers to this question are inherently complex and difficult to isolate. This chapter is a first attempt to unravel parts of the story.

The social benefits provided by institutions of higher education in the form of having a highly educated citizenry are well understood. Society benefits from scientific discoveries, creative works of art, and informative policy analyses as well as from having a more knowledgeable electorate. Institutions of higher education, however, vary greatly in their approach toward education. At liberal arts colleges, where graduate degrees are seldom awarded, the primary mission is focused on educating

undergraduates. Even though graduating students who will eventually earn a PhD is not the sole objective (and maybe not even a primary objective) of liberal arts colleges, the graduate school success of their students is important to liberal arts colleges. As socially conscious institutions, colleges value education and the benefits that a graduate education offers. Many faculty members at liberal arts colleges measure their contribution to society in part by the students they produce, including future PhD recipients who go on to undertake meaningful research of their own. More locally, the rate at which an institution's students pursue graduate study indicates generally how successful the institution is at fostering growth in its students' enjoyment of learning and a desire to pursue their own path toward understanding and discovery after college. Liberal arts colleges also have a preference, at least marginally, for hiring faculty with a liberal arts background. This suggests there is some consensus, at least among college deans, that liberal arts college graduates may have a greater appreciation, if not a greater affinity, for teaching (Astin 1999; Warch 2001). And more pragmatically, college rankings, the accreditation process, and granting agencies such as the National Science Foundation (NSF) all consider the graduate school success of alumni when evaluating institutions of higher education.

This chapter also provides insight into the relationship between faculty scholarship and the graduate school choices of students. Whether faculty scholarship should be required at liberal arts colleges has long been debated. Through the 1950s, college faculty were not expected to be engaged in research. Over the last forty years, however, scholarship expectations have changed. Presently, the most elite colleges require their faculty to be deeply engaged in research. Most lower-ranked colleges also consider scholarship in tenure decisions, though the quantity and quality of the scholarship requirements are less than at the top institutions and vary considerably across institutions (McCaughy 1994).

Some argue that imposing unnecessary research expectations on faculty detracts from high-quality teaching, the foremost stated mission of liberal arts colleges, as research competes for scarce funds and faculty time. Faculty who spend more of their time engaged in research, the argument goes, have less time to devote to teaching and advising, persuading fewer students to pursue a PhD.¹ In contrast, others maintain that engagement in scholarship, at least at the very best liberal arts colleges, helps faculty become better teachers (McCaughy 1994). Faculty research can engage students directly and foster excellent teaching. As a result, students are more likely to pursue a PhD.² The results presented herein suggest that both effects exist, with the positive effects of faculty scholarship being strongest at the best colleges.

GENERATING PHD CANDIDATES

For our purposes here, the process of "generating" a PhD candidate occurs during one's undergraduate education. Specifically, an institution is said to generate a PhD candidate when a graduate from that institution receives a PhD from any PhD granting institution in the United States. Since 1970, American universities of all calibers (PhD-granting and non-PhD-granting) have generated between 20,000 and 24,000 PhD candidates annually, while liberal arts colleges have generated between 3,600 and 4,900 annually.³

The National Center for Education Statistics' Higher Education General Information Survey (HEGIS) and the Integrated Postsecondary Education Data System (IPEDS) Completions Survey provide the number of undergraduate degrees awarded by each institution each year, while the National Science Foundation's Survey of Earned Doctorates reports the number of PhDs earned each year by alumni of each institution.⁴ Although the surveys contain information on thousands of institutions of higher education, the Carnegie Classification of Institutes of Higher Education system is used to focus on liberal arts colleges (institutions designated BA I or II) and universities (institutions designated Research I or II, Doctoral I or II, or Master's I or II). According to these definitions, there are 604 colleges and 732 universities. The discussion here, however, is restricted to the "top" institutions in each group. There are 165 colleges designated as BA I, and 87 universities designated as Research I. While the top universities and colleges alike account for about one-third of all undergraduate degrees awarded, the top universities consistently account for just under half of all PhD candidates generated by universities, while the top colleges account for more than two-thirds of all PhD candidates generated by liberal arts colleges.

