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Coming to America
Where Do International Doctorate Students Study and How Do US Universities Respond?

John Bound and Sarah Turner

Globalization and *internationalization* are two of the most widely used (and overused) terms in contemporary higher education discourse. There is no question that doctorate education at US universities has drawn an increasing number of students from around the world in recent decades. The growth of foreign students in US doctorate education may produce a wide range of benefits and costs for universities. Foreign graduate students may enhance output in science and engineering—including research innovations—and contribute to teaching in undergraduate and professional education. As foreign students increase the supply of workers with advanced degrees, the flow into doctorate education may also change the wage structure for those with advanced degrees in science and engineering fields (Bound and Turner 2006).

One point is clear: the expansion of foreign student participation in US colleges and universities is far from uniform. The flow of foreign students has been particularly marked outside the most highly ranked programs and at public sector universities.

In this chapter, we begin by describing the trends in doctorate attainment among foreign students at US universities. We distinguish significant trends by country of origin and type of US doctorate program. Our analysis demonstrates substantial shifts in country of origin over the last three

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decades among doctorate students, with the growth in foreign students coming largely from Asian countries, including China and India. In the main, the growth in foreign PhD students has led to expansion in program size, with this growth concentrated at programs at public institutions and those programs outside the most highly ranked.

The expansion of foreign participation in doctorate education is notably distinguished from expansion of foreign participation in other margins of US higher education, such as undergraduate education and professional training. Not only does country of student origin differ markedly, but so does institutional destination and source of funding. Highlighting the comparison between the internationalization of doctorate education and undergraduate education serves to sharpen understanding of the impact of foreign doctoral students in the production of university research and undergraduate education. In section 3.2, we present evidence relevant to these points.

Rising numbers of foreign students and the associated expansion of doctorate education may impact undergraduate education through complementarities in the university production function. We consider the link between the number of undergraduates, their distribution by field, and the scale of doctorate training. Increased foreign flows of graduate students may serve to lower the cost of undergraduate degree production resulting in expansion in undergraduate majors; alternatively, the flow of foreign students may have substantial complementarity with university research outputs. It follows that those institutions with the highest benefits from extra products in research and teaching generated by additional graduate students will have been most likely to recruit from the expanding pool of foreign doctorate students. Data on changes in undergraduate concentrations and sources of funding for graduate students provide some evidence: in the main, effects of foreign flows on undergraduate degree production are small in magnitude, while there is corresponding evidence that expansions in foreign PhDs in recent years have come with expansion in research funding. Doctorate student flows in the sciences are concurrently outputs of university education and inputs to the production of research and, to a much more modest extent, teaching.

3.1 Setting the Stage: The Flows of Foreign PhDs over Time by Country of Origin and University Destination

3.1.1 Basic Trends

While foreign students have been drawn to US universities since the first part of the twentieth century, there has been an unambiguous rise in PhDs awarded to students from abroad from the late 1950s to the mid-1990s, with considerable acceleration in growth concentrated in science and engineering

fields beginning in the late 1970s.[1] The *Survey of Earned Doctorates* provides a census of doctorates awarded by US universities by country of origin from the late 1950s to the present, and we use these data to show the broad trends by field in figure 3.1.[2] In economics and engineering, degrees awarded to students from abroad have outnumbered those awarded to US students for a number of years; in all but the life sciences, the foreign-born share has equaled or exceeded the share of US-born PhD recipients.

Focusing on explaining the rise in the participation of students from abroad in US doctorate programs, Bound, Turner, and Walsh (2009) emphasize that expanding undergraduate attainment in countries like South Korea and India produced increased demand for US doctorate education. In addition, sharp changes in political circumstances in countries like China opened a new port of entry to US graduate education that had been largely closed in the 1960s and 1970s. A further explanatory factor on the supply side of US graduate education is that substantial increases in public support for science and engineering research (and, in turn, graduate education) generate a response that may be particularly strong among students from abroad.[3]

A point of emphasis in prior descriptions of the doctorate education market is that the pattern of international flows differs quite markedly by country of origin, program characteristics, and university control and resources (see Black and Stephan [2007]) and Bound, Turner, and Walsh [2009] for further discussion). Understanding these patterns requires consideration of the nature of demand among foreign students and, significantly, the supply-side response of US universities in the context of differential funding structures for graduate education and university research across institutions.

1. Note that even in the first part of the twentieth century, universities in the United States attracted a substantial number of students from abroad, particularly in the sciences. In the period from 1936 to 1956, nearly 20 percent of PhDs in engineering and about 12 percent of PhDs in the life sciences were awarded to students who had completed undergraduate studies abroad. Bound, Turner, and Walsh (2009), and Blanchard, Bound, and Turner (2008) provide additional discussion of long-term trends in doctorate receipt by country of origin; this introductory section draws substantially on these earlier papers.

2. The *Survey of Earned Doctorates* is an individual-level census of recipients of doctorates at US institutions. Because survey participation is often coupled with the formal process of degree receipt, response rates have been quite high. Note that we focus our analysis on trends in doctorate degree recipients, though it would be conceptually preferable to examine all enrolled students; data on the latter group are much more limited in time horizon and do not allow for the examination of country of origin (see *Survey of Graduate Students and Postdoctorates in Science and Engineering,* conducted by the National Science Foundation [NSF] and National Institutes of Health [NIH]).

3. When funding in the United States for science (and, in turn, graduate education in the sciences) increases, the pool of students from abroad with preparation in scientific fields who are well-positioned to shift into US PhD programs may be relatively larger than the similar pool of recent BA degree recipients from US universities in the sciences. As such, the elasticity of demand among foreign students may be somewhat larger than among US students if foreign students are simply choosing where to attend graduate school rather than weighing the choice between a graduate program and an alternate profession. In turn, short term enrollment expansion in response to funding expansion may come disproportionately from foreign students.

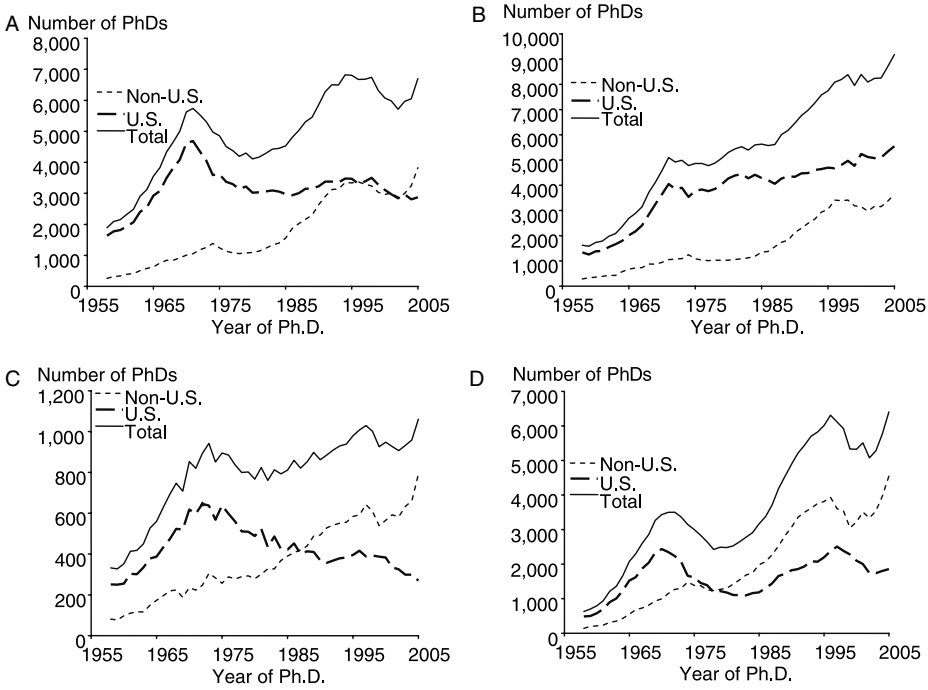

Fig. 3.1 Degrees awarded by US universities and national origin, 1958–2005: *A,* Physical Sciences; *B,* Life Sciences; *C,* Economics; *D,* Engineering

Source: NSF, *Survey of Earned Doctorates* microdata. National origin is defined by the country in which an individual went to high school. Fields defined using NSF classification, from SED annual reports.

