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Attracting Talent: Location Choices of Foreign-Born PhDs in the United States

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We analyze location choices of foreign-born science and engineering students receiving PhDs from US universities. Foreign students who stay in the United States are positively selected on observables. They tend to stay in the United States during periods of strong US economic growth and during periods of weak home country economic growth. Foreign students from higher-income countries and from recently democratized countries tend not to remain in the United States. Education and innovation may therefore be part of a virtuous cycle by which education enhances a country's prospects for innovation and innovation makes the country more attractive for scientists and engineers.

I. Introduction

Scientists and engineers are the core of the high-skilled labor force in the United States. They are key inputs in research and development (Kapur and McHale 2005), patent at much higher rates than other professionals (Hunt and Gauthier-Loiselle 2010), and are relatively likely to create high-

technology companies (Zucker and Darby 2007). Recent theories of economic growth suggest that expanding the science and engineering (S&E) talent pool would raise the long-run growth rate of the US economy (Jones 1995a, 1995b).[1]

Foreign students comprise the most rapidly growing segment of the US S&E labor force. Over the last several decades, the share of S&E PhDs granted by US universities going to the foreign-born rose sharply, from 12% in 1970 to 36% in 2011.[2] Whether newly minted degree holders choose to stay in the United States after graduation or to return home helps determine how quickly the supply of US S&E labor can expand. Yet we know relatively little about the factors governing the location choices of these individuals. Existing work examines how the supply of foreign graduate students affects research output by US universities (Stuen, Mobarak, and Maskus 2010) and the earnings and employment of US graduate students (Borjas 2009; Lan 2011). Other research considers how the inflow of scholars to the United States following the collapse of the Soviet Union altered the career trajectories of US academics (Borjas and Doran 2012a, 2012b).[3] But little work considers who stays in the United States upon completion of a PhD.[4]

In this paper, we analyze the selectivity of foreign-born students receiving PhDs from US universities who intend to stay in the United States after completing their degree. We also analyze how economic and political conditions influence such students' intentions to stay in the United States. We use data from the NSF Survey of Earned Doctorates (SED), which contains information on the characteristics of all individuals receiving a PhD from a US university from 1958 forward. Our data span the period 1960–2008. Crucially, the SED asks individuals if they intend to stay in the United States in the year following degree completion. Intent-to-stay rates reported in the SED closely track actual stay rates of foreign PhD graduates derived from earnings reported to the Social Security Administration in the years following degree completion (Finn 2010).

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[1] Hunt and Gauthier-Loiselle (2010) and Kerr and Lincoln (2010) find that US regions that attract more high-skilled immigrants produce larger numbers of S&E patents.

[2] These shares exclude from the foreign-born those who are US citizens, are US legal permanent residents, or attended high school in the United States. The share peaked at 42% in 2007, before declining during the Great Recession.

[3] Related work includes Bound et al. (forthcoming), which considers how inflows of high-skilled immigrants during technology booms affect the labor market for computer scientists in the United States.

[4] Also using the Survey of Earned Doctorates, Black and Stephan (2007) find that having personal or work ties in the United States or coming from a higher-ranked US program is correlated with intent to stay in the United States after obtaining a PhD.

In measuring the selectivity of foreign-born US S&E PhD recipients who intend to stay in the United States, we ask whether there is positive selection even among very highly educated immigrants.[5] While we do not observe student test scores or other direct measures of academic ability, we do observe indirect measures of potential, including parental education, whether a student receives fellowships or scholarships during the course of study, and the rankings of a student's PhD program and university. Students who receive merit-based financial support and who have more educated parents are more likely to desire to stay in the United States.

We also analyze the link between economic conditions, both in the United States and in the source country, and foreign students' intention to stay in the United States. There is an enormous literature on how income affects migration decisions. Our contribution is to examine how these location decisions track economic and political cycles. We find that, controlling for time trends and birth country fixed effects, foreign-born students are more likely to intend to stay in the United States the higher is the recent rate of US GDP growth, the lower is the recent rate of GDP growth in the birth country, and the lower is the level of development in the birth country. These results mesh with recent studies that document how economic conditions at the time of labor market entry affect long-run employment and earnings for high-skilled individuals.[6] They also show that booms in the United States help keep foreign PhDs from departing, whereas booms in the birth country draw students home. These patterns suggest that there is procyclicality in the supply of very highly skilled labor in the United States.

Finally, we use Polity IV scores to analyze how source country political conditions affect the location intentions of foreign-born PhD students (Marshall and Jaggers 2002). Previous work has examined whether the return of students trained in foreign universities affects democratic transitions in the home country (Spilimbergo 2009). We ask the reverse question of whether democratic transitions at home lure back US-trained PhD students. When a student's birth country becomes more democratic, the likelihood that a graduate returns home increases, suggesting that political opening induces the return of high-skilled labor from abroad.

[5] Substantial literature finds evidence consistent with the positive selection of more general groups of migrants. See Rosenzweig (2006), Belot and Hatton (2008), de Grip, Fouarge, and Sauermann (2009), and Grogger and Hanson (2011). On the determinants of immigration in high-income countries, see Clark, Hatton, and Williamson (2007), Ortega and Peri (2009), and Mayda (2010).

[6] For example, Oyer (2008) finds that better stock market conditions while MBA students are in graduate school positively affect the likelihood of their finding employment in investment banking. Graduates who initially take jobs on Wall Street tend to have higher long-run income. Similar findings hold for economists (Oyer 2006) and for college graduates more generally (Kahn 2010; Oreopoulos, von Wachter, and Heisz 2012).

In the next section, we describe the data used for the project and discuss broad trends regarding the location choices of foreign PhD students educated in the United States. In Section III, we present our empirical specification and results on the intent to stay in the United States. In Section IV, we use our empirical results to decompose variation in stay rates for PhDs for the four largest source countries. In Section V, we offer concluding remarks.

II. Data and Empirical Setting

The Survey of Earned Doctorates (SED) covers all individuals receiving a PhD from an accredited US institution from 1958 forward. We have data through 2008, which include 1.6 million observations. From this sample, we drop individuals who were born in the United States or in US territories ($N = 1.1$ million); obtained degrees before 1960, years for which we lack national economic data ($N = 2,000$); obtained PhDs from non–research universities ($N = 9,000$); are missing data on place of birth ($N = 56,000$); or are missing data on postgraduation plans ($N = 6,000$). We further drop individuals 45 years of age or older at time of degree ($N = 28,000$), which consist primarily of those who complete their PhDs over multiple decades and who may not be comparable to the full-time students that constitute the bulk of the sample. Finally, we drop individuals who attended high school in the United States, who are US citizens, or who hold green cards ($N = 40,000$). This lets us focus on the behavior of individuals who came to the United States for higher education rather than because of location decisions of their parents or for other reasons. Table A1 gives summary statistics on the SED and other data used in the empirical estimation.

Our focus is on graduates in science and engineering fields. However, in some regressions we also consider students in other fields of study. S&E fields are those most closely linked to innovation. Using data from the 2003 US National Survey of College Graduates, Hunt and Gauthier-Loiselle (2010) find that foreign-born scientists and engineers are substantially more likely than other college graduates or postgraduates to have produced a patent and are more likely still to have produced a patent that has been commercialized. S&E fields include life sciences (agricultural, biological, and health sciences), physical sciences (atmospheric, earth, and ocean sciences; chemistry; mathematics and computer science; and astronomy and physics), and engineering.

