ATTRACTING TALENT:

LOCATION CHOICES OF FOREIGN-BORN PHDS IN THE US

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October 9, 2012

We thank the International Growth Centre for financial support and Sam Bazzi, Sieuwerd Gaastra, Chen Liu, and Wei You for excellent research assistance.

Abstract

We use data from the National Science Foundation to examine the post-degree location choices of foreign-born students receiving PhDs from US universities in science and engineering. Individuals with advanced training in science and engineering are important inputs in the process of innovation. They are more likely than other college graduates or post-graduates to produce and to commercialize patents. Where they choose to live and work affects the global distribution of innovation capacity. In low-income countries, there are few opportunities to obtain advanced training in science and engineering, requiring students to pursue degrees abroad with many going to the United States. The success of these countries in luring back home students who obtain graduate degrees from US or other foreign universities determines their capacity for indigenous research and development. Over the period 1960 to 2008, 77% of foreign-born S&E PhDs state that they plan to stay in the United States.

We find that the foreign students more likely to stay in the US are those with stronger US ties, measured in terms of having a permanent residence visa or attended a US college, or stronger academic ability, measured in terms of parental educational attainment, the student's success in obtaining graduate fellowships or scholarships, and the rank of the student's university and academic department. Foreign students staying in the United States thus appear to be positively selected in terms of academic ability. We also find that foreign students are more likely to stay in the United States if in recent years the US economy has had strong GDP growth or the birth country of the foreign student has had weak GDP growth. Foreign students are less likely to remain in the US if they are from countries with higher average income levels. As a country develops, its students obtaining degrees abroad become less likely to stay in the United States and more likely to return home. Education and innovation may therefore be part of a virtuous cycle in which education enhances prospects for innovation in low-income countries and innovation makes residing in these countries more attractive for scientists and engineers.

I. Introduction

In the global competition for talent, workers trained in science and engineering are the most sought after. They are essential inputs in the production of knowledge and are eagerly recruited by companies as well as countries (Kapur and McHale, 2005). Science and engineering (S&E) graduates produce patents at much higher rates than graduates in other fields (Hunt and Gauthier-Loiselle, 2010), and top S&E scientists are relatively likely to launch high-technology companies (Zucker and Darby 2009).[1] Attracting S&E graduates thereby enhances a country's potential for economic growth (Jones, 1995a,b).

During the last half century, obtaining an advanced degree in science and engineering, especially for individuals from low-income regions, often meant studying in the United States (Freeman, 2009). In 1975, the share of science and engineering PhDs graduating from US universities was 47% of the total among students from major Asian nations and advanced European economies. This share fell to 25% in 2004, reflecting a broader internationalization of higher education and post-9/11 restrictions on student visas (Bound, Turner, and Walsh, 2009). However, the United States remains a major location for S&E training.

The population of students pursuing S&E PhDs has globalized, making it common for individuals to study in one country and to work in another. In 2007, students born outside the United States accounted for 53% of US PhDs awarded in S&E fields, up from 21% in 1960 (Figure 1). Growth in the foreign-born share of US PhDs has come entirely from low and middle-income countries (Figure 2). Many of these nations are now growing at much faster rates than the United States, making them potentially attractive locations for post-degree employment.

[1] In other related work, Hunt (2011) finds that immigrants entering the US on student or temporary works visas are much more likely to produce patents than individuals entering the country on a green card (the majority of whom would have obtained a permanent visa through having relatives in the United States).

Students from emerging economies who come to the US for advanced training often stay after completing their degrees. Finn (2010) estimates that for the 2005 cohort of US PhDs, 67% of foreign-born doctorates were working in the United States two years after graduation. The two-year "stay rate" for foreign-born PhDs rose from 54% in 1994 to 71% in 2001 and then fell modestly to 69% in 2007. For the 2005 cohort, two-year stay rates were highest for S&E graduates, especially in computer and electrical engineering (77%), computer science (75%), physical science (75%), life science (75%), and mathematics (73%).

In this paper, we examine the post-degree location choices of foreign-born students receiving PhDs from US universities. Data are from the NSF Survey of Earned Doctorates (SED), which contains information on the characteristics of all individuals receiving a PhD from a US university over the period 1958 to 2008. The SED asks individuals if they plan to stay in the United States after completing their degree. Over the sample period, 77% of foreign-born S&E PhDs state that they plan to stay in the US, which is roughly consistent with one-year stay rates reported in Finn (2010). Depending on the field, the SED figures are around 5 percentage points higher that Finn's (2010), perhaps reflecting the fact that the NSF data measure *intent to stay* whereas Finn measures actual outcomes. Some 43% of those planning to stay have made a commitment or signed a contract with an employer. We analyze both the intent to stay and the probability of having employment among those planning to stay in the US.

We examine how location choices relate to student ability and to economic conditions in the US and in the birth country. We find that the foreign students more likely to stay in the United States are those with stronger US ties and stronger academic ability. Foreign students staying in the United States therefore appear to be positively selected in terms of ability.

We also find that foreign students are more likely to stay in the United States if in recent

years the US economy has had strong GDP growth or their birth country has had weak GDP growth. Foreign students are less likely to remain in the US if they are from countries with higher average GDP levels. Because we control for birth-country fixed effects, the results indicate that for a given country its students who are being trained abroad are less likely to stay in the US the more developed the country becomes.

Our work contributes to several bodies of recent literature on international migration. One related body considers the causes of emigration (Docquier, Lohest, and Marfouk, 2007), including how average income affects bilateral migration flows (Clark, Hatton, and Williamson, 2007; Ortega and Peri, 2009; Mayda, 2010) and the impact of the structure of labor earnings on skilled migration (Rosenzweig, 2006; Belot and Hatton, 2008; Brücker and Defoort, 2009; de Grip, Fouarge and Suaermann, 2009; Grogger and Hanson, 2011). These studies suggest that emigrants are positively selected in terms of schooling and that more-educated migrants favor destination countries that reward skill more heavily. Our work shows that there is positive selection in migrant location choices even among the most highly educated individuals.