3.1.2 Changes by Country of Origin

There is considerable variation in the source of doctoral students from abroad by country of origin, and the patterns of attendance by country have changed markedly over time in distribution and scale. Table 3.1 shows the distribution of PhDs from US institutions in science and engineering fields by country of origin for the decade from 1966 to 1975 and the more recent decade from 1996 to 2005. Much of the growth has come from new demand for advanced study in science and engineering from countries rapidly climbing a development trajectory; particularly South Korea, India, Taiwan, and, more recently, China. Black and Stephan (2007) note the relatively recent concentration of doctorate students from these four Asian countries, which account for about 60 percent of doctorate recipients among non-US residents in the most recent year.

Why students from some countries are particularly likely to pursue doctorate education in the United States surely depends on opportunity costs. In general, demand for doctorate education will be lower for those students

Table 3.1 **Doctorates awarded by US universities by student country of origin, science, and engineering fields**

	1966–1975	Rank 1966–1975	1996–2005	Rank 1996–2005
China	945	5	25,334	1
India	5,255	1	9,520	2
Korea	1,252	4	7,905	3
Taiwan	4,389	2	6,820	4
USSR	8		2,958	5
Turkey	481		2,403	6
Canada	2,274	3	2,356	7
Mexico	311		1,635	8
Germany	528		1,614	9
Brazil	401		1,420	10
Japan	816	7	1,126	
Iran	684	8	996	
Greece	532	10	931	
United Kingdom	916	6	892	
Israel	636	9	342	
United States	98,679		105,955	
Total	131,946		213,113	

Source: NSF, *Survey of Earned Doctorates* microdata.

Notes: National origin is defined by the country in which an individual went to high school. Fields defined using NSF classification, from SED annual report.

with more abundant home country opportunities and, in turn, students from countries with relatively substantial university systems will be unlikely to study in the United States unless they can attend top tier doctorate programs.[4] What matters for students potentially pursuing study in the United States is the expected return to a US PhD program relative to the best alternative in the home country. Students in each country face a choice based on the expected benefit to doctorate study in the United States, and an expected return to persistence in the home country, which may include attending graduate school in the home country or pursuing some other vocation. Home

4. The decision by students from different countries to pursue doctorate education in the United States is in many respects similar to the occupational choice selection problem set forth in the Roy model (1951). Because options for post-baccalaureate study vary appreciably across countries, it follows that the opportunity cost of pursuing a doctorate degree at a US university varies among countries of origin. The result is that there are differences across countries in the total share of a nation's PhD recipients trained in the United States and variation in the representation of students by the quality of graduate programs in the United States. The predictions we outline follow from the case where expected success as a PhD in the home country and the United States are positively correlated, and the variance in returns is greater in the United States than the home country (e.g., the rewards to a top mathematician—relative to a median mathematician—will be greater in the United States than in home country). To this end, US programs tend to be dominant in the top tail of the international distribution of program quality.

country university systems differ and, as a result, the opportunity cost of pursuing a doctorate degree at a US university varies among countries of origin. What is more, receipt of a doctorate from a US university may well provide increased opportunities for employment in the United States.[5]

In the cross section, both the level of undergraduate degree attainment in foreign countries and the extent to which there are established doctorate-level programs in these countries have a substantial effect on the flow of PhD students to US institutions. Countries without large university systems but with recent expansion in undergraduate attainment will have the greatest representation of doctorate students at US institutions; students from these countries will also be represented in other well-developed university systems such as the United Kingdom, Canada, and Australia. To this end, it is not surprising that the ratio of PhDs awarded by US institutions to home country institutions is high for countries like China (0.5), South Korea (.3), and India (.75); relative to European countries like France (0.013) or the United Kingdom (0.003) (Bound, Turner, and Walsh 2009, table 1).

3.1.3 Foreign PhD Flow By Program Rank

For countries in which forgone opportunities are close to those in the United States—for example, countries with large and well-established university sectors—only a select few individuals will pursue graduate studies in the United States. These individuals will be among those with relatively high ability and receive admission offers from some of the best programs in the United States.[6] In contrast, individuals from countries with much more limited higher education systems will have fewer opportunities for graduate study in their home countries and will be much more likely to choose to pursue graduate study at a US university. In turn, these individuals may choose to come to the United States to pursue studies at programs outside the most highly ranked departments. To illustrate, the proportion of a country's PhD recipients receiving degrees from top five programs differs markedly across countries (and, to some degree, over time). For a num-

5. Most foreign students hold F-status (student) visas while in school and; to work in the United States requires adjusting the student visa to the H1B status for high-skilled visa employment with the assistance of a institutional sponsor. As such, limited provision of visas and the restrictions related to HIB employment often leave foreign doctorate recipients with a more limited set of employment options than permanent visa holders and US residents. Using an exogenous change in visa status associated with the Chinese Student Protection Act of 1992, Lan (2008) shows that permanent visa holders are about 24 percent less likely to take post-doctoral positions than temporary visa holders.

6. A related implication is that the average quality or achievement of students and the associated graduate programs selected of PhDs receiving PhDs in the United States from a particular country is inversely related to the share of a country's potential doctorate students completing advanced study in the United States. Less formally, students from a country like France receiving PhDs in the United States will likely be among the best in their home country cohorts, and attend the very top tier doctorate institutions like MIT and Stanford, while students from a country like Turkey will be spread among a broader range of US institutions as their home country options are more limited.

ber of Asian countries—notably Taiwan, South Korea, and China—PhD recipients in science are underrepresented in the top five departments and are much less likely to receive their degrees from these programs than PhD recipients from the United States in these fields. For example, while students from China are about 15.5 percent of all chemistry PhDs, they are only 5.3 percent of degree recipients from top five programs. At the other extreme, students from Canada and European countries tend to be represented in the top programs in shares in excess of their overall representation among PhD recipients from US universities.

Over time, much of the growth in doctorate education has come outside the most highly ranked programs and, in turn, expansion in foreign doctorate receipt at US institutions has been most concentrated outside the most elite—or highly ranked—programs. Figure 3.2 presents trends in doctorate awards to PhDs in selected fields distinguishing programs in the top fifteen, ranks sixteen to thirty, ranks thirty-one to fifty, outside the top fifty, and unranked. What is unambiguously clear is that in chemistry, physics, and biochemistry, foreign degree expansion is concentrated outside the top fifty and starts a dramatic upward trend in the 1980s. In engineering, the growth

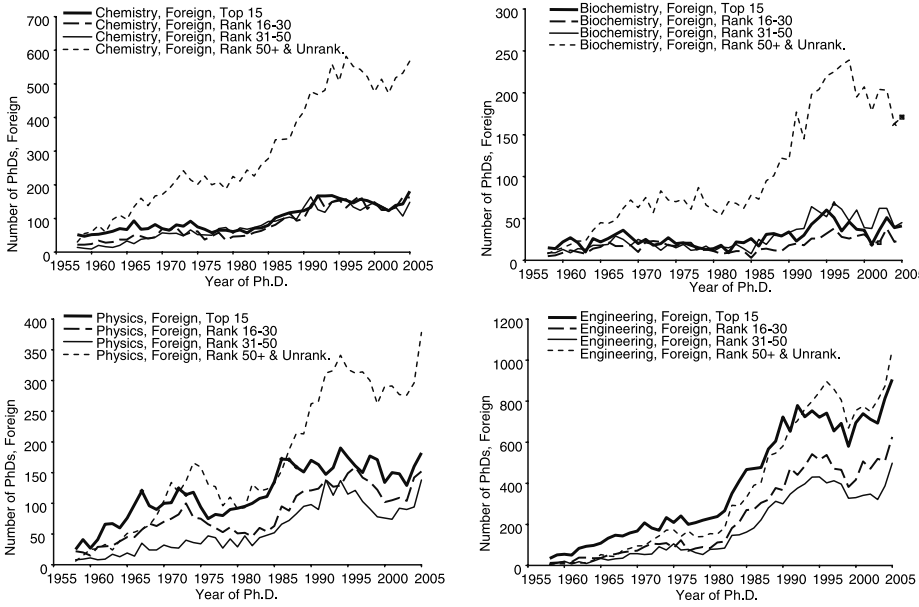

Fig. 3.2 Degrees awarded by US universities to non-US citizens by program rank, 1958–2005

Source: NSF, *Survey of Earned Doctorates* microdata. National origin is defined by the country in which an individual went to high school. Fields defined using NSF classification, from SED annual reports.

in degrees awarded occurs more broadly across program ranks, though as we will subsequently discuss, large public universities have greater representation in the top tier of engineering than in other scientific fields.