A. Rising Presence of the Foreign-Born among US S&E PhD Recipients

The rising presence of foreign students among new US S&E PhD recipients has brought with it a change in the composition of the birth countries represented by these students. Figure 1 shows the share of the foreign-born among all new S&E PhDs from US universities with the birth countries
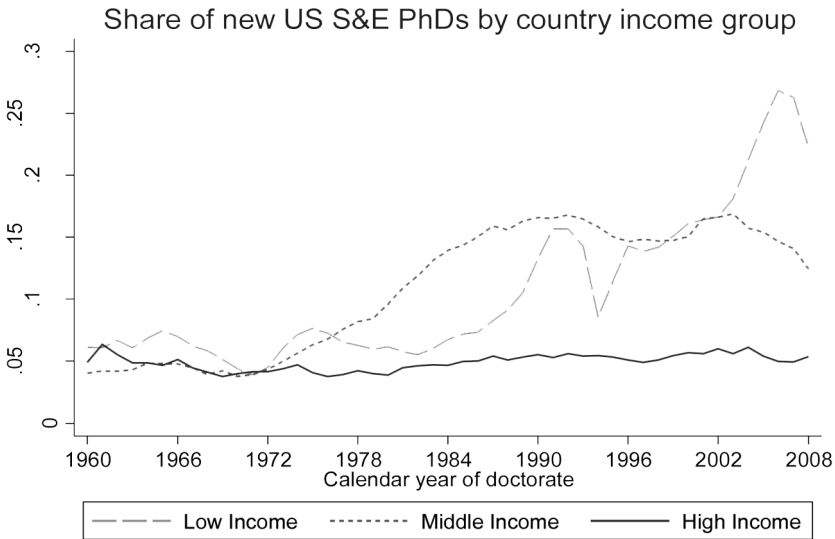
Share of new US S&E PhDs by country income group

FIG. 1.—Foreign-born S&E PhDs by birth region. Low-income countries are defined as those with per capita GDP less than $800, middle-income countries as those between $800 and $8,000, and high-income countries as those over $8,000; all based on 1985–94 GDP/capita.

of these students grouped by low-, middle-, or high-income status.[7] In the 1960s, the three income groups each accounted for roughly equal shares of new US S&E PhDs. Over time, the share of S&E PhDs from high-income countries has been flat, due in part perhaps to the strengthening of graduate education in Australia, Canada, Europe, and Japan (Bound, Turner, and Walsh 2009; Freeman 2009). Essentially all of the growth in foreign-born S&E PhDs has come from low- and middle-income nations. Student flows from middle-income countries expanded first, rising from 6% of new US S&E PhDs in the late 1960s to 22% by the late 1980s before stabilizing. Low-income countries expanded next, with their share of new US S&E PhDs rising from 8% in the early 1980s to over 25% in the early 2000s.[8]

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[7] The definitions of income groups are per capita GDP of less than $800 for low-income countries, between $800 and $8,000 for middle-income countries, and above $8,000 for high-income countries, where income values are averages for the period 1985–94 (such that some countries [e.g., China] defined as low-income during this period are middle-income today, and other countries [e.g., Korea and Taiwan] defined as middle-income are high-income today). Our income classification mirrors that for the World Bank over the same period.

[8] The mid-1990s dip in the share of S&E PhDs awarded to individuals from low-income countries is due almost entirely to China (as seen in fig. 2a). Following the events at Tiananmen Square in 1989, the number of Chinese students going to the United States for PhD study dropped sharply, leading to a corresponding fall in

Among low-income countries, China and India are by far the largest sources of PhD students to US universities, as seen in figure 2*A*. Over the period, they account for an average of 84% of students from low-income nations completing US S&E PhDs. Among middle-income countries, shown in figure 2*B*, Korea and Taiwan are the largest source countries, accounting for an average of 42% of S&E PhD recipients from this income group. The next largest middle-income source countries for S&E PhDs are Russia, Iran, and Turkey.

China and India are large source countries for PhD students in part because they have large populations. Additionally, students from these two countries exhibit relatively high propensities to pursue PhD education in the United States. A crude measure of this propensity is the number of new US S&E PhDs (a flow) divided by the birth country's population (a stock). New US S&E PhDs per capita reached a peak late in the sample period of 3.0 per 10,000 inhabitants in China and 1.7 per 10,000 inhabitants in India but remained at only 0.6 per 10,000 inhabitants in other low-income countries. Korea and especially Taiwan stand out for having very high propensities to pursue US S&E PhD training. Over the period, new US S&E PhDs averaged 13.0 per 10,000 inhabitants in Korea and an astounding 30.0 per 10,000 inhabitants in Taiwan, nearly as high as the 34.0 per 10,000 inhabitants for the United States. Thus, in the 1990s, individuals born in Taiwan were nearly as likely to complete a science and engineering PhD in the United States as were US-born individuals. For comparison, new US S&E PhDs per 10,000 inhabitants averaged 1.5 for other middle-income countries and 2.0 in non-US high-income countries (many students from which may pursue advanced training closer to home).

B. Post-Degree Location Decisions for Foreign PhD Recipients

The SED asks PhD recipients about their post-graduation plans. For our analysis, the question of primary interest is: "In which country do you intend to live after graduation (within the next year)?"

Figure 3 shows that the majority of foreign-born PhD recipients intend to stay in the United States, with average affirmative responses of 82% for those from low-income countries, 58% for those from middle-income coun-

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the share of PhDs awarded to Chinese students 4–6 years hence. The dip may reflect short-lived restrictions on emigration from China, possibly in response to the US Chinese Student Protection Act of 1992, under which the United States granted permanent residence to Chinese immigrants who arrived in the United States between April of 1989 and June of 1990. The share of S&E PhDs awarded to Chinese students returned to its pre-1989 peak by the late 1990s and then continued to rise. See Lan (2011) on the consequences of the Chinese Student Protection Act for US native-born PhDs.

A

Share of new US S&E PhDs by country

Calendar year of doctorate

-------- China   — — — India   —— Other low income

B

Share of new US S&E PhDs by country

Calendar year of doctorate

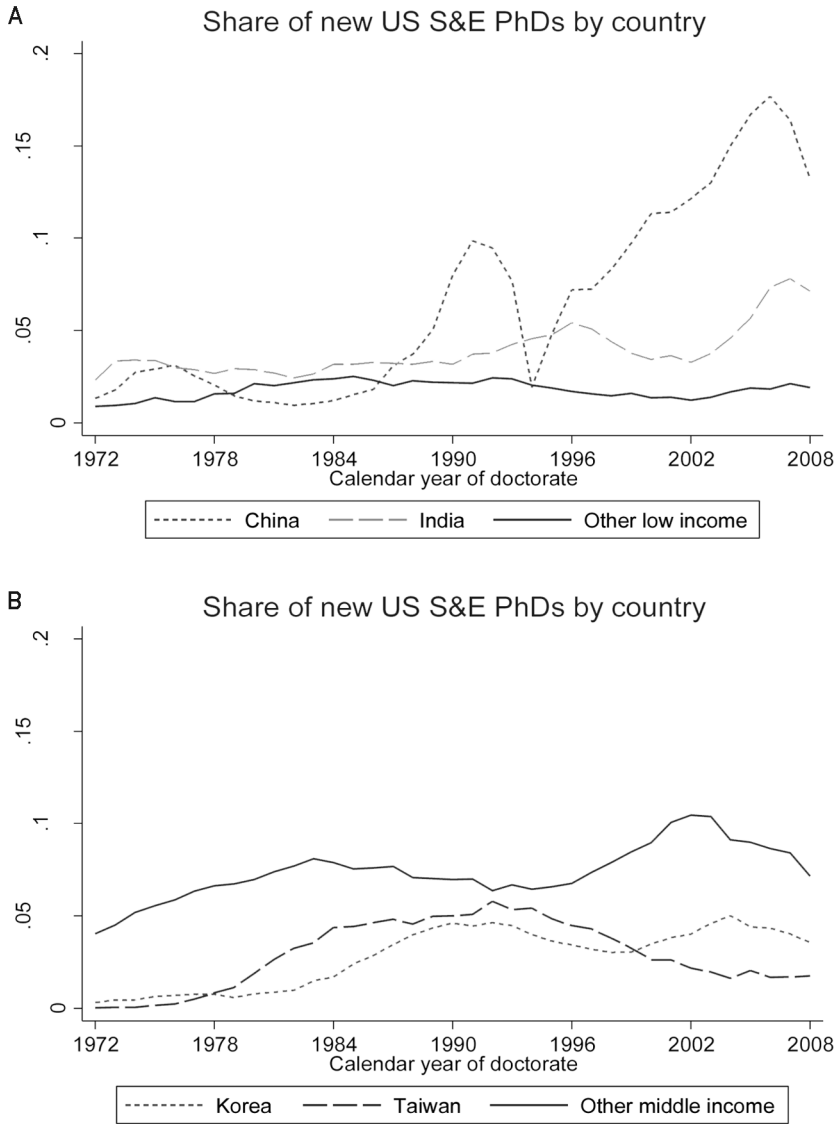-------- Korea   — — — Taiwan   —— Other middle income

Fig. 2.—Foreign-born S&E PhDs by birth country. *A*, Low-income countries; *B*, medium-income countries. Low-income countries are defined as those with per capita GDP less than $800, middle-income countries as those between $800 and $8,000, and high-income countries as those over $8,000; all based on 1985–94 GDP/ capita.