Using data from the Survey of Earned Doctorates and the Completions Survey, the rate at which each institution or each type of institution that generates PhD candidates can be calculated and will simply be called the PhD generation rate. Two issues, however, are worth mentioning. First, the Survey of Earned Degrees does not report when the PhD recipient received her undergraduate degree. Thus, a five-year rolling window between undergraduate and graduate degrees is used.⁵ Second, to smooth the data from year to year, the yearly PhD generation rate is calculated as all PhDs awarded within two years as a fraction of all undergraduate degrees awarded within two years. For example, the rate of generating PhD candidates for all liberal arts colleges in 1975 is calculated as all PhDs received by graduates of liberal arts colleges from 1973 through 1977 measured as a fraction of all undergraduate degrees awarded by liberal arts colleges from 1968 through 1972.

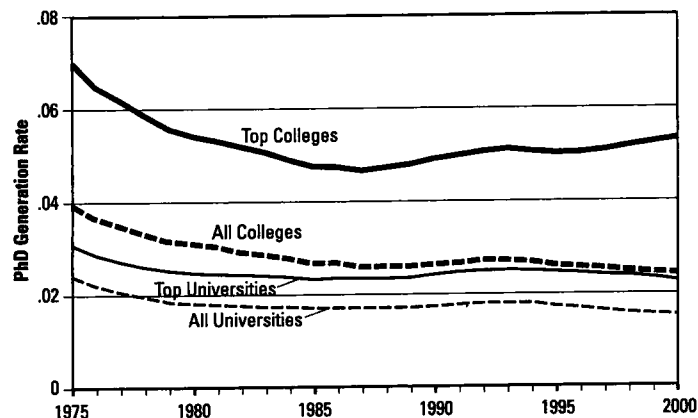


Figure 6.1. PhD generation rates by type of institution.

Source: Author's calculations using the NSF Survey of Earned Doctorates and HEGIS/IPEDS Completion Survey.

Note: Colleges are all BA I and II Carnegie classified institutions in 1994. Universities are all Research I and II, Doctoral I and II, and Masters I and II Carnegie classified institutions in 1994. Top colleges are the BA I institutions, while top universities are the Research I institutions.

Yearly PhD generation rates for the top liberal arts colleges versus the top universities and for all liberal arts colleges versus all universities are shown in figure 6.1. Rates of generating PhD candidates steadily fell from 1975 until 1985 for all types of institutions. Since 1985, however, only the top liberal arts colleges have experienced an increase in generation rates—from just under 4.7 in 1987 to over 5 percent by 1992 and in excess of 5.3 percent since 2000. Comparatively, the rate at which top universities generate PhD candidates fell below 2.5 percent by 1980, and has hovered between 2.2 and 2.5 percent ever since. A similarly persistent gap, though not as large, exists between all colleges and all universities. Whereas the rate of generating PhD candidates for all colleges fell from just over 3 percent in 1980 to 2.4 percent in 2000, it fell for all universities from 1.8 percent in 1980 to under 1.6 percent in 2000.

These differences in the rates of generating PhD candidates are substantial. Throughout the 1990s, for example, whereas liberal arts colleges graduated one person for almost every eight university graduates, graduates of liberal arts colleges earned one PhD for every five earned by university graduates. The ratios are even more striking for the top institutions. From 1985 to 1995, the top liberal arts colleges consistently generated PhD candidates at twice the rate of the top universities.

By 2000, as they had in the mid 1970s, the top liberal arts colleges were generating PhD candidates at a rate two and a half times greater than that of the top universities.

CHOOSING TO PURSUE A PHD

There are many possible explanations for why liberal arts colleges generate PhD candidates at a greater rate than their university counterparts. Liberal arts colleges might be more attractive to students who will later be drawn to graduate study. Students at liberal arts colleges also interact frequently with their professors, and typically at a deeper level than do students at universities. This closer relationship may lend itself to faculty members encouraging students to go on to graduate school more often, and/or that graduate school advice is more frequently followed. It may be that the occupation that students at liberal arts colleges are most familiar with, apart from that of their parents, is that of college professor. This familiarity may lead students to attend graduate school.⁶

Others argue that it is not so much advice given and received but that the experiences afforded by liberal arts colleges naturally foster a desire to further one's education. Warch (2001), for example, argues that the one-on-one undergraduate research experiences offered to students at liberal arts colleges are not only transforming but that such opportunities are rare to nonexistent at universities where graduate students have first claim to laboratories, equipment, and the professor's time. Astin (1999), Bourque (1999), Warch (2001), and others claim that it is only natural that one-on-one research experiences are likely to have a transformative effect on students and that liberal arts faculty are particularly suited to lead such experiences. Quantitative evidence to this effect, however, is lacking.