3.1.4 Expansion of Doctorate Education by Type of University

The US market for doctorate education is differentiated and highly stratified. Of the more than 3,000 four-year institutions of higher education, 413 universities in the United States awarded doctorates in 2002, with the mean number of degrees per institution ninety-seven, and the median number thirty-eight degrees. Overall, production is relatively concentrated, with twenty institutions awarding 27 percent of the 2002 total of 39,955 degrees.[7]

Both private and public universities award PhDs, with public universities dominant in the number of institutions awarding degrees and the scale of doctorate programs. In 2005, public universities awarded over 15,000 degrees in science and engineering fields, compared to about 6,500 degrees awarded by private universities. This margin has grown appreciably since 1960, when the comparative totals were 2,989 and 2,011 doctorate degrees awarded by public and private universities, respectively. At the same time, a small number of elite private universities often occupy the top program rankings, though there is unquestioned competition between public and private universities for faculty, students, and resources. While the products of graduate education at public and private universities are widely seen as substitutes (PhDs from the University of Michigan compete with PhDs from Yale and the University of Pennsylvania for academic jobs), the financing and organization of private and public universities are sufficiently distinct in that we might expect quite different institutional response to increased demand from foreign students. Substantial subsidies from the state, combined with a much larger scale of undergraduate education, distinguish public universities from private universities, potentially affecting responses to increased demand from foreign students.

Figure 3.3 presents broad trends in the number of doctorate degrees awarded by public and private institutions, with the further distinction by Carnegie classification.[8] In each graph, there are broadly two regimes of expansion—a peak in the late 1960s, and a subsequent upturn in the

7. While this concentration is considerable, it is appreciably less than at the start of the century or the middle of the twentieth century. The interval of expansion in US higher education between 1950 and the early 1970s brought many new entrants to the higher education market. Focusing on the interval between 1958 and 1972, Bowen and Rudenstine (1992) document the extraordinary growth in the number of institutions and departments operating PhD programs. In economics, the number of PhD granting institutions increased nearly 90 percent from 57 to 108, while in mathematics the number of programs increased more than 130 percent, from 60 to 139.

8. We employ the Carnegie codes (as classified in 1994) to distinguish broad types of institutions. The primary categories are as follows.

Research Universities 1: Award fifty or more doctoral degrees1 each year. In addition, annually more than $40 million in federal support.

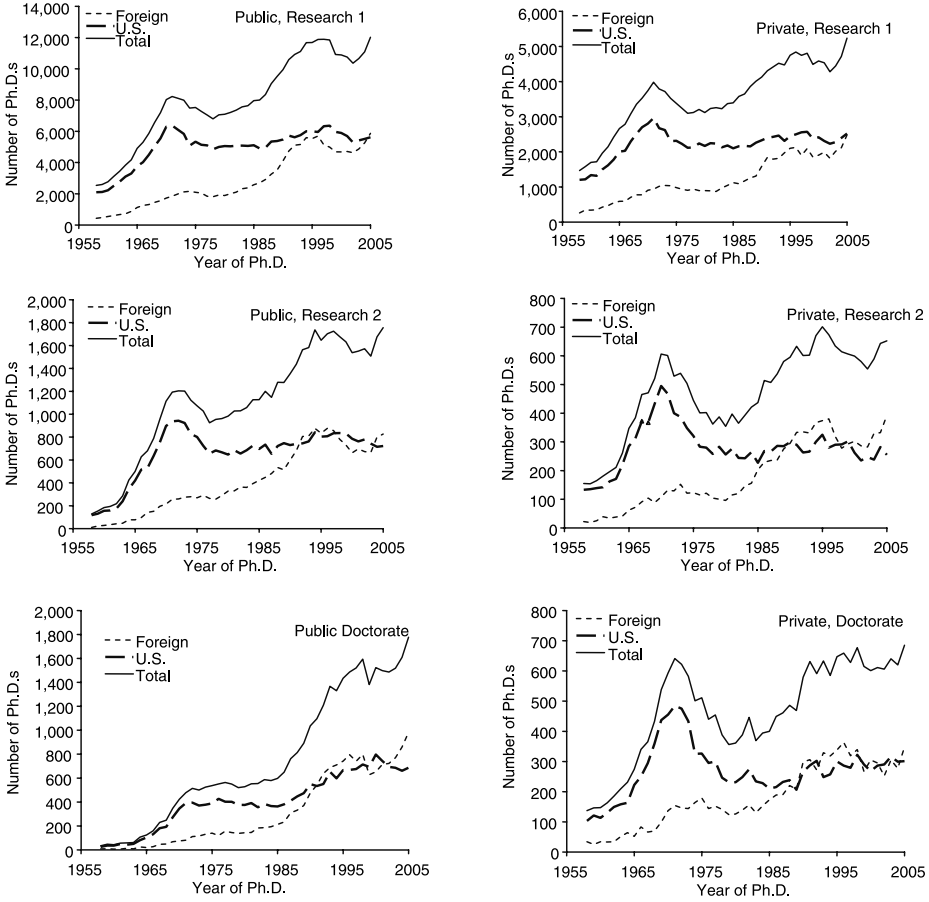

Fig. 3.3 Degrees awarded by US universities to US and foreign students by institutional control and Carnegie Classification, 1958–2005

Source: NSF, *Survey of Earned Doctorates* microdata. National origin is defined by the country in which an individual went to high school. Fields defined using NSF classification, from SED annual reports.

1980s—with the relative magnitude of fluctuations over time differing by type of institution. Private Research 1 and public Research 1 Universities have experienced more muted changes than the other institution types in the number of doctorates awarded. A clear point from the graphs is that while the early expansion was fueled by a substantial rise (and then contraction) in domestic PhDs, much of the growth in the later period comes through

Research Universities 2: Award fifty or more doctoral degrees1 each year. In addition, they receive annually between $15.5 million and $40 million in federal support.

Doctoral Universities 1 & 2: Award annually at least ten doctoral degrees—in three or more disciplines—or twenty or more doctoral degrees in one or more disciplines.

the expansion in the number of foreign PhD students in the science and engineering fields. Indeed, at all but the institutions in the doctorate category, the number of PhDs awarded to US residents only increased modestly from 1980 to the present. Strikingly, the number of foreign PhD recipients increased by a factor of 3.25 in the public sector overall, and 5.15 in the public doctorate sector. In the private sector, expansion in foreign PhDs has also been a significant force, with increases of 230 percent in the Research 1 sector, 390 percent in the Research 2 sector, and 270 percent in the doctorate sector.

One notable distinction between public and private universities is the greater emphasis of the former in the applied sciences. The unique integration of basic research, professional training, and science complementing local industry is fundamental to American public universities and foundational to the development of mass higher education at the start of the twentieth century (Goldin and Katz 1999). Doctorate programs in areas related to agriculture and engineering may be of particular interest to students from developing economies. As such, the relative concentration of foreign students at public universities is not surprising.

Focusing the discussion to consider specific institutions helps to sharpen understanding of the flow of foreign students at the PhD level. Table 3.2 presents a listing of PhDs awarded in total and to foreign students in the most recent decade and, as a point of comparison, the decade of 1966 to 1975. Notably, the institutions that award the largest number of doctorates to foreign students are not coastal universities in traditional immigrant hubs like New York and Los Angeles, but the large, public land grant universities including Texas A&M, Purdue, the University of Illinois, and Ohio State. Part of this response is surely due to the greater concentration of public universities in the applied sciences, particularly engineering, as these fields may have close ties to local industries, while also being of greatest demand among foreign students from developing countries.