F𝐼𝐺. 3.—Share of new foreign-born S&E PhDs. Low-income countries are defined as those with per capita GDP less than $800, middle-income countries as those between $800 and $8,000, and high-income countries as those over $8,000; all based on 1985–94 GDP/capita.

tries, and 57% for those from high-income countries.[9] For foreign-born students on a temporary residence visa, staying in the United States past completion of the PhD requires that they obtain employment, such that they can transition from a student visa to an employment visa (e.g., a H-1B temporary visa for high-skilled workers or an employer-sponsored green card).[10]

Figure 3 shows nonmonotonicity in the relationship between the desire to stay and birth country income levels. If high-skilled individuals choose locations based on the proportional (i.e., Mincerian) return to skill, as in Borjas (1987), one would expect the probability of staying in the United States to be higher for PhDs from other rich countries, where returns to skill tend to be relatively low (e.g., Hanushek and Zhang 2006). If individuals instead choose locations based on absolute differences in

[9] Among S&E PhD recipients born in the United States, the average fraction planning to stay in the country is 96%.
[10] Another option for recent foreign-born graduates of US universities is Optional Practical Training (OPT), which allows current or former students to work in the United States temporarily (up to 29 months for S&E degree recipients) as long as the position is related to the student's field of study and is approved by the degree-granting institution and US immigration authorities. OPT is often used as a transition to an H-1B visa.

income between countries, as in Grogger and Hanson (2011), one would expect the opposite. What we see in figure 3 is an intermediate outcome, with the probability of staying in the United States being lowest for individuals from middle-income countries. Results in Section III suggest that this pattern in part reflects middle-income countries having relatively high rates of economic growth (given that the location choices of PhD recipients are sensitive to recent changes in economic conditions).

How do we know whether individuals intending to stay in the United States actually end up doing so? One indication is that at the time of graduation a substantial fraction of new PhDs have already secured employment. Among foreign-born S&E PhDs at graduation, 55% had "signed a contract or made a definite commitment for postdoc or other work," 10% were continuing in their predoctoral employment, and 12% were "negotiating with one or more specific organizations." Only 21% were "seeking employment but have no specific prospects." Thus, nearly 80% of the individuals intending to stay in the United States either already had a job or were in the advanced stages of landing a job.

More concretely, Finn (2010) uses data from the Social Security Administration (SSA) to track the stay rates for individuals in the SED. Using a confidential version of the SED that includes the individual Social Security number, he matches groups of these numbers to Social Security income data to determine whether students in the SED remain in the United States. Figure 4 plots Finn's ex post stay rates against intent-to-stay rates based on
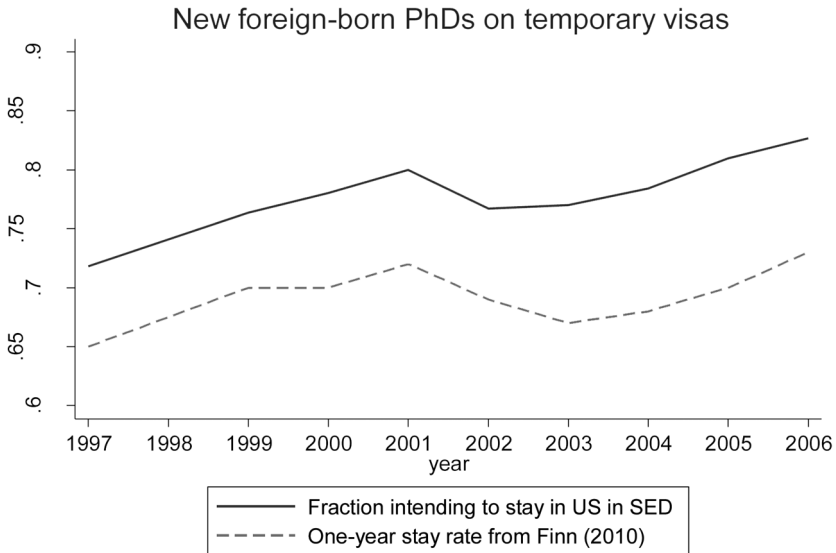

Fig. 4.—Stay Rates in SED versus Finn (2010). Intent-to-stay rate is based on author's calculations based on the SED. One-year stay rate is taken from Finn (2010).

intentions reported in the SED, which is an ex ante measure. Although intent-to-stay overstates actual stay rates by 4–5 percentage points, the two series track each other very closely, with a correlation of 0.85. Finn (2010) further estimates that stay rates fall little over time, from 71% after 1 year to 65% after 5 years. Thus, the large majority of individuals intending to stay in the United States do indeed stay, and most appear to stay at least 5 years.

Finally, part of the motivation for a recent PhD graduate to stay in the United States after obtaining his degree may be to secure a postdoctoral fellowship, which in many fields serves as an apprenticeship necessary for graduates to succeed in launching independent careers (Stephan, Franconia, and Scellato 2013). Stephan and Ma (2005), who also use the SED, document that foreign-born PhD recipients are more likely than the US-born to take a postdoctoral position out of graduate school. This difference is explained in part by the relatively strong proclivity of the foreign-born to obtain degrees in S&E fields, in many of which postdocs predominate as a post-PhD job choice, particularly in the life sciences, where over 80% of PhD recipients initially take a postdoc position. Additionally, part of the attraction of postdocs to foreign-born students may be that they can extend student visas into short-term work visas with relative ease. Indeed, Stephan and Ma (2005) find that the higher likelihood of taking a postdoc holds only for foreign-born students on temporary visas and does not apply to those who are already permanent residents or citizens. We address the importance of postdocs in the location choice of PhD recipients by including controls for the field of study and, in later specifications, federal research expenditure by field, which is a key source of funding for hiring postdocs.

C. Location Intentions and Individual Characteristics: A First Look at Selectivity

Table 1 shows the fraction of S&E PhD recipients intending to stay in the United States broken down by individual characteristics. We have three characteristics that may be correlated with the academic ability of the PhD recipient: his/her success in obtaining graduate fellowships or scholarships, the quality of his/her university and of the academic department awarding his/her PhD degree, and the education level of his/her parents. The first two characteristics are measured at the time the student begins graduate school (when most graduate funding decisions are made).[11] The third is an indication of the student's family background (an interpretation that depends on conditioning on average education in the birth coun-

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[11] Over the sample period, the primary sources of financial support for students are university research assistantships or teaching assistantships (52%), US fellowships or scholarships (11% of students), foreign fellowships or scholarships (4%), family support or own funds (11%), and other or unnamed sources of support (19%).

Table 1
Intent to Stay in the United States by Selected Characteristics of Foreign-Born Science and Engineering PhD Recipients, by Income Level of Home Country

	Low Income	Middle Income	High Income	Total
College in United States:				
No	.874	.598	.554	.710
Yes	.853	.697	.724	.744
RAship, TAship:				
No	.782	.478	.491	.582
Yes	.924	.732	.674	.818
Fellowship, scholarship:				
No	.871	.602	.567	.709
Yes	.892	.635	.631	.744
Fulbright:				
No	.873	.605	.574	.712
Yes	.769	.478	.571	.580
Ford, Mellon, Rockefeller, Wilson:				
No	.873	.605	.574	.712
Yes	.576	.135		.338
Foreign financial support:				
No	.880	.639	.595	.737
Yes	.283	.245	.238	.247
Top 40 university:				
No	.875	.587	.563	.717
Yes	.871	.625	.580	.707
Top 10 department:				
No	.871	.598	.565	.710
Yes	.902	.663	.612	.725
Father has BA degree:				
No	.836	.560	.551	.664
Yes	.910	.665	.607	.769
Mother has BA degree:				
No	.851	.581	.560	.684
Yes	.926	.687	.619	.793

try, which we do in the regression analysis by controlling for average education in the birth cohort of the student's parents).

Table 1 shows that individuals with fellowships, scholarships, RAships, or TAships are more likely to intend to stay in the United States. We interpret the positive correlation between university financial support and intent to stay in the United States as an indicator of positive selection. S&E PhD recipients who had foreign fellowships or scholarships are more likely to return home. The same is true of students with fellowships from the Fulbright Program, the Ford Foundation, the Mellon Foundation, the Rockefeller Foundation, or the Wilson Foundation.[12] Either through explicit

[12] While there may be considerable heterogeneity among the criteria used by these funding sources, we found no significant differences among them in terms of stay rates and hence include them as a single group.

application requirements or implicit selection of candidates, these institutions tend to support foreign students who plan return to the home country after completing their PhD. Regarding department quality, table 1 shows that individuals graduating from higher-ranked departments are modestly more likely to desire to stay in the United States.