A second body of related work examines the impact of high-skilled immigration on economic outcomes in sending and receiving countries. Beine, Docquier, and Rapport (2001, 2008) find evidence of brain gain, in that greater opportunities for high-skilled emigration in low-income countries increase incentives for educational attainment sufficiently to offset the human capital lost to labor outflows. Blanchard, Bound, and Turner (2009) suggest further that flows of students to the US for PhD training may improve the quality of higher education in sending countries, further enhancing local human-capital accumulation.[2] Our work indicates that the increase in incentives for educational attainment in low-income countries may be strongest among the most able, which enhances the quality of local human capital, but also that the highly talented

[2] On the production of PhDs in the United States, see also Chiswick, Larsen, and Pieper (2010).

who do succeed in going abroad for advanced training are the least likely to return home, at least immediately following their education. In receiving countries, Hunt and Gauthier-Loiselle (2010) and Kerr and Lincoln (2011) find that US regions that attract more high-skilled immigrants produce larger numbers of S&E patents. The tendency of the most able PhDs to remain in the United States may in part explain the positive impact of high-skilled immigration on patenting, given the proclivity on these individuals for innovation. These location patterns also imply that poor countries sending students to the US for advanced S&E training may see those with the greatest innovative potential choose not to return home.

Among US universities, Stuen, Mobarak, and Maskus (2010) find that academic departments that have a larger fraction of graduate students who are foreign born produce a higher number of scientific publications and generate more citations on these publications. However, Borjas and Doran (2012) find negative effects on the academic productivity of US mathematicians from the arrival of Russian mathematicians following the collapse of the Soviet Union. In a related vein, Borjas (2009) and Lan (2011) show that larger supplies of foreign-born PhDs in cohorts defined by degree year and field (either for all PhDs in the former or for recent PhDs in the latter) are associated with lower earnings for US-born PhDs. Our findings suggest that immigration-related competition effects in the job market for US-born PhD recipients may be stronger for positions that tend to attract more able graduates.

In section 2, we describe the data used for the project and broad trends regarding the location choices of foreign PhD students educated in the United States. In section 3, we present our empirical specification and results on the intention to stay in the US (and having obtained a job for those intending to stay). In section 4, we offer concluding remarks.

II. Data and Empirical Setting

The Survey of Earned Doctorates 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 post-graduation plans (N=6,000). We further drop individuals 45 years of age or older at time of degree (N=28,000), which consists 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.

We focus the analysis on graduates in science and engineering fields, for which the link to innovative activity is strongest. Using data from the 2003 US National Survey of College Graduates, Hunter and Gauthier-Loiselle (2010) find that foreign-born scientists and engineers are substantially more likely than other college graduates or post-graduates to have produced a patent and 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 physics), and engineering. For comparison, we present some results for non-S&E fields, which include education, humanities, law, economics and management, and social sciences.

II.A. Rising Presence of the Foreign Born among US PhD Recipients

Figure 1 shows that the share of US PhDs in S&E fields going to foreign-born students rises steadily over time. In non-S&E fields, the share of PhDs going to foreign students also rises

over time, but is much lower, in most years around half of the S&E value. In Figure 2, we see that low and middle-income countries account for nearly all of the growth in the foreign-student share of S&E PhDs.[3] The share of PhDs going to students from high-income countries, other than the United States, is flat over the five-decade period, due in part perhaps to the strengthening of graduate education in Australia, Canada, Europe, and Japan (Freeman, 2009).

Among low-income countries, China and India are by far the largest sources of PhD students to US universities, as seen in Figure 3a. Over the period they account for an average of 84% of students from low-income nations completing US science or engineering PhDs.[4] Among middle-income countries, shown in Figure 3b, Korea and Taiwan are the largest source countries, accounting for an average of 42% of PhD recipients from this income group. The next largest middle-income source countries for S&E PhDs are Russia, Iran, and Turkey (not shown).

China and India are large source countries for PhD students in part because they have large populations. However, students from the two countries also exhibit relatively high propensities to purse PhD education in the United States. Figure 4a shows S&E PhDs awarded on a per capita basis. US PhDs awarded reach a peak late in the sample period of 3.0 per 10,000 population in China and 1.7 per 10,000 population in India but only 0.6 per 10,000 population in other low-income countries. Korea and especially Taiwan stand out for having high propensities to pursue US PhD training. Over the period, US S&E PhDs awarded average 13 per 10,000 population in Korea and an astounding 30 per 10,000 population in Taiwan. For comparison, the ratios are only 1.5 per 10,000 population in other middle-income countries and 2 per 10,000 population in non-US high-income countries (many students from which may pursue advanced

[3] 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. Income values are averages for the period 1985-1994. Our income classification closely mirrors that for the World Bank over the same period.

[4] In Figure 3a, the shares for China are inflated in the 1970s (and in Figure 3b the shares for Taiwan are deflated) owing to the fact that during this period some individuals born in China and who obtained US PhDs were citizens of Taiwan, having moved from mainland China to Taiwan in 1949 or shortly thereafter.

training at home or close to home). For comparison, over the sample period US S&E PhDs awarded to US-born individuals average 34.0 per 10,000 population.

II.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 5a shows that the majority of foreign-born PhD recipients intend to stay in the United States, with average affirmative responses of 87% for those from low-income countries, 67% for those from middle-income countries, and 70% for those from high-income countries.[5] These numbers are roughly consistent with Finn's (2010) finding that 67% of foreign-born PhD's (across all fields) remain in the US for at least two years.