3.1.5 The Question of "Crowd Out": Evidence and Supply Elasticity In Doctorate Education

While there is no question that foreign participation in US doctorate education has increased, it is less clear whether this expansion represents net new doctorate awards or some displacement of potential US doctorate students. The growth of foreign students among overall PhD recipients and PhD recipients from US institutions affects the flow of potential US doctorate students through two potential channels. First, US students may face increased competition for slots (admission) to graduate programs. At the most competitive graduate programs, where there is typically considerable excess demand for enrollment, the admission of additional foreign students is likely to be accompanied by reductions in admissions of domestic students. Second, beyond potential crowd out effects in higher education, the overall growth in the number of foreign doctorates (both those who obtained

Table 3.2 **Doctorate degrees conferred in science and engineering by top producing public and private universities**

	1966–1975		1996–2005	
	Foreign	Total	Foreign	Total
Public universities				
Stanford University	744	3,004	1,639	4,069
MIT	958	3,528	1,530	4,297
Cornell University	941	2,881	1,485	3,149
University of Southern California	256	960	1,298	1,910
Columbia University	522	1,769	1,175	2,075
Johns Hopkins University	301	1,280	911	2,702
Harvard University	409	2,102	854	2,796
University of Pennsylvania	542	1,767	849	2,041
Princeton University	364	1,363	824	1,610
Northwestern University	364	1,614	798	1,997
Public universities				
Texas A&M University	338	1,548	2,018	3,455
Ohio State University	561	2,505	1,945	3,364
Purdue University	718	3,294	1,944	3,410
University of Illinois	1,136	4,037	1,933	4,068
University of Texas (Austin)	377	1,994	1,786	3,519
University of Michigan (Ann Arbor)	629	2,854	1,720	4,042
University of Wisconsin (Madison)	1,064	3,924	1,709	4,087
University of Minnesota (Twin Cities)	814	2,479	1,690	3,614
University of California (Berkeley)	1,452	4,500	1,608	4,783
Pennsylvania State University	381	1,838	1,590	3,237

Source: NSF, *Survey of Earned Doctorates* microdata.

Notes: National origin is defined by the country in which an individual went to high school. Fields defined using NSF classification, from SED annual report.

their degrees in the United States and those who migrated after receiving their degrees) is likely to have had a substantial effect on the labor market returns to PhD awards in science (Bound and Turner 2006).

Measuring the degree of direct crowd out in graduate education is not straightforward empirically: changes in the rate at which US students complete PhD programs may reflect both increased demand among foreign students, and other factors such as funding shocks, which would lead to increases in scale of graduate programs. While a number of studies have attempted to estimate the magnitude of potential crowd out effects, there is little conclusive evidence to support substantial crowd out effects.[9]

9. Using data from the *Survey of Graduate Students and Postdocs* and variation within academic departments, Regets (2001) finds a largely positive association between enrollment of US students and foreign students. Borjas (2004) uses within institution variation in graduate student enrollment measured in the IPEDS surveys and finds a negative effect of foreign enrollment on the level of enrollment of white men, though little effect on domestic enrollment in aggregate. Finally, Zhang (2004) used the *Survey of Earned Doctorates* and reports essentially

The case of the sharp increase in demand among Chinese graduate students beginning in the early 1980s presents a relatively clear opportunity to assess the adjustment of the US market to a sharp demand shock. Focusing on the field of physics as an illustration, consider the change in doctorate completion by year of program entry for Chinese students, other foreign students, and US residents (Bound, Turner, and Walsh 2009). At top ranked programs, the number of additional students from China is small and there is little discernable change in the overall number of PhDs awarded. Outside the most highly ranked programs, the number of Chinese students receiving PhDs from universities outside the top fifty increased from 7 to 202 between the 1980 year of graduate entry and the 1985 year of graduate school entry. Notably, this large "shock" produced no notable decline in PhDs awarded to US students at these institutions, with this number actually rising slightly from 164 to 199, while the number of students from other countries receiving PhDs also rose over this interval of graduate school entry. Data for other fields show similar patterns. Remarkably, this large cohort of Chinese students had no discernable impact on the number of US, or for that matter, other foreign students receiving PhDs in the sciences. The example produced by the particularly large and rapid influx of Chinese students in the early 1980s may be hard to reproduce in other periods, both given its scale and its arrival during a period in which funding for the sciences in general—and the physical sciences in particular—was expanding rapidly. Nevertheless, this evidence does suggest that it is plausible that realized expansions in the representation of foreign doctorate students need not crowd out domestic doctorate attainment by US students.

Our conclusion is that outside the most highly ranked programs, many doctorate programs are relatively elastic in scale.[10] "Supply elasticity" at the PhD level is much greater outside the top tier universities, particularly outside the top fifty; these are institutions with programs often below the minimum efficient scale, many of which experienced sharp declines in domestic student interest in the mid-1970s. In turn, at the universities and programs where the expansion of foreign doctorate recipients has been the largest, our interpretation is that crowd out is minimal in the sense that additional doctorate recipients from abroad do not substitute for domestic PhD production at the institutional level.

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no evidence of crowd-out of native students associated with additional PhDs awarded to native students. A limitation of this broad line of inquiry is that expansion in the representation of foreign students in US graduate programs may well be endogenously related to other factors such as the availability of funding which simultaneously affect the demand for graduate students.

10. Indeed, for the programs that are unranked or ranked very modestly, the period of growth in the 1960s and early 1970s represented both expansion in scale and the entry of new programs; the entry of new programs in this category was extraordinary, with a threefold increase in the primary science fields. As the market contracted in the 1970s, and then expanded in the 1980s, the adjustment came in terms of the scale of programs, with apparently few programs either exiting or entering the market.

Proceeding from this assessment, we offer the marked comparison between doctorate students and undergraduate students from abroad in the next section, as differences in country of origin, sources of funding, and institutional destination are substantial. In section 3.3, we consider the expansion in doctorate education generated by foreign students in the context of the university production function, focusing on the link with university research support and undergraduate education.

3.2 The Differentiation of Doctorate Education and Undergraduate Education for Foreign Students

To understand the distinct context of the participation of foreign students in doctorate education, it is instructive to examine broad comparisons with the flow of international students to US undergraduate programs. Overall, one might be tempted to regard the flow of undergraduate students and graduate students from abroad as closely coupled trends. Figure 3.4 shows total enrollment of graduate and undergraduate students from abroad at US colleges and universities from 1955 to 2005; the trends are largely overlapping, and the levels for 1965 and 2000 are close to identical. However, this broad correlation hides substantial differences in country of origin, source of support, and institutional destination. Moreover, foreign students are a much larger share of doctorate recipients from US institutions than under-

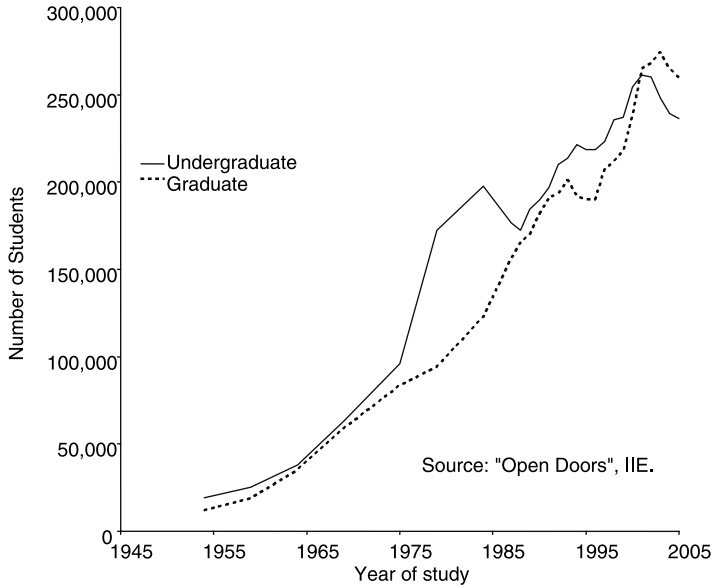

Fig. 3.4 Comparing growth of foreign undergraduate and doctorate enrollment
Source: Enrollment data are from *Open Doors* surveys (IIE, various years).

graduate degree recipients and, as such, shifts in the pattern of matriculation among foreign doctorate students would likely have substantial equilibrium effects and implications for university research.

3.2.1 College and University Choices in the United States

Graduate students are much more likely to be concentrated at public universities, while undergraduates are more likely to gravitate to private institutions. An obvious—if tautological—explanation is that many private institutions, such as liberal arts colleges, do not have substantial graduate programs in the sciences or do not have graduate programs at all. However, the distribution of noncitizens enrolled at the undergraduate level at US institutions is appreciably different than domestic students, as shown in table 3.3. While noncitizens are about 2.1 percent of aggregate undergraduate enrollment, these students comprise about 3.2 percent of the undergraduate body at private institutions, where they are even more likely (4.4 percent) to be represented among the institutions awarding PhD degrees.