A large literature documents intergenerational persistence in schooling, earnings, and other economic outcomes (e.g., Solon 1999; Black and Devereux 2010). Intergenerational persistence in schooling may reflect better-educated parents raising their children to value education, passing along genes that are associated with academic success, or being better able to provide financially for the higher education of their children. S&E PhD recipients whose mother or father has a BA degree are more likely to intend to stay in the United States. These correlations provide further evidence consistent with positive selection of stayers.[13]

D. Location Intentions and Economic Conditions

Table 2 provides a look at the relationship between intent-to-stay rates, the income level of the S&E PhD recipient's home country, and the state of the business cycle both at home and in the United States. We again divide countries according to low-, middle-, or high-income status. For each country in the SED, we classified each year in our sample period as falling into a period of low, medium, or high growth. Economic growth is defined in terms of GDP growth over the 3 years prior to graduation, which we term lagged GDP growth. Within each country, we then standardized lagged GDP growth by the within-country standard deviation of lagged GDP growth. This was done to deal with the substantial heterogeneity across countries in GDP growth volatility. Finally, we classify all years into low-, medium-, or high-growth periods, depending on whether the standardized growth rate is below the 25th percentile of the standardized growth distribution, between the 25th and 75th percentiles, or above the 75th percentile. To account for the state of the US business cycle, we simply classify years according to quartiles of the lagged US GDP growth rate distribution.[14] Table 2 reports stay rates for low-and high-growth periods; stay rates during medium-growth periods generally fell between the two.

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[13] Parents' education captures only some of the sources of ability differences between PhD recipients. Yet it may capture differences that matter. Studies show a positive link between a worker's earnings and the schooling of his/her parents, even after holding other worker characteristics constant (Lam and Schoeni 1993; Dearden 1999).

[14] In work not reported here, we experimented with these definitions. We defined lagged GDP growth in terms of a 5-year average; we used unstandardized growth rates to define high and low growth, and we defined high and low growth in terms of peaks and troughs of the business cycle rather than in terms of the distribution of lagged GDP growth. These alternatives generated results similar to those reported both in table 2 and in the regressions below.

Table 2
Stay Rates for Foreign-Born US Science and Engineering PhD Recipients by Home Country Income Level and Level of Economic Growth in the Home Country and the United States

Income Level of Home Country	Home Country Economic Growth		US Economic Growth	
	Low	High	Low	High
Low	.816	.853	.848	.887
Medium	.647	.613	.552	.648
High	.604	.609	.558	.600

NOTE.—Economic growth is defined in terms of quartiles of standardized rates of GDP growth, where standardization is carried out within each country. Low growth pertains to the first quartile; high growth pertains to the fourth quartile.

Looking down the columns of table 2 expands on the lesson from figure 2: the stay rate for low-income countries not only exceeds the stay rate for middle- and high-income counties but does so largely independent of the state of economic growth either in the home country or the United States. Comparing the first and second columns, we see that stay rates tend to be higher when home country growth is higher. The exception is middle-income countries, but for the most part, this is the opposite relationship from what we would expect. The expected relationship shows up quite strongly when we compare the third and fourth columns. This shows that, regardless of income level, S&E PhD graduates are more likely to stay in the United States when US GDP growth is high. The relationship is particularly strong for PhD recipients from middle-income countries, who are almost 15% (e.g., 8.5 percentage points) more likely to stay in the United States during periods of strong economic growth than during periods of weak economic growth.

III. Results

In the empirical analysis, we estimate a linear probability model of the intent to stay in the United States for S&E PhD recipients who were born outside of the United States, who attended high school outside the United States, and who are not US legal permanent residents.[15] We limit attention to graduates who received their PhDs after 1984, by which time the post-Mao relaxation of emigration controls in China began to result in significant numbers of Chinese students completing PhDs in the United States. We pool observations across time and include as regressors a dummy for whether the student received a BA from a US college, the student's academic

[15] In an earlier version of the paper, we reported results for samples that included foreign-born PhD recipients who had green cards and/or who had attended high school in the United States. Unsurprisingly, those with stronger US connections are more likely to intend to stay in the United States.

potential (whether father has a BA, whether mother has a BA, whether student received graduate fellowships or scholarships), the quality of the student's graduate degree program (whether university was ranked in 2003 among the top 40 US universities, whether PhD program was ranked in 1995 by the National Research Council among the top 10 US programs in the field), recent economic conditions (average growth in log per capita GDP in the United States and in the birth country over the previous 3-year period, average log per capita GDP in the birth country over the previous 4-year period), political conditions in the birth country (average Polity IV score in the previous 3-year period), demographic controls for the student (gender, marital status, quadratic in current age, quadratic in age at completion of BA degree), average education of the parents' birth cohort for the student (fraction of adults in the student's birth country approximately 25 years older than the student completing primary, secondary, or tertiary education), a time trend, dummies for the PhD degree field, and dummies for the birth country. To save space, we do not report the coefficients for whether the mother had a BA (which was never significant), the demographic controls, average education of the parents' birth cohort, the time trend, or the birth country dummies. Standard errors are clustered by country of birth.

A. Intent to Stay in the United States

Table 3 presents the baseline regression results. The first column includes the full sample spanning the period 1985–2007; the second column restricts the sample period to the years 1985–2002, for which NSF funding data are available. The third column restores the full sample period but limits the sample to the top four source countries (China, India, Korea, and Taiwan). The fourth column, which we discuss later, limits the sample to PhD fields that send a relatively high fraction of graduates to work in the private sector (rather than to academics or to government). We focus our discussion for now on results in column 1.

We see that intent to stay in the United States is positively associated with having a BA from a US institution. It is also more likely for a graduate whose father has a BA. Because we control for average education in the parents' birth cohort, the effect of the father's educational attainment is relative to the average in the student's origin country. Having a father who has completed college is associated with a 2.2 percentage point higher desired stay rate. Those intending to stay are thus positively selected in terms of parental education.

Additional measures of individual potential include the student's success in obtaining graduate fellowships or scholarships. Intent to stay is more likely among students whose primary funding for their doctoral education was a university research assistantship, a university teaching assistantship,

Table 3
Regression Results

	High School outside United States (1)	High School outside United States (2)	Top Four Countries (3)	Private Sector PhD Fields (4)
Sample period	1985–2007	1985–2002	1985–2007	1985–2007
Obtained BA in				
United States	.056**	.049**	−.014	.043**
	(.014)	(.014)	(.010)	(.015)
Father has BA	.022**	.025**	.019**	.017*
	(.006)	(.007)	(.003)	(.007)
RAship/TAship	.098**	.091**	.077**	.099**
	(.019)	(.018)	(.004)	(.026)
Fellowship/scholarship	.053**	.042**	.066**	.044*
	(.014)	(.013)	(.005)	(.022)
Fulbright	−.076	−.066	−.034	−.021
	(.046)	(.046)	(.092)	(.118)
Ford/Rockefeller/				
Mellon/Wilson	−.243**	−.221**	−.288**	−.268*
	(.062)	(.057)	(.072)	(.134)
Foreign scholarship	−.215**	−.216**	−.283**	−.242**
	(.033)	(.034)	(.012)	(.039)
Top 40 university	−.001	.004	.004	.013
	(.007)	(.008)	(.003)	(.010)
Top 10 PhD program	.017**	.016*	.015**	.020*
	(.006)	(.007)	(.005)	(.008)
Ranked PhD program	.002	.006	.005	.003
	(.004)	(.005)	(.003)	(.004)
Ranked BA institution	.003	.013*	.014**	−.001
	(.005)	(.006)	(.004)	(.008)
Lagged GDP growth,				
United States	3.170**	3.542**	2.917**	4.055**
	(.710)	(.766)	(.122)	(.879)
Lagged GDP growth,				
birth country	−.510**	−.543**	−.734**	−.564**
	(.192)	(.197)	(.059)	(.209)
Lagged GDP per				
capita, birth country	−.138**	−.145**	−.178**	−.131**
	(.023)	(.039)	(.011)	(.023)
Lagged Polity IV,				
birth country	−.007**	−.008**	−.015**	−.007*
	(.002)	(.002)	(.001)	(.003)
NSF funding,				
broad field		.103**		
		(.039)		
R^2	.26	.27	.21	.28
N	126,951	87,637	78,867	48,458

NOTE.—Dependent variable = 1 if intends to stay, 0 otherwise. In addition to the variables shown, all regressions included a dummy for whether the mother had a BA, a sex dummy, a marital status dummy, age, age squared, age at BA, age at BA squared, a time trend, the share of the parents' age cohort with primary, secondary, and tertiary schooling, and dummies for the PhD field. Standard errors, clustered by birth country, are in parentheses.

* $p < .05$.
** $p < .01$.

a university fellowship, or a scholarship. Having a RAship or TAship is associated with a 9.8 percentage point higher stay rate, and having a fellowship or scholarship is associated with a 5.3 percentage point higher stay rate. The primary funding alternative to fellowships or scholarships is own funding or family support. Students who succeed in obtaining financial support from the university or other US sources are thus more likely to intend to stay in the United States than students on restricted funding or family funding.