For foreign-born students on a temporary residence visa, which is 70% of the sample, staying in the US past completion of the PhD requires that they obtain employment, such that they can transition from a student visa to an employment visa, such as the H-1B temporary visa for high-skilled workers or an employer-sponsored legal permanent residency visa (or green card).[6] The SED also asks respondents about the status of their post-graduation plans. Figure 5 shows the share of those who "have signed a contract or made a definite commitment for postdoc or other

[5] Among S&E PhD recipients born in the US, the average fraction planning to stay in the country is 96%.

[6] Another option for recent foreign-born graduates of US universities is Optional Practical Training, 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.

work" among those who intend to stay.[7] Over the sample period, the share of graduates who obtained a job at time of graduation averages 52.6% for low-income countries, 51.6% from middle-income countries, and 60.7% from high-income countries (other than the US for which the share is 65.8%). In part of our analysis, we estimate the determinants of job-finding among new foreign-born PhDs planning to stay in the US, which allows us to examine selection into employment among those intending to remain in the US.

Figure 5 shows non-monotonicity in the relationship between the desire to stay and birth-country income levels. If highly 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 US 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 income between countries, as in Grogger and Hanson (2011), one would expect the opposite. What we see in Figure 5 is an intermediate outcome, with the probability of staying in the US being lowest for individuals from middle-income countries. Results in section 3 suggest that this pattern in part reflects middle-income countries having relatively high growth rates (and the location choices of PhD recipients being sensitive to current economic conditions).

To see location choices for individual countries in more detail, Table 1 shows the fractions intending to stay in the US for low-income countries that supply at least 400 S&E PhDs over the sample period and middle-income countries that supply at least 1500 S&E PhDs over the period. Intent to stay in the US rises from the first half of the sample (1960-1984) to the second half (1985-2008) in 15 of the 18 low-income countries and 11 of the 18 middle-income countries.

To examine the characteristics of foreign-born PhD recipients who intend to stay in the

[7] Other responses to this question are: returning or continuing in pre-doctoral employment, negotiating with one or more specific organizations, seeking position but have no specific prospects, other full-time degree program, do not plan to work or study, or other.

United States, we utilize data from the SED on student background and data from the National Research Council on the rankings of university PhD programs by department (National Research Council, 1995 and 2003).[8] Table 2 shows the fraction of S&E PhD recipients intending to stay in the US by individual characteristics. Table A1 gives summary statistics on these characteristics and other variables used in the empirical analysis.

One important factor affecting student intent to stay in the US is visa status. The SED reports whether foreign-born students are naturalized US citizens, have a legal permanent residence visa, or have a temporary residence visa (e.g., a student visa). Being a citizen or having a green card guarantees that a graduate can work in the United States. There are two primary channels through which individuals obtain green cards: being sponsored by a family member who is a citizen or legal permanent resident or being sponsored by a US employer.[9] Having a green card (or already being a citizen) therefore indicates the strength of the graduate's ties to the US, either through family connections or through connections to a US employer. Obtaining a green card often takes six or more years (and becoming a citizen an additional five years), meaning that these connections must have been established well before the date at which we observe the student completing the PhD degree. In Table 2, the likelihood that a foreign-born graduate intends to stay in the US is much higher for those who are citizens or who are legal permanent residents. The likelihood is also higher for those who attended high school or completed their BA in the United States (a result that holds whether we examine all foreign-born students are just those who are not legal permanent residents).

[8] Not all PhD programs represented in the SED data are ranked by the NRC. Programs absent in the NRC include multi-disciplinary programs and programs that are specific to a few universities (e.g., cognitive science) or programs in less renowned universities. In the regression analysis, we control for whether a program is ranked. A further issue with the NRC rankings is that they are available for only two time periods, the early 1990s and the early 2000s. In the analysis, we use three alternative measures of department ranking: the earlier ranking, the later ranking, and the average of the rankings. We report results for the former measure.

[9] Smaller numbers of green cards are available to refugees, which over the sample period would apply primarily to individuals from Cuba, Cambodia, Laos, or Vietnam, and via a lottery.

We have three measures of the academic ability of the PhD recipient: her success in obtaining graduate fellowships or scholarships, the quality of her university and of the academic department awarding her PhD degree, and the education level of her parents. The first two measures indicate the ability of the student as perceived at the time she begins graduate school (when most graduate funding decisions are made). The third is an indication of the student's family background (an interpretation that depends on conditioning on average educational levels in the birth country, which we do in the regression analysis by virtue of controlling for average education in the birth cohort of the student's parents).

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%). In Table 2, individuals with fellowships, scholarships, RAships, or TAships are more likely to intend to stay in the United States. The exceptions are individuals on foreign fellowships or scholarships or fellowships from the Ford Foundation, the Fulbright Program, the Mellon Foundation, or the Rockefeller Foundation, each of which imposes restrictions that are meant to compel the graduate to return to the home country after completing the PhD. We interpret the positive correlation between university financial support and intent to stay in the US as an indication that students with higher academic ability are less likely to desire to return home after their studies.

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. 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 of positive selection of stayers in terms of actual or potential academic performance. Regarding university or department quality, Table 2 shows no difference in intent to stay in the US by overall ranking of the university or by ranking of the student's specific PhD program.

For S&E PhD recipients, part of the motivation for staying in the United States after their degree may be to obtain a post-doctoral fellowship, which in many fields serves as an apprenticeship necessary for graduates to succeed in launching independent careers. Is intending to stay in the US synonymous with seeking a postdoc? The SED includes a question about whether graduates intend to take a postdoc, but only for years 2003 and later. Among all foreign-born S&E graduates, 53% intend to take a postdoc, compared to 51% of US-born graduates. Among foreign-born S&E PhDs planning to stay in the US, 55% intend to take a postdoc and among those planning to stay in the US who have also obtained a job, 53% intend to take a postdoc. These patterns suggest that the choice to stay in the United States is not dictated by a student's desire for a postdoctoral fellowship.