To try to begin to fill this void, a survey was sent to 850 current full-time faculty members at liberal arts colleges asking when they themselves knew they wanted to go to graduate school and what factor was most responsible for that decision. Surveys were returned by 358 faculty members for a response rate of 42 percent. Of those returned, 152 were from faculty who attended a liberal arts college as an undergraduate, while 206 attended a research university as an undergraduate. The tabulation of responses is given in table 6.1.⁷

The question of timing is addressed in panel A. Roughly 50 percent decided to go on to graduate school during their last two years of college, regardless of type of undergraduate institution. University students were more likely to make the decision before entering college or early in college, while liberal arts college students were more likely to make

TABLE 6.1
The Timing and Motivation for Graduate School by Undergraduate Institution

Type of Undergraduate Institution	Liberal Arts College (N = 152)		Research University (N = 206)	
A. When did you know you were going to go to graduate school?				
Before college	14	9%	30	15%
Freshman/sophomore year of college	14	9%	30	15%
Junior/senior year of college	83	55%	102	49%
After college	41	27%	44	21%
B. To what factor would you most attribute your decision to go to graduate school?				
Family	16	11%	15	7%
Undergraduate institution	89	58%	97	47%
Employment goals	43	28%	73	36%
Self-motivation	4	3%	21	10%

Source: Author survey. In the summer of 2006, the author sent the survey to 850 randomly chosen faculty members of elite liberal arts colleges, of which 358 were returned.

the decision after working for some time. None of these differences, however, are statistically significant at the 5 percent level.

The question of who or what most influenced the decision to go to graduate school is reported in panel B. The responses are broadly grouped into four categories: family, undergraduate institution (including a professor, classmates, a research experience, or a particular class), employment goals (including frustration with one's job, needing a PhD to do interesting research, or wanting to teach at the collegiate level), and self-motivation. Although much more research should be done on the motives underlying the decision to go to graduate school, this simple survey provides some evidence that liberal arts colleges connect with their students in a way that universities do not. Whereas 48 percent of graduates of universities attribute the primary factor in their pursuit of a PhD to something concerning their undergraduate institution, 58 percent of graduates from liberal arts colleges do. (The difference is statistically significant with a p -value of 0.032.)

The other statistically significant difference in table 6.1 concerns self-motivation. Whereas 10 percent of graduates from universities attribute their pursuit of a PhD to self-motivation, only 3 percent of graduates from a liberal arts college do (with a p -value of 0.005). This difference might be attributable to the difference in how students and professors interact on university campuses or simply to the number of students on university campuses. For a student to be an academic standout on a university campus, she must rise above thousands, not hundreds. To do this requires an inner desire for academic success. Whereas this desire undoubtedly exists in the standouts at liberal arts colleges, it may be more necessary on university campuses, and thus is more frequently noted by such graduates.

Although we are cautious of the small sample sizes and rudimentary survey method, it appears that liberal arts colleges deliver on their promise to interact closely with students. More research in this area, however, would be worthwhile. In particular, how engaging students in undergraduate research projects likely affects future decisions concerning PhD pursuits remains largely unknown. If liberal arts colleges have an advantage in this area, then calls for further funding, such as from NSF grants, to expand such opportunities at liberal arts colleges should be explored (Warch 2001).⁸

QUANTITATIVE ANALYSIS

We now turn our attention from comparing liberal arts colleges and universities to that of exploring empirically why some colleges generate PhD candidates more frequently than others. Attention here is restricted to BA I colleges as defined by the Carnegie Classification system in 1994. Using the number of graduates from each college from 1989 through 1998 and the number of doctorates earned by alumni of each college between 1994 and 2003, each college's PhD generation rate was calculated. The average college in the sample saw 4.2 percent of its graduates go on to earn a PhD.

To carry out a statistical analysis of PhD generation, additional data was collected from two sources. The 1995 edition of *America's Best Colleges* by *U.S. News and World Report* lists 161 top liberal arts colleges in 1994 and provides data on the 75th percentile Scholastic Aptitude Test (SAT) score of incoming freshmen (an average of 1235) and per-student expenditures.⁹ Expenditures per student ranged from a low of \$4,510 to a high of \$23,715, with the average college spending \$13,420 per student. Barron's 1994 *Profiles of American Colleges* reports enrollment, percentage of students who are female, student-faculty ratio, and the percentage of incoming students who scored above a 700 on the verbal and math sections of the SAT.