Intent to stay is less likely among students receiving their primary financial support from private foundations, a foreign government, or other foreign institution. Students with foreign funding are 21.5 percentage points less likely to desire to stay in the United States, and students with restrictive support from a US private donor (Ford, Mellon, Rockefeller, or Wilson) are 24.3 percentage points less likely to intend to stay.

A further indication of student ability may be the quality of the student's university and PhD program. However, we find that students from top 40 universities are no more or less likely to stay in the United States than other students. Students from higher-ranked PhD programs are more likely to desire to stay in the United States, though the correlation is not always precisely estimated.[16] Students graduating from programs ranked in the top 10 in their field (in terms of faculty quality) are 1.7 percentage points more likely to intend to stay in the United States. There is a weak positive correlation between intent to stay and the quality of a student's undergraduate college, although this effect is precisely estimated in only one regression.

The imprecision of the results for department and university rankings may be due in part to measurement error. We lack measures of program or university quality that vary by year. For PhD programs, we use National Research Council rankings from 1995 (and obtain similar results for NRC rankings from 2005); for overall university rankings, we use the Academic Rankings of World Universities from 2003. This means we miss any changes in the quality of academic departments and universities over time, which may be especially important for disciplines that are relatively young (e.g., neuroscience, computer engineering). Our results thus may understate the association between program quality and intent to stay.

The remainder of the table reports the effects of economic and political conditions on stay rates. The estimates show that intent to stay in the United States is weaker when per capita GDP growth in the birth country is higher and that it is stronger when per capita GDP growth in the United States

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[16] In unreported results, we experimented with other measures of university ranking, using flexible specifications that included dummies for being in the top 5, top 10, top 20, etc. In no case did we find that university ranking is significantly correlated with intent to stay. After controlling for the quality of the PhD program, there is essentially zero correlation between the intent to stay and the overall ranking of a student's PhD-granting university.

is higher. Thus, business cycle conditions affect PhD recipient location choices, with students favoring the country with the stronger recent growth record.[17]

Our findings echo Oyer's (2008) results for MBA graduates. He shows that the state of the stock market just prior to entering the labor market has enduring effects on the sector in which business graduates work. We find effects of business cycle conditions on the initial country in which a PhD graduate intends to reside. Because of persistence in location choices, the choice of initial country after the degree is likely to matter for a student's long-run location. Finn (2010) finds that the fraction of those working in the United States 5 years past the PhD (65%) is only 6 percentage points lower than the fraction working in the United States 1 year past the PhD (71%). Business cycles may have lasting as well as short-term effects on the stock of PhDs.

Although both US and home country economic conditions have significant effects, stay rates are more sensitive to business cycle fluctuations in the United States than at home. Based on the results in column 2 of table 3, a one standard deviation increase in the lagged US GDP growth rate (1.2%) is associated with a 3.8 percentage point increase in the intent to stay; a one standard deviation increase in the (within-country) birth country GDP growth rate (4.3%) is associated with a 2.2 percentage point decrease in the intended stay rate. A US economic boom combined with a birth country economic bust could therefore produce a sizable increase in US stay rates. Such an event occurred in the late 1990s for Korea, as the Asian financial crisis produced a sharp contraction in the country's GDP while the US economy grew robustly as part of that decade's technology boom. In Section IV, we graphically depict the importance of business cycle swings for observed variation in stay rates for the four major source countries for PhD students in the United States (China, India, Korea, and Taiwan).

The next row in the table shows a negative correlation between intent to stay and the recent average level of per capita GDP in the birth country.[18] Because the regressions include controls for birth country fixed effects, this indicates that intent to stay weakens as a country develops. Graduates are more disposed to stay in the United States earlier in the birth country's development process and more disposed to leave the United States later in the development process. A two standard deviation increase in per capita GDP (110 log points), which is comparable to the increase in Taiwan's av-

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[17] In the regressions in table 3, we use growth rates averaged over the 3 years prior to a student's degree completion (i.e., for 2000 we use growth rates averaged over 1996–97, 1997–98, and 1998–99); results are similar if we use growth rates averaged over the previous 5 years.

[18] With a time trend in the regression, we cannot separately identify the impact of the level of US per capita GDP (as over the sample period US average income is nearly perfectly predicted by the trend).

erage income from 1980 to 2000, is associated with a 15 percentage point decrease in the intended stay rate. One explanation for this finding is that developed countries have relatively strong demand for R&D labor (Kortum 1997), making the desire to return home increasing in average income. This pattern is suggestive of a feedback mechanism, in which the number of S&E PhDs locating in a country positively affects its rate of economic growth, thereby increasing the attractiveness of the country to PhDs in the future, which may have further beneficial effects on growth. Such mechanisms are prominent in theories of economic growth that attempt to explain why countries transition from low-growth to high-growth states (e.g., Azariadis and Drazen 1990; Ciccone and Matsuyama 1996; Durlauf and Quah 1999).

Finally, we find that there is a negative association between democracy in the birth country and the desire to stay in the United States. Marshall and Jaggers (2002) measure the authoritarian tendencies of a regime on a 20-point scale, with −10 being perfect dictatorship and +10 being perfect democracy. In 2000, Qatar and Saudi Arabia have Polity IV scores of −10, Liberia and Sierra Leone have scores of 0, and Australia, Canada, New Zealand, and most of Western Europe have scores of 10. The coefficient estimates in column 1 indicate that a two standard deviation increase in the Polity IV score (6.6) in the 3 years prior to graduation would be associated with a 4.6 percentage point decrease in the intent to stay in the United States.[19] Democratic openings thus appear to induce recently minted PhDs to return to their countries of origin. While existing research documents the impact of political upheaval on foreign student flows (e.g., Stuen, Mobarak, and Maskus 2010), we are not aware of research on the impacts of democratic transitions on return migration.

Column 2 of table 3 reports estimates from a regression that include annual NSF funding by field, which is only available through 2002 (National Science Foundation 2004). Higher NSF funding is positively correlated with the intent to stay in the United States; a one standard deviation increase in NSF funding (0.78) is associated with a 7.8 percentage point increase in recent S&E PhDs' intention to stay. At the same time, adding NSF funding to the model has little effect on the other regression coefficients. For this reason, we employ data from the full sample period for the remainder of the estimates in tables 3–5.

Column 3 restricts the sample to the four largest sending countries, China, India, Korea, and Taiwan, which together account for 62% of foreign-born US S&E PhDs over the period 1985–2007. Many of the

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[19] For comparison, Korea experienced an 11 point change in its Polity IV score during the democratization process that occurred in the country between 1986 and 1989.

coefficients are similar to those obtained from the full sample. The exceptions mostly involve political and economic conditions. Students from the top four sending countries are slightly less sensitive to US economic growth, slightly more sensitive to home country economic growth, and more sensitive to the home country political situation than their counterparts from other countries.

B. Variation across Academic Disciplines within and outside of S&E

So far, we have pooled data across S&E fields. We have also ignored disciplines outside of science and engineering. In table 4, we estimate regressions similar to those in column 1 of table 3 separately for seven disciplinary categories. Three are S&E fields, including physical sciences (atmospheric, earth, and ocean sciences; chemistry; mathematics and computer science; astronomy and physics), life sciences (agricultural science, biological sciences, health sciences), and engineering, and four are non-S&E fields, including economics (finance, accounting, marketing, management strategy, organizational behavior), social sciences (except economics), humanities (including communications and law), and education.

The results in table 4 are roughly similar across the three S&E fields. Among non-S&E fields, the estimates for economics and social sciences most closely resemble those for science and engineering. Differences between fields emerge when we examine correlates of academic potential. In the S&E fields, as well as economics and social science, the father's education coefficient is positive and significant. In humanities and education, it is small and imprecisely estimated. Coefficient estimates in all fields are similar for having a RAship/TAship, but not for having a fellowship or scholarship. The positive selection that we observe among foreign S&E graduates is weaker for graduates in social science, humanities, and education.

We also see some differences across fields in students' responsiveness to economic conditions. For the S&E fields, economics, and social science, US GDP growth, home country GDP growth, and the level of home country GDP all have significant effects in the expected direction. In humanities and education, by contrast, those coefficients tend to be substantially smaller and several are insignificant.