A number of institutions in the United States, such as Boston University, Northeastern University in Massachusetts, and Babson College in the northeast, actively recruit foreign students. At Babson College, about one-quarter of the students are from abroad, while at Boston University, inter-

Table 3.3 Citizenship of undergraduate enrollment, 2005

	US citizens & permanent residents	Temporary residents	Percent temporary residents
Public institutions			
Doctorate-granting institutions	3,020,268	70,864	2.3
First professional institutions	89,408	2,163	2.4
Master's-granting institutions	1,849,660	40,251	2.1
Bachelor's-granting institutions	277,580	6,536	2.3
Two-year institutions	5,967,200	91,920	1.5
Other/unknown degree level	90,515	397	0.4
Two-year institutions and other	6,057,715	92,317	1.5
Total, public	11,294,631	212,131	1.8
Private institutions			
Doctorate-granting institutions	716,683	33,083	4.4
First professional institutions	117,761	2,953	2.4
Master's-granting institutions	1,003,922	36,978	3.6
Bachelor's-granting institutions	698,870	15,808	2.2
Two-year institutions	267,049	3,555	1.3
Other/unknown degree level	38,086	275	0.7
Two-year institutions and other	305,135	3,830	1.2
Total, private	2,842,371	92,652	3.2
All institutions	14,137,002	304,783	2.1

Sources: Authors' tabulations from Webcaspar. IPEDS Fall Enrollment Survey, 2005.

national students are typically about 7 percent of the freshman class (Jan 2008; Schworm 2008). Some in the field of college recruiting have posited that favorable exchange rates increase the attractiveness of US institutions, while concurrently, US universities have been more aggressively recruiting from abroad.[11] While a select few institutions are able to offer full financial aid to international students, much of the impetus for overseas recruiting is tied to the capacity of students to pay substantial tuition expenses either directly, or through home country fellowship support.

3.2.2 Country of Origin

The countries that send a high fraction of students to study in the United States at the undergraduate level are very different from those with large flows of students to US doctorate education (or graduate school, more generally). While the overall ratio of foreign undergraduate to foreign graduate students was about 0.9 in 2007, there are many countries well above and well below this ratio, as shown in table 3.4. The countries with disproportionately high representation of undergraduates enrolled in the United States relative to graduate students tend to be those with substantial income inequality. Oil-rich countries are well-represented in this list. At the other extreme, countries with relatively high representations of graduate students include countries like China and India that are on rapid development trajectories, with modest existing university infrastructure. In addition, European countries like Italy and France—with well-developed state higher education systems—appear much lower on the list; as few undergraduate from these countries pay to study in the United States, while very top tier students may pursue graduate study in the United States.

The data certainly suggest a model in which capacity to finance undergraduate education is a determinant of undergraduate enrollment. Indeed, there is some evidence that commodity price shocks—particularly oil—are an important determinant of undergraduate enrollment flows from a number of Middle Eastern countries. Figure 3.5 provides an illustration of the fluctuation in enrollment from oil-rich countries in association with oil prices. In these countries, it may well be that American undergraduate education is a luxury good, with changes in income leading to increased enrollment rates. But, a college education is certainly more than a consumption good; and it seems likely that access to capital afforded by positive oil shocks generates financing for higher education for students from these countries, as there are certainly many more well-qualified students from other countries

11. A July 2008 article, written when the dollar to pound exchange rate was about two, quotes a number of students as benefiting from the weak dollar, with the price of a US education declining relative to substitutes in the UK (Schworm 2008). For example, Martin Prochazka, a student from the Czech Republic, notes, "It wasn't the only reason but it was pretty important. I checked into London but it was twice the price."

Table 3.4 Undergraduate and graduate enrollment by country of origin, 2007

Place of origin	Undergraduate	Graduate	Total	Ratio: UG/grad
High undergraduate/graduate				
Qatar	201	27	228	7.444
Haiti	962	137	1,099	7.022
El Salvador	772	160	932	4.825
Hong Kong, China	5,148	1,594	6,742	3.230
Japan	22,247	7,008	29,255	3.175
Saudi Arabia	3,394	1,270	4,664	2.672
United Arab Emirates	523	202	725	2.589
Kuwait	1,050	421	1,471	2.494
Venezuela	2,691	1,187	3,878	2.267
Low undergraduate/graduate				
Germany	3,218	3,702	6,920	0.869
Russia	1,884	2,308	4,192	0.816
France	2,201	2,848	5,049	0.773
Ukraine	636	868	1,504	0.733
Italy	874	1,783	2,657	0.490
Taiwan	7,330	16,679	24,009	0.439
Egypt	442	1,037	1,479	0.426
India	12,581	59,570	72,151	0.211
China, PRC	9,988	47,968	57,956	0.208
World Total	233,789	266,336	500,125	0.878

Source: Open Doors 2007, "Table 2 International Students by Academic Level and Place of Origin, 2006/07."

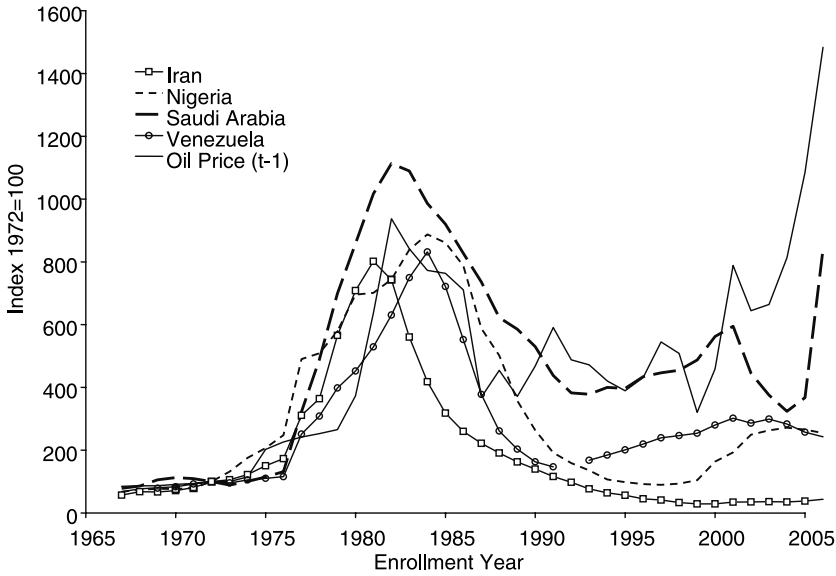

Fig. 3.5 Enrollments in the United States of students from major oil-producing countries

Sources: Enrollment data are from *Open Doors* surveys (IIE, various years); data on oil price data are from the Energy Information Administration (http://www.eia.doe.gov/aer/).

abroad who would apply to US universities if they were able to finance the tuition expenditures.[12]

One testable implication is that overall flows of graduate students should be much less sensitive to currency shocks and prices of major export goods (e.g., oil) than flows of undergraduate students. As we will pursue in more detail in subsequent sections, it is not home country financing but US university financing that is the primary source of support for foreign doctorate students; as such, we expect research funding and other determinants of university resources to be primary in determining the number of foreign doctorate students accommodated by US universities.

3.2.3 Sources of Support

It follows that we should expect to see undergraduate students heavily dependent on "own" support—paying full tuition at undergraduate institutions—while graduate students are more likely to rely on financial assistance through teaching appointments, research assistantships, and fellowships. Indeed, even as there may be many students from abroad who would like to borrow to finance investments in both undergraduate and graduate education in the United States, the absence of well-functioning international capital markets likely makes such actions impossible.

Charting the sources of support for both undergraduate and graduate students is a daunting challenge, and the following data are subject to some nontrivial problems, often recording support in broad terms like "primary," or based on imperfect institutional recording of funding sources. As international flows of students increase, better tracking of student enrollment, degree completion, and sources of support is imperative to account for the benefits and costs of globalization at US colleges and universities.