Finally, the Web of Science database was used to determine the number of articles attributed to each college in the Arts and Humanities Citation Index (A&HIS), the Social Science Citation Index (SSCI), and the Science Citation Index Expanded (SCI-Expanded) from 1989 through 1998.¹⁰ Using each college's enrollment and student-faculty ratio, the number of articles per college was transformed into the number of articles per faculty member over the ten-year period. The average school had 0.3, 0.4, and 0.6 articles in A&HIS, SSCI, and SCI-EXPANDED, respectively, per faculty member for the entire ten years. These low rates reflect that they are calculated per faculty member and not per faculty

member in each division. Combining the three indexes, the average college had almost 2.5 entries of any kind—not just journal articles—per faculty member over the ten years; put differently, the average faculty member contributed an entry to the index once every four years. Whereas the least prolific college had almost no entries, the most prolific college averaged just under one publication per faculty member per year.

When attention is restricted to only BA I colleges with an enrollment of between 500 and 3,500 students for which there is no missing data, there are 148 colleges in the sample. All the colleges used in the analysis, along with their PhD generation rate of students who graduated between 1989 and 1998, appears in table 6.2.

EXPLAINING PHD GENERATION RATES

Using these data, the relationship certain factors have with generating PhD candidates from liberal arts colleges can be explored. To do this, two models were estimated using ordinary least squares regression—one for the 81 colleges in the first and second tiers and one for the 67 colleges in the third and fourth tiers, according to the *U.S. News* guide.¹¹ The dependent variable is each college's rate at which it generates PhD candidates as reported in table 6.2. The explanatory variables include the college's 75th percentile SAT score, log of enrollment, percent of students who are female (measured 0 to 100), per-student expenditures (measured in thousands of dollars), whether the college offered a business degree in the 1990s, whether the college is located in the Northeast,¹² and the number of Web of Science database citations per faculty member from 1989 to 1998.¹³ Offering a business degree was included for two reasons. First, offering such a degree might indicate that the college attracts students who are more inclined to pursue professional degrees or who have more immediate job expectations after graduation. Second, a business major may compete with the more traditional majors offered at liberal arts colleges, which in turn may limit student options for pursuing a doctorate after graduation. Location has also been included because of the historical presence of many elite colleges, and clusters of elite colleges, in the Northeast. Kaufman and Woglom (2005) also account for location.

The results from both models are reported in table 6.3. The percent of students scoring in the top quartile of the SAT is positively related to generating PhD candidates for both groups of colleges, though the magnitude of the effect is much greater for tier 1 and tier 2 colleges than for tier 3 and tier 4 colleges. While neither enrollment nor the percent of students who are female is statistically significant in either