The SED asks students about the sector in which they intend to seek employment, which applies to graduates who are not seeking further study or taking a postdoc, traineeship or other temporary position after their degree. Table 3 reports the desired sector of employment for foreign-born PhD recipients not intending to stay in the US and for those intending to stay. Those not intending to stay in the US are relatively more likely to choose academia or government jobs, perhaps reflecting sectors where foreign demand for PhDs is relatively strong. Those intending to stay in the US are relatively likely to select private industry.

III. Results

To begin the empirical analysis, we estimate a linear probability model of the intent to stay in the United States for recent science and engineering PhD recipients born outside the US. We pool observations across time and include as regressors measures of the student's ties to the US (whether a naturalized citizen, whether has a green card, whether received BA from a US college), the student's academic ability (whether father has a BA, whether mother has a BA, whether student received graduate fellowship or scholarship), the quality of the student's graduate degree program (whether university is ranked among the top 40 US universities, whether PhD program was ranked in 1995 by the National Research Council among the top 10 programs in the field), recent economic conditions (average growth in log per capita GDP in the US and in the birth country over the previous five-year period, average log per capita GDP in the birth country over the previous five-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. Standard errors are clustered by the country of birth of the graduate.

III.A Intent to Stay in the United States

Table 4 presents the baseline regression results. In the first column, we see that intent to stay in the US is positively associated with being a US citizen, having a green card, or having received a BA from a US university. Each of these variables is an indicator of the strength of the graduate's ties to the United States. Not surprisingly, intent to stay is more likely among those

with stronger US connections, be they family or professional, which facilitate obtaining the right to legal permanent residence.

Intent to stay is more likely for a graduate whose father has a BA but is uncorrelated with whether the mother has a BA.[10] In many poor countries, educational attainment of women lags well behind that of men, especially in earlier decades. The father's education may therefore be a stronger indicator of the student's "inherited" ability. 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.

Additional measures of individual ability 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, a university fellowship, or a scholarship. However, intent to stay is less likely among students receiving their primary financial support from a foreign government or other foreign institution or from US donors whose support tends to be conditional on students returning to their home countries after completing their degrees.[11] The primary funding alternative to fellowships or scholarships is own funding or family support. We thus see that students who succeed in obtaining financial support from the university or other US sources are more likely to intend to stay in the US than students on restricted funding or family funding. There is no correlation between intent to stay and the ranking of the university or of the graduate degree program, a perhaps surprising feature of the results. The ranking of the graduate program is subject to measurement error owing to the fact that it is not time varying, which may in part account for the weakness of program ranking in determining intent to stay.

[10] The correlation between father having a BA and mother having a BA is 0.55.
[11] The latter category includes the Fulbright Program, the Ford Foundation, the Rockefeller Foundation, and the Mellon Foundation.

Turning to economic conditions, intent to stay in the US is weaker in years following higher per capita GDP growth in the birth country and stronger in years following higher per capita GDP growth in the US. These findings suggest that recent business-cycle conditions affect PhD recipient location choices, with students favoring the country with the stronger recent growth record. There is a negative correlation between intent to stay and the recent average level of per capita GDP in the birth country. Because the regressions include controls for birth country fixed effects, this result indicates that intent to stay weakens as a country develops. Graduates are more disposed to stay in the US earlier in the birth country's development process and more disposed to leave the US later in the development process. One explanation for this finding is that developed countries are likely to have relatively strong demand for R&D labor, making desire to return home increasing in the level development. (In the aggregate, there is an obvious feedback mechanism, with the number of S&E PhDs locating in a country affecting its rate of economic growth.)

Finally, we see that men are weakly less likely to intend to stay in the US and that there is no correlation between marital status and intent to stay. Overall, the results suggest that intent to stay in the United States is stronger for PhD recipients with higher observed ability (measured at the start of their programs, when funding decisions are made), from countries with weaker recent economic growth or earlier in their development trajectory, and following periods of stronger US economic growth.

These general patterns are largely robust to various sample restrictions. A first issue is that the sample includes a mix of temporary visa holders, green card (legal permanent residence visa) holders, and naturalized US citizens. One may imagine that the responsiveness of location choices to individual characteristics or economic conditions may differ among these groups, owing to the

relative freedom of legal permanent residents to choose where to live and work. The second column of Table 4 drops US citizens from the sample and the third column further drops green-card holders, both of whom have a right to permanent residence in the United States. These restrictions have little impact on the results, as coefficient estimates are similar across the first three columns.

A second issue is that the sample spans five decades, during which there were dramatic changes in the labor markets for highly educated students in the US and abroad and in the international options for doctoral education in science and engineering. Such changes may have altered the composition of students choosing to pursue PhD training in the United States, which may in turn affect estimation results for PhD-recipient location choices. In the fourth column of Table 4, we restrict the sample to 1985 and later. The results are again similar to the first column. Finally, we restrict attention to the five countries that send the largest number of PhD students to the US: China, India, Korea, Taiwan, and Hong Kong. For the most part, the estimates from this restricted set of countries are similar to those from the full sample.

III.B Employment among those intending to stay in the US

The large majority of foreign-born PhD recipients intends to stay in the US after completing their degree. In Table 5, we report estimates of the factors that influence whether they have a position in hand before graduating. The sample for this set of regressions consists of SED respondents who indicated that they intended to stay in the US.

A handful of factors consistently influences the probability of having a job across our various subsamples. Stronger ties to the US reduce the probability of having a job, as does higher per-capita GDP in the country of origin. Higher ability, as measured by fellowship support and

attending a top-ten ranked department, raise the likelihood of having a job, as do higher US GDP growth, being male, and being married.