Overall, the data from Institute of International Education (IIE) show that among undergraduate students, 81.6 percent of foreign students finance their studies through "personal and family funds."[13] When we focus on doctorate students in the sciences, the distribution of funding sources is dramatically different, with only about 5 percent of foreign students relying on "own" sources as their primary support mechanism in graduate school in recent years. Indeed, foreign students are somewhat less likely to rely on own support for graduate study than their domestic peers, presumably because the latter have greater access to credit markets and family

12. To be sure, a small number of the super elite colleges and universities in the United States are able to offer need-blind admission and full financial aid to international undergraduate students; these institutions include: MIT, Harvard, Princeton, Dartmouth, Williams, and Middlebury, with most of these institutions opening aid to international students around the year 2000. See http://www.edupass.org/finaid/undergraduate.phtml for a list of universities that offer significant financial aid (both need-based and merit, but not athletic) to international students.

13. *Open Doors 2007,* "Table 15 International Students by Primary Source of Funding 2005/06 & 2006/07."

resources so they still may have an option of attending even if they are not fully funded. In turn, foreign students are somewhat more likely to have an employment source of support—either teaching assistantship or research assistantship—than their domestic US peers, while they are somewhat less likely to be supported by fellowship funding. Note that the proportion of foreign students funded through research assistantships rose markedly from the decade of the 1980s to the present, with this shift particularly prominent for students receiving their degrees from public institutions as shown in the second panel of table 3.5.

Our comparison of students from abroad at the doctorate level and undergraduate level leads to several propositions that motivate more focused consideration of the foreign students in graduate education in the next section. First, the fact that undergraduates typically pay for most—if not all—of the cost of attendance leads to quite different distributions of country of origin by level of study. In addition, the implication of the large share of students—particularly foreign students—who are funded through their doctorate studies is that their presence provides substantial benefits to the university in terms of teaching and research. In the next section, we turn to the question of how the expansion in doctorate education generated by

Table 3.5 **Sources of support for doctorate recipients in science and engineering fields by decade of PhD**

	1977–1979		1980–1989		1990–1999		2000–2005	
	US (%)	Foreign (%)	US (%)	Foreign (%)	US (%)	Foreign (%)	US (%)	Foreign (%)
				A All universities				
Teaching assistant	20.9	18.3	18.2	21.0	14.7	20.8	13.3	17.1
Research assistant	39.2	41.9	43.4	41.9	43.3	50.7	33.9	52.8
Fellowship	18.3	12.4	14.4	13.6	15.6	16.1	32.8	24.0
Loan/own/family	19.0	10.6	21.4	11.9	22.5	10.4	15.2	5.1
Others	2.6	16.7	2.6	11.6	4.0	2.1	4.8	0.9
				B Public universities				
Teaching assistant	23.8	20.3	20.5	22.6	16.4	21.9	15.4	18.2
Research assistant	39.5	43.0	43.0	41.5	42.4	52.0	36.4	56.8
Fellowship	15.0	9.3	11.6	11.9	12.8	13.6	26.7	19.2
Loan/own/family	19.9	10.6	22.8	12.2	24.8	10.7	16.6	5.0
Others	1.9	16.8	2.1	11.8	3.6	1.8	5.0	0.9
				C Private universities				
Teaching assistant	14.8	14.5	12.8	17.4	10.5	17.9	8.3	14.6
Research assistant	38.5	39.7	44.3	42.8	45.5	47.6	28.0	43.2
Fellowship	25.5	18.4	21.0	17.6	22.1	22.2	47.6	35.8
Loan/own/family	17.1	10.7	18.0	11.0	16.9	9.4	11.8	5.3
Others	4.1	16.7	4.0	11.2	4.9	2.8	4.3	1.1

Sources: Authors' tabulations. NSF, *Survey of Earned Doctorates* microdata.

foreign flows affects undergraduate degree production in both the private and public sectors of higher education.

3.3 The Effects of the Expansion of Foreign Doctorate Students on Undergraduate Education

That so many graduate students in general—and foreign doctorate students in particular—support their studies with teaching and research appointments is an implicit demonstration of the complementary role played by graduate students in the university production function. We are interested in addressing whether the complementarity is stronger in teaching or in research. Whether researchers (and the consumers of research) or undergraduate training are the most likely beneficiaries of additional graduate students represents an important dimension of university resource allocation.

While increased student demand among foreign undergraduates often comes with additional tuition dollars, foreign doctorate students often receive considerable financial support from universities. For this reason, one would expect spillovers to other dimensions of university production such as research and undergraduate education.[14] To this end, the growth of doctorate education generated by increased demand among students from abroad should make it less costly for the university to increase complementary activities like more undergraduate education or research output. Similarly, if research funding increases (e.g., positive government science shock), we would expect an increase in graduate enrollment to the extent that graduate education and research are complementary.

Our original contribution in this chapter is to explore the link between graduate flows and undergraduate flows, noting that a number of other researchers have tackled the difficult question of the link between foreign graduate flows and research output (see Black and Stephan 2007; Stuen, Mobarak, and Maskus 2007; Chellaraj, Maskus, and Mattoo 2008).

3.3.1 Undergraduate Teaching and Doctorate Education

One potential link to the expansion of doctorate training in the sciences is growth in undergraduate education. Without establishing strict causal-

14. What motivates this analysis is a model of economies of scope in the production of graduate education, undergraduate education, and research in the university. With the presence of some economies of scope in the university production function of such that the total cost (TC) of production of graduate education along with undergraduate education and research must be less than the production of these activities separately, implying the following expression is positive: $SE_G = (TC\{0, Q_G, 0\} + TC\{Q_U, 0, Q_R\} - TC\{Q_U, Q_G, Q_R\})/(TC\{Q_U, Q_G, Q_R\})$, where Q_G is the number of graduate students enrolled, Q_U is the number of undergraduates, and Q_R is the quantity of research produced. If additional doctorate students represent exogenous shifts, in the sense that at each level of financial support more students are willing to enroll, the effective price of complementary activities declines and we would expect more undergraduate output or research output in proportion to the degree of complementarity.

ity, complementarity in production between undergraduate and graduate education in the sciences would be indicated by a positive link between enrollment and degree attainment in the two areas. One mechanism is that a large influx of graduate students would make it attractive to expand undergraduate education.[15] In turn, undergraduate education in the sciences might be affected on two margins: (a) overall increases in student numbers (e.g., expansion proportionate with the university), and (b) a relative increase in undergraduate majors in fields associated with the expansion of graduate education.

To quantify the link between graduate flows and undergraduate flows, we are interested in estimating relationships of the form:

$$\ln \mathrm{UM}_{ijt} = \alpha_i + \delta_j + \lambda_t + \beta \ln \mathrm{PhD}_{ijt} + \varepsilon_{ijt},$$

where *i* indicates field, *j* indicates university, *t* indicates year, UM specifies undergraduate majors, and PhDs indicates the scale of the doctorate program. In turn, the estimated parameter β is the elasticity of undergraduate majors in field *i* with respect to additional PhDs in field *i*. One explanation for concurrent changes in PhDs and undergraduate majors is aggregate university expansion. Our interest is particularly focused on how changes in doctorate program scale generated by (potentially) exogenous shifts in foreign students affect undergraduate concentrations. To capture these changes we can focus on foreign PhDs as the key explanatory variable, what might be called the reduced form relationship, or present instrumental variables (IV) estimates with foreign PhDs serving as the instrument for all PhDs, as increases in participation from foreign students are plausibly (though perhaps not entirely) a result of home country changes exogenous to the US education market.

Table 3.6 presents estimates over the extended period from 1970 to the present of the effect of PhD expansion in the sciences on BA levels. Our within institution estimates tend to be precisely estimated, with effects of very modest magnitude. The IV estimates suggest elasticity estimates of 0.09 at public institutions and 0.12 at private institutions, implying that a 10 percent increase in science doctorate cohort size would be associated with an increase in undergraduate majors on the order of 0.9 percent and 1.2 percent respectively. Probing these estimates more deeply, we note that the estimate for private institutions is much smaller at the Research 1 institutions than at the other types of private doctorate institutions. We have also investigated the effects of PhD flows on relative concentrations of undergraduate majors in the sciences (share of science majors within the institution), and we find essentially no significant effects.