TABLE 6.2
List of Colleges and 1989–98 Generation Rates

College	Rate	College	Rate	College	Rate
Agnes Scott College	4.8	Gettysburg College	3.0	Oglethorpe University	1.2
Albion College	2.8	Gordon College (MA)	3.5	Ohio Wesleyan University	3.8
Albright College	3.2	Goshen College	4.6	Pitzer College	3.9
Allegheny College	5.9	Goucher College	4.4	Pomona College	11.4
Alma College	3.1	Grinnell College	11.1	Presbyterian College	1.6
Amherst College	9.3	Guilford College	2.3	Randolph-Macon College	2.3
Antioch University	1.8	Gustavus Adolphus College (IL)	2.9	Randolph-Macon Woman's College	4.0
Augustana College (IL)	3.2	Hamilton College	4.5	Reed College	18.4
Austin College	3.1	Hamline University	1.5	Rhodes College	5.9
Bard College	4.1	Hampden-Sydney College	1.9	Ripon College	5.1
Barnard College	7.4	Hampshire College	6.6	Salem College	1.0
Bates College	5.4	Hanover College	3.3	Sarah Lawrence College	3.3
Beloit College	7.5	Hartwick College	2.1	Scripps College	4.7
Bethany College (WV)	2.1	Hastings College	2.9	Shepherd College	0.6
Birmingham Southern College	2.5	Haverford College	12.1	Siena College	1.1
Bowdoin College	6.5	Hendrix College	6.4	Skidmore College	2.2
Bryn Mawr College	7.5	Hiram College	3.7	Smith College	5.3
Bucknell University	4.1	Hobart and William Smith College	3.2	Southwestern University	2.8
Carleton College	14.6	Hollins College	1.8	Spelman College	2.6
Central College (IA)	2.6	Hope College	4.7	St. Andrews Presbyterian College	2.5
Centre College	4.5	Houghton College	3.5	St. John's University (MN)	4.0
Chatham College	3.4	Huntingdon College	1.9	St. Lawrence University	3.3
Claremont McKenna College	2.2	Illinois College	1.2	St. Mary's College of MD	1.4
Coe College	2.7	Illinois Wesleyan University	3.5	St. Olaf College	7.1
Colby College	4.5	Juniata College	5.1	Swarthmore College	18.0
Colgate University	4.3	Kalamazoo College	11.2	Sweet Briar College	1.9
College of St. Benedict (MN)	1.7	Kenyon College	5.1	Transylvania University	2.5
College of Wooster	7.7	Knox College	7.5	Trinity College (CT)	3.8
College of the Holy Cross	3.6	Lafayette College	4.1	Union College (NY)	3.4
Colorado College	5.0	Lake Forest College	2.6	University of Dallas	1.6
Concordia College (MN)	2.3	Lawrence University	7.7	UNC at Asheville	1.3
Connecticut College	3.5	Lewis and Clark College	1.6	University of Puget Sound	1.7
Cornell College	3.2	Luther College	3.4	University of the South	4.5
Davidson College	7.0	Macalester College	7.3	Ursinus College	2.4
DePauw University	3.4	Manhattanville College	1.8	Vassar College	6.8
Denison University	3.5	McDaniel College	1.5	Virginia Military Institute	2.0
Dickinson College	3.5	Middlebury College	4.3	Virginia Wesleyan College	1.1
Drew University	2.6	Mills College	2.1	Wabash College	7.9
Earlham College	8.3	Millsaps College	2.7	Wartburg College	2.2
Eckerd College	2.5	Monmouth College	2.7		
Erskine College	2.0	Moravian College	1.9		
Franklin College (Indiana)	1.0	Morehouse College	1.2		
Franklin and Marshall College	5.7	Mount Holyoke College	7.4		
Furman University	4.3	Muhlenberg College	3.6		
Georgetown College	1.3	Nebraska Wesleyan University	2.6		
		Oberlin College	13.4		
		Occidental College	7.0		

TABLE 6.2—cont.

College	Rate	College	Rate	College	Rate
Washington College	1.8	Westminster	1.7	Willamette University	1.5
Washington and Jefferson College	2.2	College (PA)		William Jewell College	1.7
Washington and Lee University	2.0	Westmont College	2.5	Williams College	8.2
Wellesley College	8.2	Wheaton College (IL)	2.4	Wittenberg University	3.5
Wesleyan University	6.9	Wheaton College (MA)	5.1	Wofford College	2.5
Westminster College (MO)	2.4	Whitman College	6.3		
		Whittier College	1.4		

TABLE 6.3
OLS Regression Results

	Tier 1 and Tier 2 Colleges	Tier 3 and Tier 4 Colleges
SAT 75th percentile score	0.0203*** (0.0049)	0.0037** (0.0017)
Natural log of enrollment	0.3578 (0.8361)	-0.0782 (0.3464)
Percent students who are female (0 to 100)	0.0048 (0.0172)	-0.0069 (0.0066)
Per student expenditures in \$1,000	0.0721 (0.1271)	0.1484** (0.0673)
College offers a business degree (0/1)	-1.9485*** (0.6893)	0.2123 (0.3922)
College is located in the northeast (0/1)	-3.0178*** (0.6677)	0.8110* (0.4451)
Citations per faculty member, 1989-98	0.4497** (0.2289)	-0.0161 (0.1856)
Constant	-24.3854 (8.6792)	-2.8280 (3.6664)
Number of observations	81	67
R-squared	0.5615	0.2482
Adjusted R-squared	0.5195	0.1590

Notes: The dependent variable is each college's overall PhD creation rate measured, 0 to 100, and is calculated as the number of PhD's earned by alumni of the college from 1994 to 2003, measured as a percent of the college's graduates from 1989-98. Standard errors are reported in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

regression, the most important point to be taken from table 6.3 is how different generating PhD candidates is for the colleges in the top two tiers than it is for the colleges in the next two tiers. There are meaningful differences between the generation of PhD candidates and college expenditures, offering a business degree, college location, and faculty scholarship. Each of these is discussed in turn below.¹⁴

While expenditures per student are not statistically significant in explaining the generation of PhD candidates from tier 1 or tier 2 colleges,

expenditures are statistically significant at the 5 percent level at tier 3 and tier 4 colleges. The magnitude of the effect, however, is very small. A \$1,000 increase in per-student spending is associated with less than a 0.15 percentage point increase in PhD generation. For the typical college, this suggests that increasing the annual budget by over \$1 million annually would be associated with one additional graduate going on to eventually earn a PhD every other year.