Interpreting these estimates is difficult, since they probably mix the circumstances facing the degree recipient with conditions on the job market. PhD recipients with strong ties to the US may feel less pressure to find employment, since they are legally able to remain in the US regardless of their employment status. Alternatively, students without US citizenship or a green card may be simply more likely to declare their intent to stay if they are able to find work before completing their degree. Higher-ability students may face greater demand for their skills than lower-ability students. Greater GDP growth in the US presumably makes positions more abundant. Employment rates for men are higher than those for women generally, and for married as compared to unmarried workers.

III.C Variation across Academic Disciplines

So far, we have pooled data across S&E fields and ignored disciplines outside of science and engineering. In Table 6, we replicate the regressions in the first column of Table 4 separately for seven disciplinary categories. Three are S&E fields, physical sciences (atmospheric, earth, and ocean sciences; chemistry; mathematics and computer science; physics), life sciences (agricultural science, biological sciences, health sciences), and engineering; and four are non-S&E fields, economics and management (finance, accounting, marketing, management strategy, organizational behavior), social sciences (except economics), humanities (including communications), and education. There is considerable evidence in the literature that skilled labor trained in in S&E fields contributes to innovation in the form of patenting. There is less evidence about the contributions to innovation of skilled individuals trained in non-S&E fields.

The results in Table 6 are similar across the three S&E fields, with most coefficient estimates in the first to third columns being close in value. Among non-S&E fields, the estimates for economics and management most closely resemble those for science and engineering. In all non-S&E fields, intent to stay in the US is positively correlated with being a naturalized citizen, having a green card, or having obtained a BA in the US. Having stronger family or professional ties to the United States affects location decisions in all PhD fields.

Differences between S&E and non-S&E fields emerge when we examine correlates of academic ability. In all non-S&E fields, the coefficient on father's education is small and imprecisely estimated. Coefficient estimates in S&E and non-S&E fields are similar for having a RAship/TAship but not for having a fellowship or scholarship. Thus, the strong evidence of positive selection in ability that we observe for intent to stay in the US among S&E graduates is weaker outside of science and engineering. When we examine the impact of economic conditions on location decisions, economics and management is the only non-S&E discipline for which US per capita GDP growth, birth-country per capita GDP growth, and birth-country average income each has a statistically significant impact on the intent to stay in the United States. In the three other non-S&E fields, the link between economic conditions and location decisions for recent PhD recipients is weaker.

II.D Robustness Checks

In addition to the estimates shown above, we have estimated a number of other models to assess the robustness of our main results. We have controlled for non-linear time trends; replaced our measure of GDP growth with H-P filtered GDP growth; included sector-specific GDP growth; included gini coefficients for the birth country; allowed interactions between our ability measures

and economic conditions; and replaced the 1995 NRC rankings with 2005 rankings. The additional variables were generally insignificant, and they never materially changed the main results reported above.

IV. 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 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.

We find that S&E graduates with the strongest academic ability, measured in terms of their attributes and performance at the time they enter graduate school, are those most likely to intend to stay in the US and to find employment in the US job market. 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 attracts the best and brightest to study at its universities and lures the best and brightest among these to stay in the US after their studies are completed. We know less about the long-run location choices of these individuals in terms of how many end up remaining in the US as permanent residents or becoming citizens.

Policies surrounding student visas also shape the post-degree location choices of PhD recipients. Students receiving support from foreign institutions, or from private foundations that

provide incentives for graduates to return to their home countries after the degree, are less likely to intend to stay in the US. This finding does not necessarily mean that restrictive scholarship funding is an effective means for low-income countries to produce a highly skilled labor force. At the application stage, such funding strategies could dissuade individuals from pursuing restrictive funding options or from seeking to study abroad at all.

Economic conditions are an additional important factor shaping the location choices of recent PhD recipients in S&E fields. A stronger US economy makes it more likely that graduates will intend to stay in the US and to find a job. A weaker economy in the graduate's home country has the same effect, as do recent external debt crises or natural disasters. The pro-cyclicality of the location choices of S&E PhDs could be a mechanism through which study abroad increases the amplitude of global business-cycle fluctuations.

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. Less is known about how such cycles begin.