In discussing these results, it is worth emphasizing that while the results

15. Alternatively, increased local undergraduate demand would lower the cost of recruiting additional graduate students.

Table 3.6 Link between science PhDs and undergraduate participation in sciences

	Public (1)	Private (2)	Public (3)	Private (4)	Public (IV, foreign) (5)	Private (IV, foreign) (6)
Ln Foreign PhD	0.0432*** (0.007)	0.0556*** (0.012)				
Ln All PhD			0.0945*** (0.007)	0.0972*** (0.013)	0.0901*** (0.014)	0.1231*** (0.025)
Constant	6.4705*** (0.028)	5.7660*** (0.046)	6.1781*** (0.033)	5.5083*** (0.054)	6.2442*** (0.060)	5.4720*** (0.099)
N	5,286	2,571	5,859	2,952	5,286	2,571
R^2	0.27	0.183	0.302	0.187	n/a	n/a
Number of inst	197	99	207	116	197	99

Source: Authors' tabulations from restricted use *Survey of Earned Doctorates.*
Note: estimates in log levels with year and institution fixed effects
***Significant at the 1 percent level.

may be unsurprising to many observers, they contribute important evidence to an otherwise speculative discussion. One explanation for the very modest effects of PhD supply shocks on undergraduate education is that there may be little net change in course offerings or reductions in student faculty ratios that would make science majors more attractive to undergraduate students. New graduate students employed as teaching assistants may simply substitute for line faculty (who, in turn, may allocate more time to research), or adjunct faculty. A second, and perhaps more persuasive argument, is that additional graduate students—particularly those from abroad—adding to program size may not be deployed to teaching functions, but research functions; our pursuit of this latter hypothesis follows.

Still, there is sufficiently long history of discussion of the role of graduate students in undergraduate teaching and the expansion of university programming that we investigate the extent to which the circumstances of the 1960s were different fundamentally than those operating since the 1980s. Figure 3.6 shows the long trend in BA degrees awarded and PhD degrees awarded in the US over a century, and the broad correlation is unmistakable. However, a closer look at the data for doctorate granting institutions—that is, focusing on BA degrees awarded in the sciences by corresponding institutions—shows a much different correlation (or lack thereof) in figure 3.7. While undergraduate degree attainment continued to rise into the early 1980s, this was the period when doctorate programs were largely contracting; thereafter, contraction in undergraduate degrees corresponded with growing doctorate receipt (particularly among foreign students) in the 1980s. The most recent period shows little link between changes in undergraduate and graduate education in either the public or private sectors. Looking back

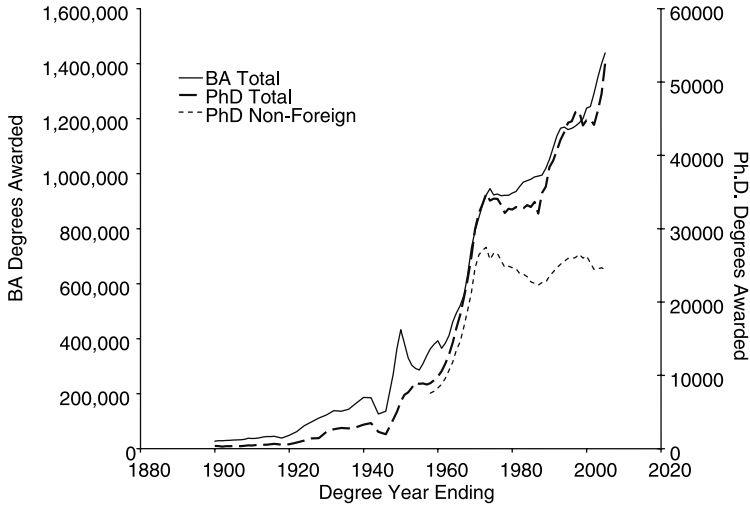

Fig. 3.6 BA degrees and PhD degrees awarded by year, 1900–2005

Source: Data assembled from government sources in Goldin (1999) with the most recent years updated from the *Digest of Education Statistics* (2007).

to the period of the 1960s, it has been argued that the dynamics generating the robust growth in doctorate attainment and dramatic decline in doctorates awarded (particularly to US residents) in the early 1970s can be attributed to a confluence of historical factors. Indeed, there is evidence that the elimination of 2-S military draft deferments for graduate study in the late 1960s, followed by erosion in the domestic academic labor market, dramatically slowed the rate of doctorate attainment among US residents (Bowen, Turner, and Witte 1992).

3.3.2 Research Funding and Doctorate Education

If additional doctorate students in the sciences—specifically, additional foreign doctorates—are not adding to the outputs in undergraduate teaching, it merits asking how the funding of these students aligns with the teaching and research functions (and outputs) of universities. As a caveat to this discussion, we note that the data available on financial support of doctorate students in the *Survey of Earned Doctorates* is far from ideal. We observe the "primary source of support" over the graduate career rather than more informative measures of the level and composition of support; in addition, the "primary source" measure is only observed from 1977 to the present. Absent other sources of information, we start with these data to fix broad trends.

Table 3.7 presents the distribution of primary source of support for for-

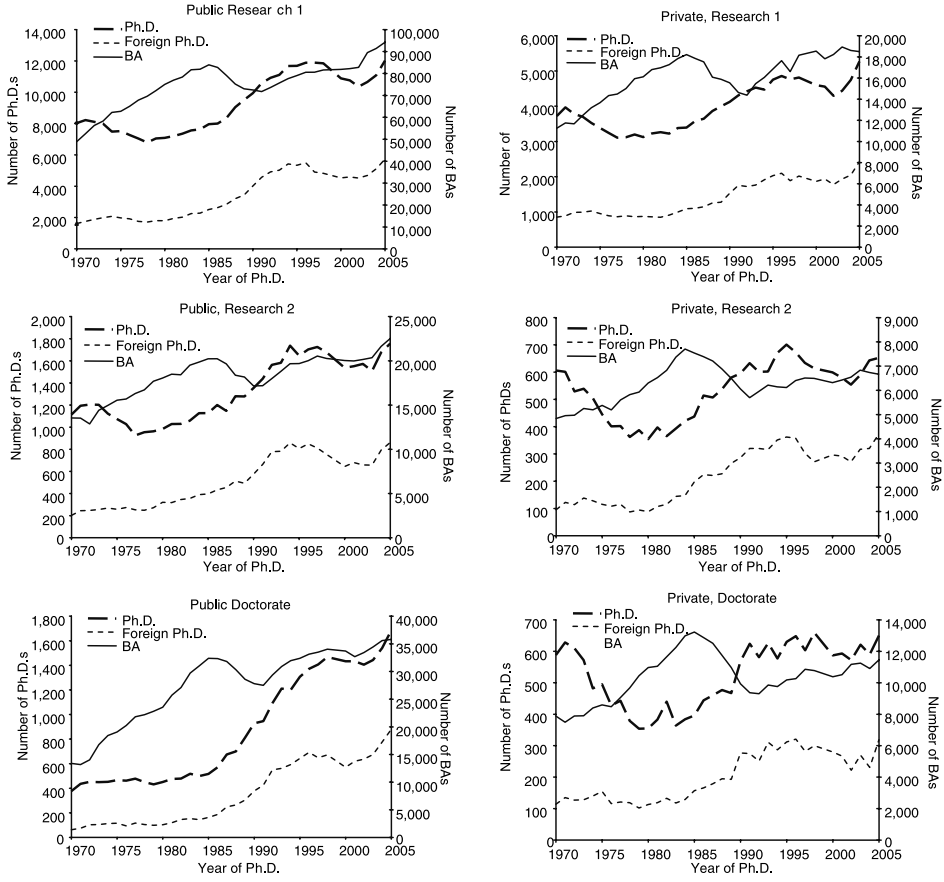

Fig. 3.7 Trends in BA and PhD degrees by type of institution

Sources: NSF, *Survey of Earned Doctorates* microdata. National origin is defined by the country in which an individual went to high school. Fields defined using NSF classification, from SED annual report.

eign and US students by field and type of institution for broad field classifications in the sciences. Outside of economics, the share of both foreign and US students reporting "teaching assistantship" (TA) as their primary source of support declines from the late 1970s to the current period, with these drops most marked in the physical sciences and engineering. As such, these data are largely consistent with the very small effects of expansion of doctorate education on undergraduate education reported in the prior section. It is worth noting that the field of economics—particularly at public universities—looks very different than the physical and life sciences in patterns of support. In economics, over 46 percent of foreign PhD recipients