It is intriguing in table 4 that the two fields with the largest coefficients on lagged US GDP growth—engineering and economics—are ones with relatively strong ties to the private sector. Does the degree of integration between a PhD field and the private sector job market matter for the impact of business cycle conditions on graduate location intentions? In column 4 of table 3 we investigate this issue. To categorize the private-sector orientation of PhD fields, we examine the fraction of US-born PhD graduates who plan to take private sector jobs (defined as jobs in a for-profit industry or

Table 4
Regression Results by Field of PhD

Variable	Physical Science	Life Science	Engineering	Economics	Social Science	Humanities	Education
Obtained BA in United States	.044**	.059**	.053**	.108**	.120**	.125**	.078**
	(.013)	(.018)	(.017)	(.019)	(.024)	(.018)	(.025)
Father has BA	.016*	.028**	.017**	.020*	.017*	−.003	.008
	(.007)	(.006)	(.006)	(.009)	(.007)	(.009)	(.009)
RAship/TAship	.083**	.130**	.128**	.112**	.114**	.145**	.162**
	(.015)	(.020)	(.018)	(.016)	(.015)	(.017)	(.019)
Fellowship/scholarship	.051**	.090**	.076**	.071**	−.009	.008	−.044
	(.012)	(.017)	(.017)	(.013)	(.014)	(.016)	(.027)
Fulbright	−.197*	−.020	−.045	−.487**	−.389**	.226	−.074
	(.084)	(.132)	(.093)	(.160)	(.049)	(.197)	(.164)
Ford/Rockefeller/Mellon/Wilson	−.298**	−.215**	−.557**	−.346**	−.089	−.117	−.204**
	(.023)	(.080)	(.126)	(.060)	(.049)	(.122)	(.045)
Foreign scholarship	−.170**	−.159**	−.227**	−.118**	−.142**	−.120**	−.094**
	(.032)	(.023)	(.039)	(.019)	(.025)	(.022)	(.032)
Top 40 university	−.002	−.017**	.004	−.026*	−.015	.015	−.014
	(.007)	(.006)	(.008)	(.010)	(.010)	(.010)	(.009)

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Top 10 PhD program	.017*	−.002	.012	.083**	−.018	.055**	
	(.006)	(.013)	(.009)	(.015)	(.014)	(.015)	
Ranked PhD program	.005	.061**	.004	−.074**	.013	−.015	
	(.005)	(.015)	(.006)	(.022)	(.010)	(.018)	
Ranked BA institution	.006	.004	.000	−.025*	−.016	−.004	−.037
	(.013)	(.009)	(.013)	(.010)	(.019)	(.017)	(.019)
Lagged GDP growth, United States	1.473**	1.080**	2.412**	1.744**	2.073**	.971*	.544
	(.318)	(.303)	(.400)	(.439)	(.315)	(.371)	(.303)
Lagged GDP growth, birth country	−.327**	−.270	−.634**	−.380*	−.492*	−.408	−.337*
	(.124)	(.146)	(.174)	(.192)	(.242)	(.217)	(.146)
Lagged GDP per capita, birth country	−.120**	−.162**	−.127*	−.179**	−.109*	−.049	−.136
	(.037)	(.030)	(.049)	(.047)	(.048)	(.040)	(.077)
Lagged Polity IV, birth country	−.008*	−.003	−.008*	−.008*	−.007*	−.007**	−.009*
	(.003)	(.002)	(.003)	(.003)	(.003)	(.003)	(.005)
R^2	.19	.34	.25	.20	.17	.17	.19
N	51,256	40,791	62,748	19,613	15,492	13,895	11,050

Note.—Dependent variable = 1 if intends to stay, 0 otherwise. In addition to the variables shown, all regressions included a dummy for whether the mother had a BA, a sex dummy, a marital status dummy, age, age squared, age at BA, age at BA squared, a time trend, the share of the parents' age cohort with primary, secondary, and tertiary schooling. Sample is high school outside the United States. Sample years are 1985–2002. Standard errors, clustered by birth country, are in parentheses.
* $p < .05$.
** $p < .01$.

business) upon graduation. We choose US-born graduates for the classification in order to avoid having the language, culture, or visa issues that may affect immigrant job search play a role in defining the private-sector orientation of a PhD field.

Across all fields since 1984, 9.3% of US-born PhDs plan to work in a for-profit business upon graduation. The shares are highest in engineering (50.5% in plastics engineering, 44.6% in ceramics sciences engineering, 41.3% in metallurgical engineering) and in parts of the physical and life sciences (polymer chemistry 42.3%, forestry science 40.0%, food science 33.8%). Overall, engineering accounts for 15 of the top 25 PhD fields in terms of private-sector orientation (there are 313 total fields). The least private sector–oriented S&E fields tend to be biological sciences that study entire organisms (evolutionary biology at 0.8%, anatomy at 1.0%, plant pathology at 1.2%, and zoology at 1.4%).

Turning back to table 3, column 4 restricts the sample to the subset of S&E graduates from column 1 who earned PhDs in the fields that have above-median shares of private-sector orientation. Comparing columns 1 and 4 of table 3, we see that the coefficient on lagged US GDP growth is almost one-third larger for private sector–oriented fields than for all fields. Results are similar when we define private sector orientation of a field to be above the mean or in the top tercile. It thus appears that foreign PhD stay rates are more sensitive to the US business cycle in fields that are more oriented toward the private sector in terms of PhD employment. Coefficients differ little across fields for birth country GDP growth or per capita GDP.

C. Robustness Checks

One concern about our regression models arises because economic conditions may not only influence S&E graduates' decisions to stay in the United States when they complete their PhD but also influence their decisions to seek graduate training here in the first place. If, in addition, economic conditions are temporally correlated, then our estimates in table 3 may reflect not only how economic circumstances influence S&E PhD recipients' completion-year intentions to stay in the United States but also part of their rationale for first entering the United States. To deal with this issue, we return to our main sample of S&E PhD recipients, expanding the model in column 1 of table 3 by adding measures of US and home country economic conditions at the time the student began PhD study. Under the concerns described above, this should reduce in absolute value the estimated effects of completion-year economic conditions.

Expanding the model this way requires us to limit the sample period to 1992–2007, since the year in which the student began PhD study does not appear in the SED before 1992. The regression in column 1 of table 5 reestimates the model reported in column 1 of table 3 over this shorter pe-

Table 5
Regression Results with Additional Business Cycle and Political Controls

Variable	(1)	(2)	(3)	(4)
Lagged GDP growth, United States	2.041**		2.043**	2.059**
	(.365)		(.322)	(.351)
Lagged GDP growth, birth country	−.743**		−.835**	−.739**
	(.189)		(.183)	(.188)
Lagged GDP per capita, birth country	−.152**		−.111	−.155**
	(.038)		(.064)	(.037)
Lagged polity IV, birth country	.005*		.005*	.005*
	(.002)		(.002)	(.002)
Lagged GDP growth, United States				
(year of PhD entry)		−.705	.018	
		(.415)	(.178)	
Lagged GDP growth, birth country				
(year of PhD entry)		−.227	−.248**	
		(.128)	(.088)	
Lagged GDP per capita, birth country				
(year of PhD entry)		−.074**	−.042	
		(.026)	(.042)	
Lagged Polity IV, birth country				
(year of PhD entry)		.007*	−.000	
		(.003)	(.003)	
Time to completion				.010**
				(.003)

NOTE.—For all columns, $N = 88,859$, $R^2 = .27$. Dependent variable $=1$ if intends to stay, 0 otherwise. In addition to the variables shown, all regressions included all variables shown in table 3, plus a dummy for whether the mother had a BA, a sex dummy, a marital status dummy, age, age squared, age at BA, age at BA squared, a time trend, the share of the parents' age cohort with primary, secondary, and tertiary schooling, and dummies for the PhD field. Sample is high school outside the United States. Sample years are 1992–2007. Standard errors, clustered by birth country, are in parentheses.
* $p < .05$.
** $p < .01$.

riod. The regressors in the two models are identical, though in table 5 we report only the coefficients involving economic and political conditions in order to save space.

The coefficients differ somewhat between the full and the short sample periods. The coefficient on US GDP growth is smaller in table 5 than in table 3, although the coefficient on home country GDP growth is larger in the shorter sample than in the full sample. The coefficients on the level of home country GDP are similar in the two sample periods. The biggest change involves the Polity IV coefficient, which changes sign from negative to positive.[20]

[20] In unreported results, we explored whether the switch in sign was a function of the different types of regime changes that took place during the 1980s versus the 1990s. In the 1980s, regime change was concentrated in Latin America and East Asia, where governments tended to change from authoritarian regimes under military control to democratically elected civilian regimes. In the 1990s, in contrast,

In column 2 of table 5, we replace the completion-year measures with their entry-year counterparts. These are measured as 3-year lags of economic and political conditions, but they are dated from the year the student began the PhD rather than the year he or she completed it. US GDP growth now has the wrong sign, and both it and home country GDP growth have insignificant coefficients. Only the level of home country GDP is significant, and its coefficient is about half the magnitude of its completion-year counterpart in column 1.[21]

Both sets of variables are included in the model reported in column 3 of table 5. The coefficients on the completion year variables are generally similar to those reported in column 1. The main change is that the coefficient on home country per capita GDP is no longer significant. Of the four variables reflecting entry-year economic and political conditions, only one is significant. We conclude that the completion-year measures are not merely picking up the effects of entry-year conditions on students' decisions to begin US graduate study.