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Figure 1

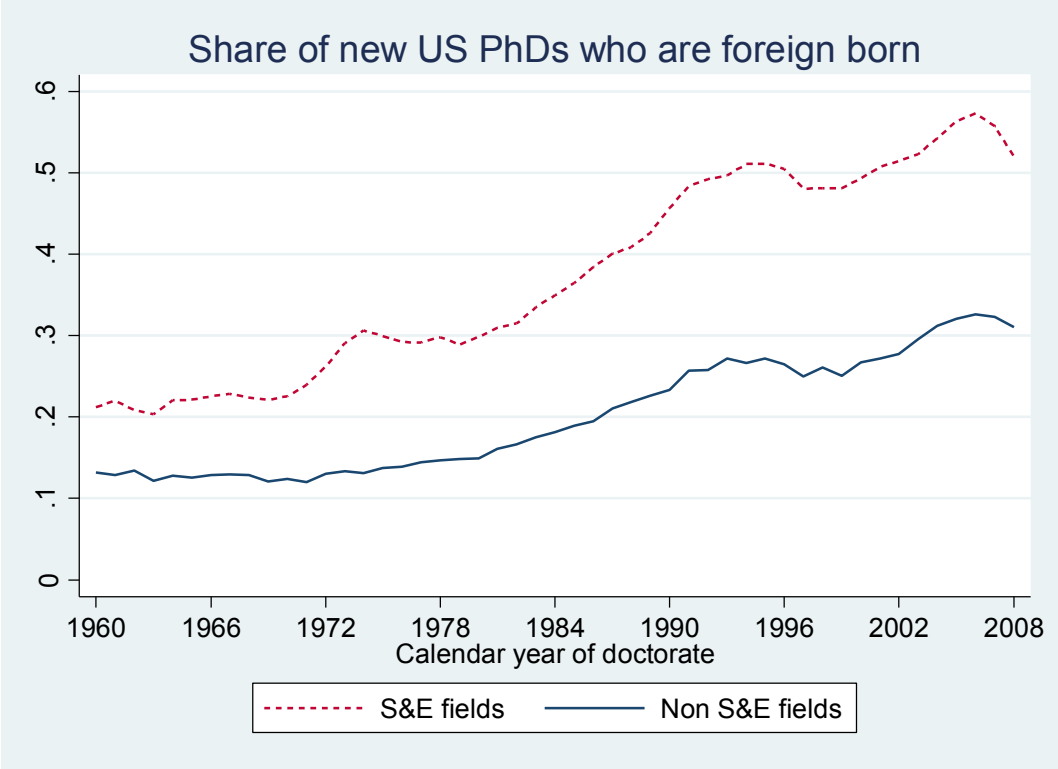

Share of new US PhDs who are foreign born
0
.1
.2
.3
.4
.5
.6
1960
1966
1972
1978
1984
1990
1996
2002
2008
Calendar year of doctorate
S&E fields
Non S&E fields

Figure 2: Foreign-born S&E PhDs by birth region

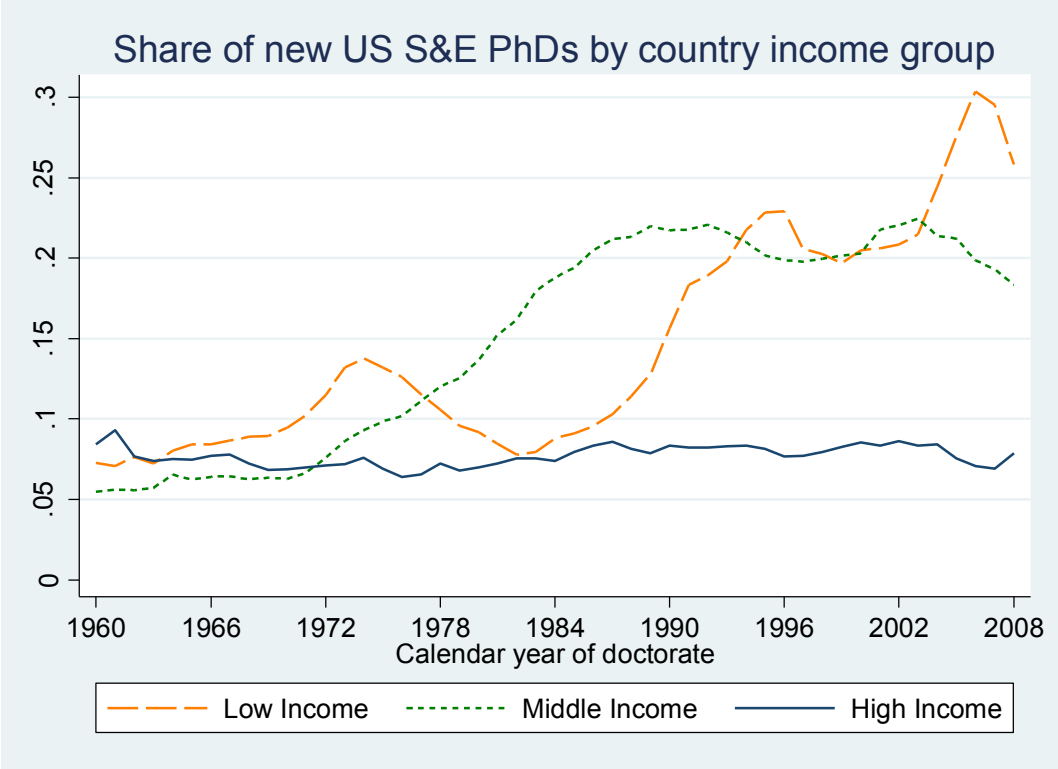
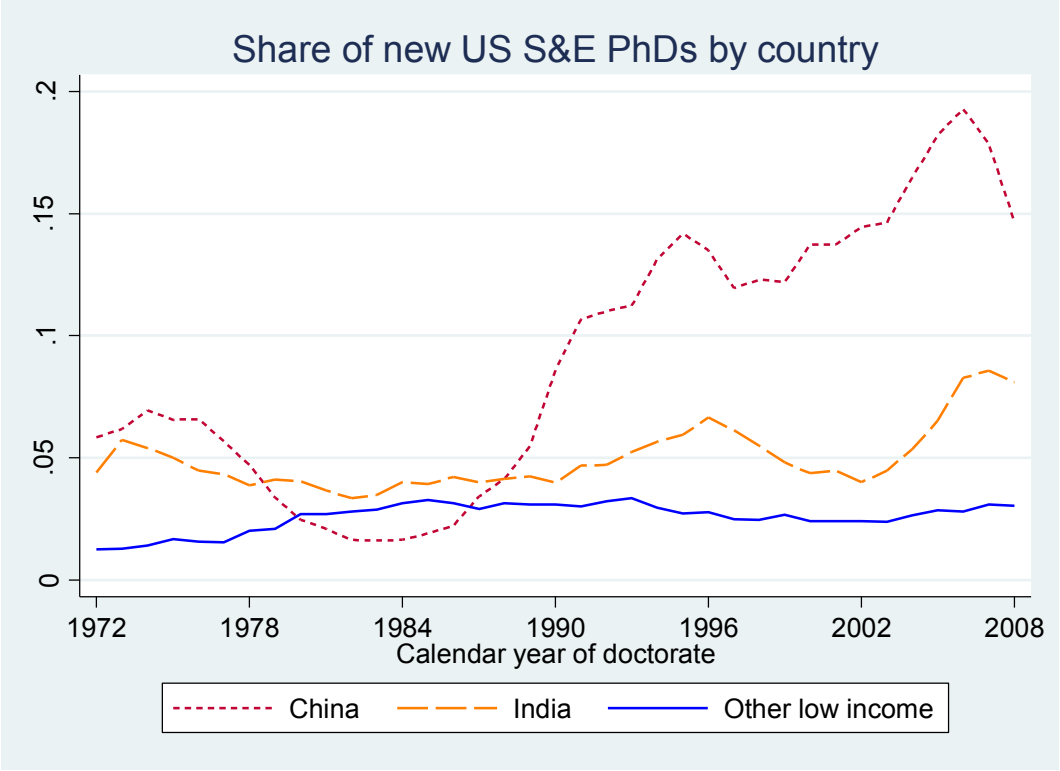