Among colleges in the top two tiers, those that offer a business degree generate PhD candidates at a rate that is almost 2 percentage points lower than those that do not offer a business degree. Offering a business degree by colleges in the bottom two tiers, however, is not statistically associated with generating PhD candidates. One interpretation of this finding is that not only are good students at the best colleges attracted to nontraditional liberal arts majors like business, but also that students who choose these majors develop less interest in graduate school or find it more difficult to pursue a graduate degree.

Tier 1 and tier 2 colleges located in the Northeast are predicted to generate PhD candidates at a rate that is 3 percentage points lower than comparable colleges not located in the Northeast. In contrast, tier 3 and tier 4 colleges in the Northeast are predicted to generate PhD candidates at a rate that is almost 1 percentage point higher than comparable colleges not in the Northeast. Wall Street and the U.S. financial/banking industry could be an explanation for this pattern if the financial sector of the United States, which is located predominantly in the Northeast, has a preference for hiring the best students from the best regional colleges.

Finally, the relationship between generating PhD candidates and faculty scholarship also varies by tier. Among tier 1 and tier 2 colleges, faculty scholarship is positively related to generating PhD candidates, while faculty scholarship is unrelated to PhD generation rates at tier 3 and tier 4 colleges. This suggests that both arguments mentioned earlier—that increased faculty scholarship might detract from a professor's time to advise and teach or it might add to faculty interactions with students—hold, but that they are realized to varying degrees at different colleges. Faculty at the best colleges who are engaged in scholarship may affect their students positively toward graduate school. At lower-ranked colleges, however, faculty scholarship does not appear to be a catalyst for encouraging students to pursue a doctoral degree.¹⁵

EXPLAINING PhD GENERATION RATES ACROSS DISCIPLINES

Using the same data as above, the relationship certain factors have with generating PhD candidates from within each division was explored. To

do this, the previous models were estimated using seemingly unrelated regression (SUR), which allows for better estimation of parameters when error terms are correlated across equations. Each model estimates three equations, with the dependent variables being each college's PhD generation rates in the humanities, social sciences, and natural sciences.¹⁶ The explanatory variables are the same as in table 6.3, except that each equation includes division-specific faculty citations.¹⁷

The regression results strongly suggest that PhD generation rates at liberal arts colleges are correlated across academic divisions. The correlations of the error terms are greater than one-half and are positively correlated at the 1 percent level. Moreover, if the errors were randomly distributed, one would expect roughly ten colleges (one in every eight) to have all positive or all negative errors in each of the three equations. Instead, of the 81 tier 1 and tier 2 colleges, 21 had all positive errors while 28 had all negative errors. Similarly, of the 67 tier 3 and tier 4 colleges, 14 had all positive errors and 22 had all negative errors.

The estimated relationships between generating PhD candidates and college enrollment, per-student expenditures, offering a business degree, being located in the Northeast, and faculty scholarship largely support the results from table 6.3. A notable difference, however, concerns the percentage of female students. Although the percent of a college's student body that are women was unrelated to PhD generation rates originally, having a greater percentage of women students on campus is associated with generating more PhD candidates in the humanities and social sciences when compared to the natural sciences.

The results concerning test scores are roughly the same under the SUR model as they were in table 6.3. A college's 75th percentile SAT score is positively associated with PhD generation rates for both groups of colleges, but a 100-point increase is associated with between a 0.6 and 0.9 percentage point increase, depending on discipline, for the top two tiers while a 100-point increase is associated with only a 0.1 percentage point increase for the bottom two tiers. The model can be expanded by replacing the 75th percentile SAT score with the percent of students who scored above a 700 on each subject test of the SAT. Almost 20 percent of the colleges, however, fail to report these variables. Consequently, many estimated coefficients are statistically insignificant, as they are associated with large standard errors given the smaller sample sizes. That said, the results suggest that student abilities matter in their choices of major and graduate study. The percentage of students who score above 700 on the verbal portion of the SAT is positively associated with generating PhD candidates in the humanities and social sciences but unassociated with generating PhD candidates in the natural sciences. Conversely, the percent of students who score

above 700 on the math portion of the SAT is positively associated with generating PhD candidates in the natural sciences but unassociated with generating PhD candidates in the humanities or social sciences.