It is possible that including economic conditions at time of PhD entry does not entirely purge the estimation of correlation between intent to stay and choices over when to start and when to complete the PhD. As a further robustness check, we add time to PhD completion (the difference between reported year of entry for PhD study and year of PhD degree) as a regressor, recognizing obvious concerns over the potential endogeneity of this variable to unobserved factors related to the intent to stay in the United States. Time to complete the PhD appears in column 4 of table 5. While it is statistically significant—and positive, thus indicating that those taking longer to complete their PhDs are more likely to intend to stay in the United States—the inclusion of the variable has virtually no impact on our other coefficient estimates (either those reported in table 5 or the other regressors that are unreported). We therefore conclude that while the timing of PhD completion may be a worthy issue in its own right, its interaction with the decision of whether to stay in the United States does not appear to affect inference on the economic variables of interest.[22]

A related concern is that our estimates of completion-year GDP growth or per capita GDP may not reflect the true impact of these variables but

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regime change was concentrated in Eastern and Central Europe, which were undergoing the transition from communism to more open societies. We included an interaction between the Polity IV variable and a dummy for whether the country was communist at any time after 1950. The interaction was insignificant, suggesting that the above explanation does not apply.

[21] Taken together, entry-year economic conditions in col. 2 are jointly statistically significant (with an F-statistic of 5.33). In col. 3, they are also jointly significant (F-statistic of 4.99).

[22] In unreported regressions, we performed a further robustness check in which we included economic conditions in the estimation based not on the actual year of PhD completion but based on the projected year of PhD completion (where we

rather the impact of some omitted variable that is correlated with these regressors. In unreported results, we examined the robustness of our results to the inclusion of additional variables that capture economic conditions in the birth country. To see if stay rates were a function of specific aspects of economic development rather than simply average income, we included measures of economic openness (exports plus imports over GDP, inward foreign direct investment over GDP), technological sophistication (cellphone subscriptions per capita), or industrial sophistication (share of manufacturing in GDP). In each case, we defined these variables as the average over lagged values in the previous three periods. Adding these variables had no impact on the coefficient estimates for birth country GDP growth or per capita GDP. Furthermore, none of these variables, except for the manufacturing share of GDP, was precisely estimated.

Another possibility is that results are being driven by strengthening economic linkages between the United States and the birth country, which may contribute to economic development or expand job prospects abroad for US-trained PhDs. Over the sample period, there is a dramatic expansion in foreign activities by US multinationals, with employment in the foreign affiliates of US parent firms increasing by 68% between 1983 and 2007. We included measures of the presence of US multinational enterprises in the birth country (defined to be the level or change in employment in foreign affiliates owned by US multinationals in the 3 years previous to a student's graduation). These variables are neither economically nor statistically significant.

As further robustness checks, we controlled for nonlinear time trends, replaced our measure of GDP growth with H-P filtered GDP growth, included lagged sector-specific GDP growth in the United States (for agriculture, construction, government, manufacturing, retail and wholesale trade, and services), included lagged Gini coefficients for the birth country, and allowed for interactions between our ability measures (father's education, having an RAship or TAship) and business cycle conditions in the United States or the birth country. The additional variables were generally insignificant and did not materially change the main results reported in table 3.

IV. Economic Conditions and Location Intentions for PhD Graduates from China, India, Korea, and Taiwan

To consider the importance of economic conditions for PhD recipients' intentions to stay in the United States, we provide a graphical depiction in this section of the link between lagged GDP growth and S&E PhD recipients' stay rates. For reasons of space we restrict attention to the four

predicted year of PhD completion based on economic conditions at entry into PhD training and other controls included in table 3). This exercise yielded results substantially similar to those we report in tables 3 and 4 (though with somewhat larger standard errors on the Polity IV variable).

largest sending countries: China, India, Korea, and Taiwan. For the sake of symmetry, we separately depict the link between stay rates and political conditions as well.

For each country in figure 5, we plot three lines over time: the actual stay rate, the predicted stay rate from the model in column 3 of table 3, and the simulated stay rate. The simulated stay rate is the predicted value from column 3 of table 3 in which we have replaced both lagged home country GDP growth and lagged US GDP growth with their country-specific mean values over the sample period. Comparing predicted and simulated stay rates provides a depiction of how business cycle conditions affect the share of S&E PhD recipients who remain in the United States after graduating.[23] If we first compare actual and predicted stay rates, depicted as dashed and unmarked solid lines, respectively, we see that the model captures the time-series variation in stay rates, particularly since we do not include variables used to improve a model's time-series fit, such as lagged dependent variables or high-order polynomials in time.

Now comparing predicted and simulated stay rates, we see that business cycles differ in their importance in different sending countries. In China and India, stay rates are high. In the case of China, the model overpredicts sensitivity to the business cycle. However, the decline in stay rates at the end of the sample period (when the model tracks the actual data fairly well) may represent the shape of things to come, considering China's rapid recent growth in real per capita GDP. In the case of India, figure 5 shows that almost all of the variation in the actual stay rate over time can be attributed to the business cycle.

In Korea and Taiwan, the difference between the predicted and simulated stay rates shows that the US recession of the early 1990s had a pronounced effect on location intentions, reducing stay rates among Koreans by roughly 8 percentage points (in 1993) and among Taiwanese by nearly 10 percentage points.[24] The Asian financial crisis, which began in 1997, then led to a steep rise in the share of S&E graduates seeking to stay in the United States. In the case of Korea, the country's GDP initially plunged, falling by 7% from 1997 to 1998, but then it recovered quickly with growth rates above 4% in each of the following 6 years. The pattern in Taiwan is quite similar to that in Korea, reflecting common region-wide movements in

[23] Preliminary analyses not reported here indicated that more of the business cycle effect was due to variation in US GDP growth than to variation in home country GDP growth. This is consistent with our finding above that stay rates were generally more strongly affected by US GDP growth than by home country GDP growth.

[24] Kim (2010) notes that the supply of PhDs in Korea rose sharply after about 1990. He shows that the number of Koreans earning PhDs rose around that time, but fig. 5 makes clear that part of the increase in supply also stemmed from the decline in the rate at which US-educated Korean-born PhDs remained in the United States.
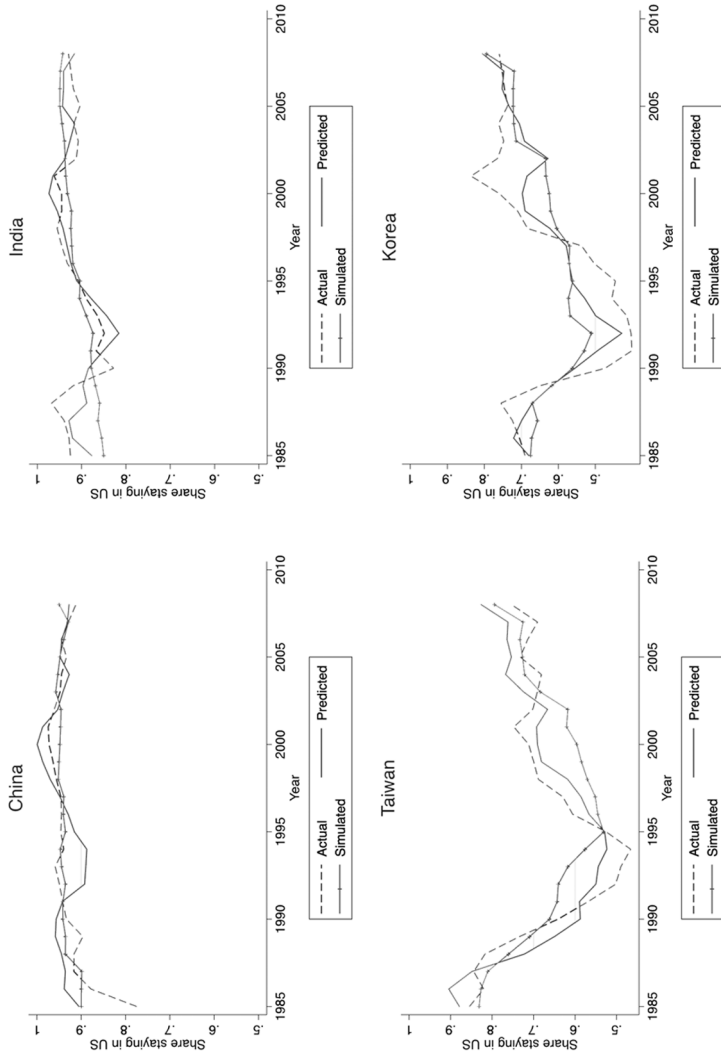
Fig. 5.—Simulated effects of business cycle on stay rates for four largest sending countries. Dashed lines: actual intent-to-stay rates are from SED; solid lines: predicted intent-to-stay rates based on regression estimates reported in table 3, column 3; lines with plotting symbols: predicted intent-to-stay rates based on regression estimates reported in table 3, column 3, but with lagged GDP and lagged GDP growth held constant at country-specific mean. All are authors' calculations.