Table 3.7 **Source of support by citizenship, institution type, and field (selected periods)**

	1977–1979		1980–1989		1990–1999		2000–2005	
	Foreign	US	Foreign	US	Foreign	US	Foreign	US
			Public, physical sciences					
TA	39.7	33.7	39.0	28.5	37.6	25.1	31.8	24.6
RA	36.0	38.0	39.0	45.0	46.0	43.5	50.6	43.1
Fellowship	7.7	12.2	8.4	9.5	8.1	11.0	12.8	18.7
Loan/own	6.8	14.5	7.7	15.7	7.1	18.0	4.1	10.5
Other source support	9.4	1.6	6.3	1.6	1.2	2.5	0.8	3.2
Number of observations	1,353	5,033	7,929	18,771	15,660	20,991	10,836	12,429
			Public, engineering					
TA	12.1	8.9	16.2	9.5	12.9	7.0	9.2	6.4
RA	56.7	42.0	52.0	44.0	59.0	46.4	68.4	43.8
Fellowship	6.7	18.5	9.5	16.0	10.8	16.9	14.5	25.9
Loan/own	11.4	25.3	13.4	25.4	14.6	22.4	6.3	14.4
Other source support	13.2	5.2	8.9	5.1	2.4	7.2	1.7	9.5
Number of observations	1,719	1,892	10,162	7,643	18,892	13,273	13,880	7,724
			Public, life sciences					
TA	11.8	19.1	10.7	16.9	13.1	13.0	11.7	11.9
RA	38.0	42.0	35.0	44.0	52.0	42.3	50.8	31.9
Fellowship	11.8	16.7	17.8	12.0	21.1	12.8	29.9	32.6
Loan/own	14.6	21.0	17.5	25.3	11.7	29.2	6.4	19.6
Other source support	23.9	1.1	19.1	1.6	2.2	2.7	1.2	4.2
Number of observations	1,785	7,119	8,308	29,673	16,402	29,757	11,589	21,993
			Public, economics					
TA	37.7	39.4	39.1	41.3	43.6	42.6	46.0	42.6
RA	17.0	18.0	15.0	16.0	14.7	13.0	15.0	16.7
Fellowship	12.0	13.3	11.9	9.6	18.1	8.5	26.1	14.0
Loan/own	21.8	28.2	22.1	32.3	21.4	35.0	11.5	25.0
Other source support	12.0	1.0	11.6	1.1	2.2	0.9	1.5	1.8
Number of observations	284	731	1,559	2,359	2,264	1,930	1,746	1,158
			Private, physical sciences					
TA	23.1	22.2	25.8	18.4	28.0	16.5	23.4	16.7
RA	37.0	38.0	43.0	47.0	48.7	48.7	45.1	36.8
Fellowship	19.2	24.3	14.4	20.0	15.4	19.0	26.1	35.5
Loan/own	7.8	12.6	7.6	12.0	6.0	12.1	4.2	7.8
Other source support	13.4	2.5	8.8	3.0	1.9	3.8	1.2	3.3
Number of observations	849	2,691	4,069	9,152	7,121	8,877	4,973	4,786
			Private, engineering					
TA	10.5	7.0	11.5	6.4	11.1	6.2	8.7	4.0
RA	52.0	46.0	55.0	51.0	58.7	49.9	59.8	39.7
Fellowship	11.6	18.5	12.7	18.7	16.0	22.0	23.8	39.3
Loan/own	11.6	17.7	9.7	14.6	9.9	12.2	5.8	8.5
Other source support	14.4	11.2	11.2	9.1	4.3	9.7	1.9	8.5
Number of observations	1,022	1,207	4,951	4,468	7,640	6,199	5,087	3,277

Table 3.7 (continued)

	1977–1979		1980–1989		1990–1999		2000–2005	
	Foreign	US	Foreign	US	Foreign	US	Foreign	US
			Private, life sciences					
TA	11.0	10.6	10.3	10.0	9.2	7.0	6.9	4.8
RA	29.2	42.0	28.0	45.0	39.8	45.8	29.3	21.1
Fellowship	24.8	27.5	27.5	21.3	35.4	23.6	54.5	57.9
Loan/own	14.9	17.1	20.0	21.1	13.0	20.9	7.7	13.1
Other source support	20.1	2.3	13.9	2.2	2.6	2.8	1.6	3.0
Number of observations	463	2,451	2,045	10,176	4,962	11,136	3,971	9,069
			Private, economics					
TA	10.3	14.3	20.5	17.3	25.9	21.1	21.9	16.7
RA	8.7	11.0	8.0	14.0	9.4	16.1	9.4	9.5
Fellowship	28.3	42.4	29.4	33.2	38.0	32.2	56.6	50.7
Loan/own	30.2	29.5	27.0	33.4	20.8	28.8	11.3	20.9
Other source support	22.5	2.8	15.0	2.1	6.0	1.9	0.9	2.2
Number of observations	311	495	1,291	1,686	1,863	1,399	1,587	671

Source: Authors' tabulations from restricted use *Survey of Earned Doctorates.*

Note: The first five rows of each panel show the distribution of primary support for those respondents providing usable answers to this question.

and 42.6 percent of PhD recipients from the United States at public universities relied on funding through teaching assistantships as the primary source of support in the most recent period of observation. In other scientific fields these shares are much lower and have been trending down, not up, over time, with TA positions serving as the primary source for less than 12 percent of doctorate recipients in the life sciences, and less than 10 percent in engineering.

How, then, are doctorate students financed in the most recent decades if they are decreasingly engaged in undergraduate teaching? While there are substantial differences in starting levels across fields, we see clear increases in research assistantship (RA) support for foreign graduate students. If the share of foreign PhD students funded by research positions increases while the number of foreign students is also increasing, it follows that the total number of research assistant positions held by foreign students must also be increasing. Table 3.7 shows that this shift in source of support is particularly strong at public institutions (again, excepting economics). For economics, it is likely that there are fewer scale economies in research that allow for the employment of graduate students in labs or on research grants; in turn, demand for undergraduate courses may have expanded, while demand in the sciences more generally has remained flat.

For US doctoral students, the clear shift is toward fellowship funding as a

primary source of support over the last three decades.[16] If fellowship support is increasingly needed to attract US doctoral students while foreign students are willing to attend with research assistantships, the price to institutions of attracting an additional student to study in the sciences may be higher for domestic applicants than the parallel price for foreign students.

3.4 Conclusion and Next Steps

"Who pays?" and "who benefits?" are fundamental questions in higher education policy. At the undergraduate level, the answer is relatively straightforward: undergraduate students (and their parents) pay for higher education through tuition and receive largely private benefits.[17] Thus, the decisions of foreign students to pursue undergraduate education in the United States are determined largely by capacity to pay. At the graduate level, it is much more common for universities to support students through research and teaching positions, as well as fellowships. For students from abroad, these financing sources are likely to be crucial in facilitating attendance, in the absence of well-functioning capital markets.

Doctorate production in science and engineering fields plainly intersects with the research and undergraduate teaching functions of the university. Evidence presented in this chapter suggests that the expansion of foreign doctorate attainment in the sciences—particularly outside of economics—at US universities has been largely aligned with the research function at universities. The availability of research funding has been significant in supporting the increased demand among foreign doctorate students. Substantial increase in funding for science and engineering research generated by the federal stimulus (American Recovery and Reinvestment Act), and intense fiscal pressures faced by US research universities raise important questions about how US universities will incorporate the flow of talent from abroad in graduate education in the coming years.

16. Significantly, the data available to us do not distinguish between fellowship support provided by external sources (which may be restricted to domestic students) and fellowship support provided through the funds of universities. This distinction in source of fellowship funding is critical to the interpretation of the differential trends in sources of support for US and foreign students. External awards (e.g., NSF awards to individuals) are implicit subsidies to universities in the production of graduate education while university-supported fellowship awards are direct institutional costs without the direct obligation to participate in university research (as distinguished from independent research) that is implicit in research assistantship appointments.

17. To be clear, this statement is relative in the sense that tuition price is likely to be well below the actual cost of provision at many undergraduate institutions (hence many full pay students pay less than full cost); in addition, beyond the private benefits to higher education that accrue in the form of improved earnings, there may be some external benefits to consider in a full calculation.

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