Figure 3: Foreign-born S&E PhDs by birth country

(a)



(b)

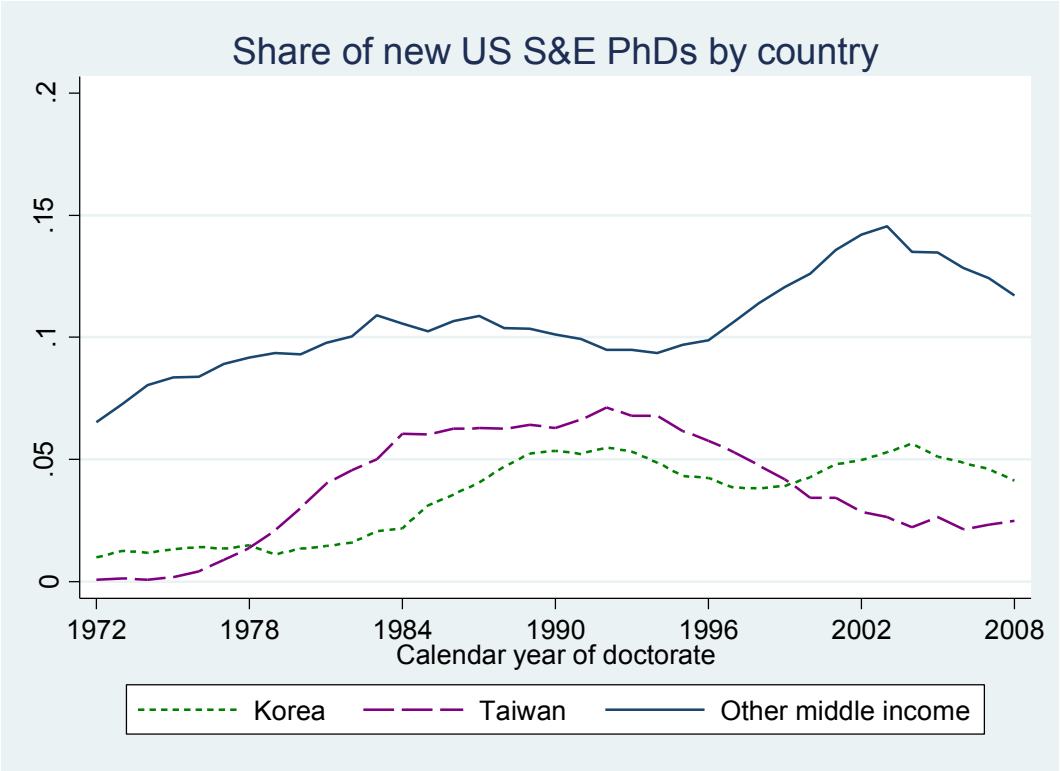
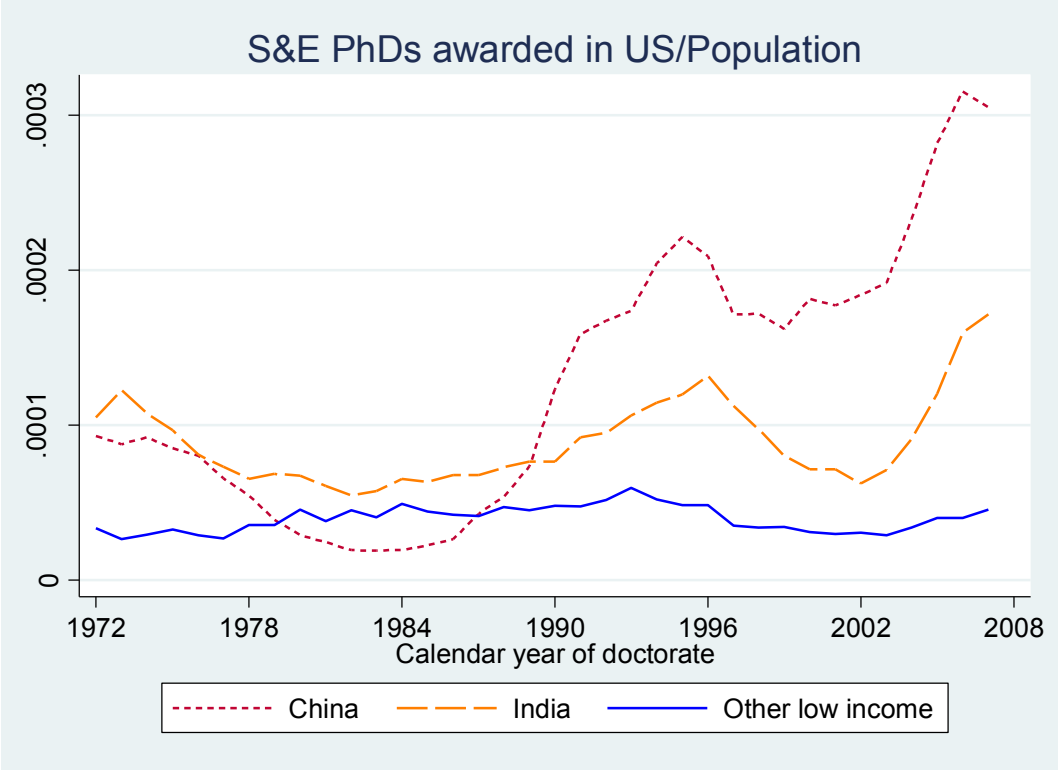