A final test of robustness is also worth mentioning. The Completions Survey data are not disaggregated enough to calculate the number of graduates in each academic division for each college. When a student has a double major, for example, only one of her majors is recorded in the data. Accurate division-specific PhD generation rates can be calculated, therefore, only if every double major always had a double major in the same division. Making the heroic assumption that the Completions Survey data accurately reflects the distribution of undergraduate degrees, division-specific PhD generation rates were calculated along with division-specific shares of undergraduate degrees. The model was reestimated, once using the division-specific generation rates as dependent variables and once including each division's share of undergraduate degrees as an explanatory variable in that division's equation. Both sets of results qualitatively match the original SUR results, but estimates are much less stable across equations and models, and standard errors are larger.

COLLEGE POLICIES AND GENERATING PHDs

Generating PhD candidates from elite liberal arts colleges remains a mysterious process, but this chapter has begun to shine some light on the differences across colleges. First, within colleges, PhD generation is highly correlated across academic divisions. Second, college characteristics and student traits matter. Most important is student ability (as measured by test scores) upon entering college, but location, the percentage of students who are women (positively related to generating PhD candidates in the humanities and social sciences; negatively related in the natural sciences), and curriculum (colleges that offer a business major generate PhD candidates at a slower rate) also matter. Third, faculty research plays an important but selective role: PhD generation is positively related to faculty scholarship, especially in the social and natural sciences, but only among the top eighty or so colleges.

Although the above mentioned factors are important, they do not tell the entire story. The regressions only explain about 50 percent of the variation in PhD generation rates among the top two tiers of colleges, and even less so in the next two tiers. To try to better understand the process of generating PhD candidates, the regression results were used to identify twenty-one colleges that consistently generate more PhD candidates than regression analysis predicts and twenty-six colleges that consistently generate fewer PhD candidates than regression analysis

predicts. Using these two groups of colleges, a search was undertaken regarding each college's career center webpage and the services offered pertaining to graduate school. Under the assumption that colleges with career centers in the 1990s that focused attention on student applications to graduate school would continue to do so, a present-day comparison between the career centers between these two groups of colleges could be fruitful. Although quantitatively comparing web pages across colleges is difficult, the overall assessment shows that career centers at colleges that consistently generate more PhD candidates than expected are about twice as likely to offer a greater amount of information and provide access to multiple web resources to students who are interested in graduate school than are career centers at colleges that consistently generate fewer PhD candidates than expected.

The directors of the career centers at the top performing colleges were also asked their opinion concerning how their centers meet student needs. The overriding theme given by directors of career centers is that they do not focus on funneling students toward graduate school; rather, when students come to them for advice, the approach is to present the student with many options—job, graduate school, professional school, volunteer work, and so on. Although graduate school is not the focus, it is discussed and presented as a viable option. All of the centers also had resources available to students to help with the process of applying to graduate school—from providing practice Graduate Record Examination tests, to offering a list of alumni to talk to at various graduate programs, to helping write a personal statement. Of course, it is unclear if the mission of career centers and the services provided result in greater interest in graduate school or if the students at colleges that generate many PhD candidates require the career center to serve their needs.

In addition to career centers, these colleges can also be compared using the previously discussed faculty survey. Of the 358 responses to the faculty survey, 31 faculty members attended one of the colleges that consistently generate more PhD candidates than expected while 17 attended one of the colleges that consistently generate fewer PhD candidates than expected. Although the sample size is very small, some interesting patterns emerge. Compared to students from colleges that consistently generate fewer PhD candidates than expected, students from the colleges that consistently generate more PhD candidates than expected were more likely to make the decision to go to graduate school in their last two years of college (61 percent vs. 47 percent) and were less likely to make the decision early in college or even before college (16 percent vs. 35 percent). There are also notable differences to what the respondents most attributed their decision to go to graduate school. Compared to students from the colleges that consistently generate

fewer PhD candidates than expected, students from the colleges that consistently generate more PhD candidates than expected were more likely to attribute the decision to a professor (36 percent vs. 24 percent) and less likely to attribute the decision to a particular class (7 percent vs. 18 percent) or not enjoying work (3 percent vs. 18 percent). Response rates were more equal in attributing the decision to an undergraduate research project (7 percent vs. 6 percent) or not wanting to stop with schooling or having a love of learning (7 percent vs. 12 percent).