GDP during the Asian financial crisis. The fact that simulated stay rates are flatter than predicted stay rates after the Asian financial crisis indicates that both Korea- and Taiwan-born S&E PhDs were responsive to changes in home country GDP growth.

We checked whether other measures capture the link between economic conditions and stay rates. However, after considerable experimentation, we did not find alternative measures that performed better than lagged GDP growth. With lagged GDP growth in the regression, measures of recent birth country financial, banking, or currency crises from Reinhardt and Rogoff (2008b) or "sudden stops" in capital inflows from abroad from Reinhardt and Rogoff (2008a) were statistically insignificant in nearly all cases. Lagged growth rates are the strongest and most robust economic predictors of the location choices for foreign-born PhDs.

Figure 6 depicts the role of political conditions, as captured by the Polity IV index. Each panel in figure 6 plots three lines: the actual stay rate, the predicted stay rate from the model in column 2 of table 3, and a simulated stay rate. The actual and predicted stay rates are exactly the same as those presented in figure 5. In figure 6, the simulated stay rate is the predicted value from the regression in column 2 of table 3 after replacing the actual Polity IV index by its country-specific mean over the sample period.

Since the Polity IV index was constant for China over the sample period and was nearly constant for India, political conditions had nothing to do with variation in stay rates in those countries. The same is not true for Korea or Taiwan. Korea transitioned from military rule to democracy in 1988; Taiwan's process of democratization has been more gradual, beginning with a slow shift away from authoritarian rule in the late 1980s and culminating with direct presidential elections in 1996. Korea's abrupt political opening explains a sizable share of the decline in its S&E PhDs intentions to remain in the United States during the late 1980s. Whereas Korea's simulated stay rate was 15 percentage points below the actual stay rate in 1985, by 1991 the two series coincided. Political conditions also help explain why the stay rate of Taiwanese S&E PhDs fell in the late 1980s and early 1990s.

V. Final Discussion

If innovation is the key to sustaining positive rates of long-run economic growth, highly skilled labor with training in science and engineering is the input that makes innovation and therefore growth possible. Graduates in S&E fields have relatively high propensities to produce and to commercialize patents, and the stars among these graduates have relatively high propensities to launch high-technology business ventures. Over the last half century, the United States has been the most important training ground for the global supply of science and engineering talent. Where S&E PhDs choose to locate after they have completed their education is likely to affect the global distribution of innovative capacity.
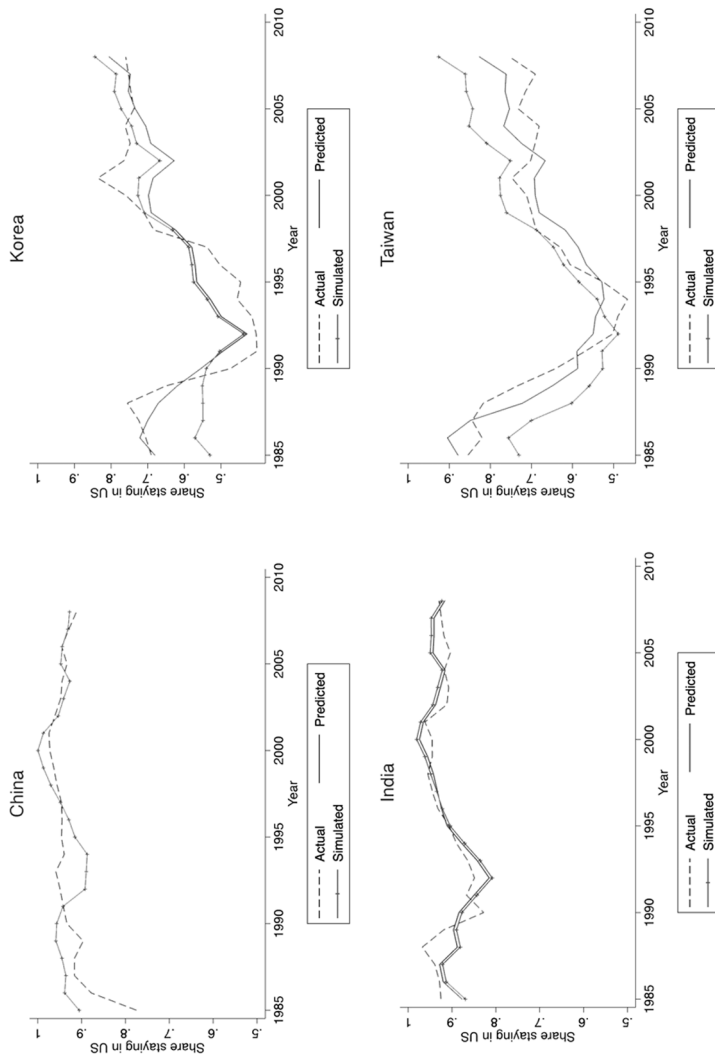
FIG. 6.—Simulated effects of political conditions on stay rates for four largest sending countries. Dashed lines: actual intent-to-stay rates are from SED; solid lines: predicted intent-to-stay rates based on regression estimates reported in table 3, column 3; lines with plotting symbols: predicted intent-to-stay rates based on regression estimates reported in table 3, column 3, but with lagged Polity IV scores held constant at country-specific mean. All are authors' calculations.

We find that S&E PhDs with the strongest academic potential, measured in terms of their attributes and performance at the time they enter graduate school, are those most intent on staying in the United States. These results are consistent with a growing body of evidence that finds positive selection in emigration from low-income countries (e.g., Grogger and Hanson 2011). The United States tends to succeed in luring the best and brightest foreign students it has attracted to study in the country to stay in the United States after their degrees are completed. We know less about the long-run location choices of these individuals in terms of how many end up remaining in the United States as permanent residents or becoming citizens. However, if productivity is high early in researchers' careers (Lehman 1953; Simonton 1991), even short-term location intentions may have important economic consequences.

Economic conditions are among the most important factors shaping the location intentions of recent PhD recipients in S&E fields. A stronger US economy makes it more likely that graduates will intend to stay in the United States. A weaker economy in the graduate's home country has the same effect. The responsiveness of PhD location intentions to business cycle conditions may create a link between the volatility of output and cycles in long-run economic growth. More short-run volatility appears to produce greater fluctuations in the supply of highly skilled labor, possibly contributing to variation in long-run growth rates.

Business cycle considerations aside, we do see that as countries develop they become more attractive locations for PhDs in science and engineering. There is obvious potential for a virtuous cycle in education and innovation, with returning S&E PhDs increasing innovation in the home country, thereby enhancing prospects for economic growth and raising the attractiveness of the home country as a location for future PhD recipients. Korea and Taiwan are possible examples of self-reinforcing processes. They also provide examples of the powerful role that democratization can play in encouraging highly skilled workers to return home.

Appendix

Table A1
Summary Statistics for Main Estimation Sample
(**Table 3, Column 2**)

Variable	Mean
Stay in United States	.737
Obtained BA in United States	.051
Father has BA	.503
Mother has BA	.308
RAship/TAship	.650
Fellowship/scholarship	.108
Fulbright fellowship	.001
Ford/Mellon/Rockefeller/Wilson	.001

Table A1 (Continued)

Variable	Mean
Foreign scholarship	.065
Top 40 university	.452
Top 10 PhD program	.104
Ranked PhD program	.590
Ranked BA institution	.594
Male	.792
Married	.617
Age	32.25
Age at BA	22.67
Share of parents' age cohort with tertiary education	4.89
	(4.98)
Share of parents' age cohort with secondary education	10.55
	(9.92)
Share of parents' age cohort with primary education	22.55
	(12.77)
Lagged GDP growth, United States	.026
	(.011)
Lagged GDP growth, birth country	.060
	(.038)
Lagged GDP per capita, birth country	7.772
	(1.42)
Lagged polity IV, birth country	1.991
	(7.18)
N	126,951

NOTE.—Authors' calculations based on SED, 1985–2007. For continuous variables, standard deviations are in parentheses.

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