Finally, it is interesting to hear from the colleges directly as to what they think the source of their college's success is. The dean of faculty (or equivalent) at each of the colleges that consistently generated more PhD candidates than expected was asked to "describe why you think it is that your college is successful at having its students go on to earn PhDs." The common theme from all deans was curriculum. Although the abilities and talents of incoming students matter in terms of which colleges are most likely to produce future PhD candidates, the academic experiences of students while in college also play a role. Providing a serious curriculum, encouraging students to take on challenges, and developing a campus environment that respects intellectual curiosity all contribute to the development of students. The idea of a campus culture in which graduate school is well thought of was articulated by many deans. Two examples stand out: Kalamazoo College and Scripps College.

Kalamazoo College has long been successful at generating PhD candidates. Its generation rate was 9.2 percent in the 1970s, 10.6 percent in the 1980s, and 12.2 percent in the 1990s. It is also at or near the top in per-capita volunteers to the Peace Corps. In the 1960s, Kalamazoo undertook a substantial curriculum change, called the K-Plan, that frames each student's entire four years of college. All students participate in a first-year seminar and in an off-campus internship during their second year. Study abroad is strongly encouraged in the third year, with over 80 percent of students participating. And all students are required to complete an individual research project during their senior year, many of which are yearlong endeavors.¹⁸

Scripps College is the only all-women's college in the consortium of Claremont Colleges. Scripps has long offered a humanities focus to its students, but it intentionally widened its curriculum and recruited students in the 1980s in order to match that curriculum. The required humanities curriculum was developed into the Core Program,¹⁹ in which all faculty are expected to teach regularly. The Core Program is a three-course sequence with a shared theme of "culture, knowledge, and representation." In addition to a more interdisciplinary curriculum, a new science building opened in 1990, and the number of science faculty was substantially increased. The number of science majors

increased from just a few each year in the 1970s to its present numbers of between thirty and forty graduating science majors each year. These developments, however, have helped to vastly increase Scripps College's PhD generation rate across all academic fields—not just in the sciences. The PhD generation rate at Scripps was 2.4 percent in the 1970s and 4.2 percent in the 1980s; it has since increased further, to an average of 5.7 percent in the 1990s.

This chapter has begun to explore why some colleges are better than others at generating PhD candidates. Much more research is needed. In particular, a careful analysis of why individuals choose to go to graduate school would be fruitful. Do the best colleges generate future PhD students or are the best colleges simply the best at recruiting future PhD students to their campuses? Do undergraduate research experiences push students toward graduate school? If so, are these experiences different at colleges than at universities? Is the academic lifestyle at liberal arts colleges appealing to its students so that this exposure explains why graduates of these colleges pursue doctoral degrees at about twice the rate of graduates from large universities? The answer to these and many other questions would help us better understand the connections between an individual's undergraduate experience and her decision to go on to graduate school, possibly helping colleges better target this outcome.

UNDERGRADUATE STEM RESEARCH EXPERIENCES

Impact on Student Interest in Doing Graduate Work in STEM Fields

MYLES BOYLAN

Does participation in undergraduate research in science, technology, engineering, and mathematics (STEM) affect the likelihood that participants will enter STEM graduate programs and succeed? This is one of many questions addressed in the literature on the effects of undergraduate research (UGR). Typically such studies examine the impact of UGR on a number of factors: the completion of a bachelor's degree in a STEM field; the probability of transitioning to graduate school after earning the bachelor's degree; changes in the depth of commitment to or level of interest in continuing into graduate school (because many UGR participants have already planned to attend graduate school); the decision or plan to pursue a career in STEM, especially in research; the research skills learned (operating lab equipment, applying appropriate statistical analyses, reading and synthesizing prior research papers, finding key prior research papers in a library, working independently, writing in appropriate scientific styles); the ability to think like a scientist; and the acquisition of communication skills (presentation; working effectively with faculty, graduate students, and undergraduate peers on teams).

Some studies also have considered the costs and benefits of UGR as well as its limits, such as the percentage of majors who can be effectively provided with quality UGR experiences given department size.