Figure 4: S&E PhDs awarded in US as share of birth-country population

(a)



(b)

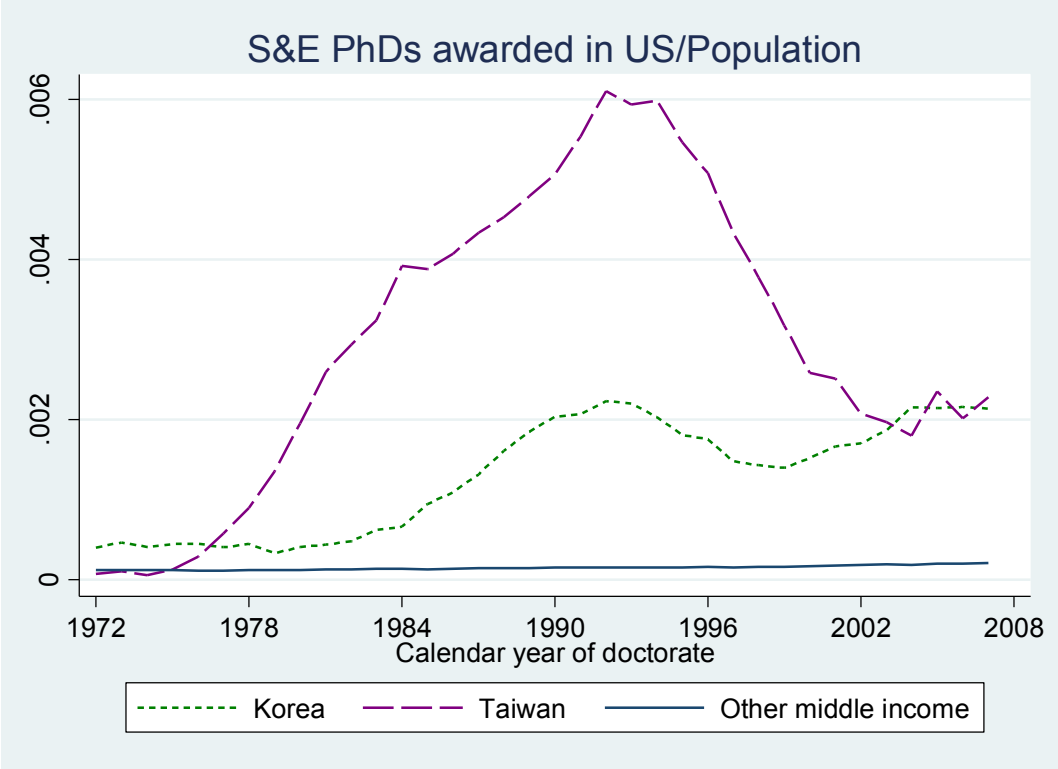
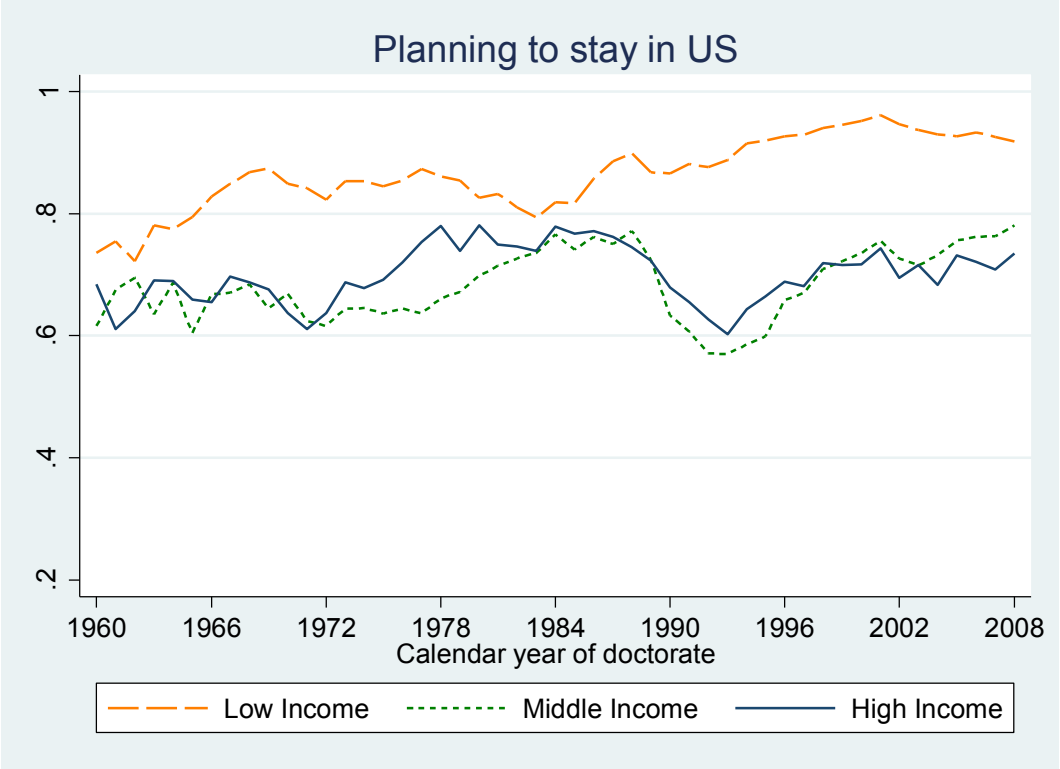


Figure 5: Share of new foreign-born S&E PhDs

(a)



(b)

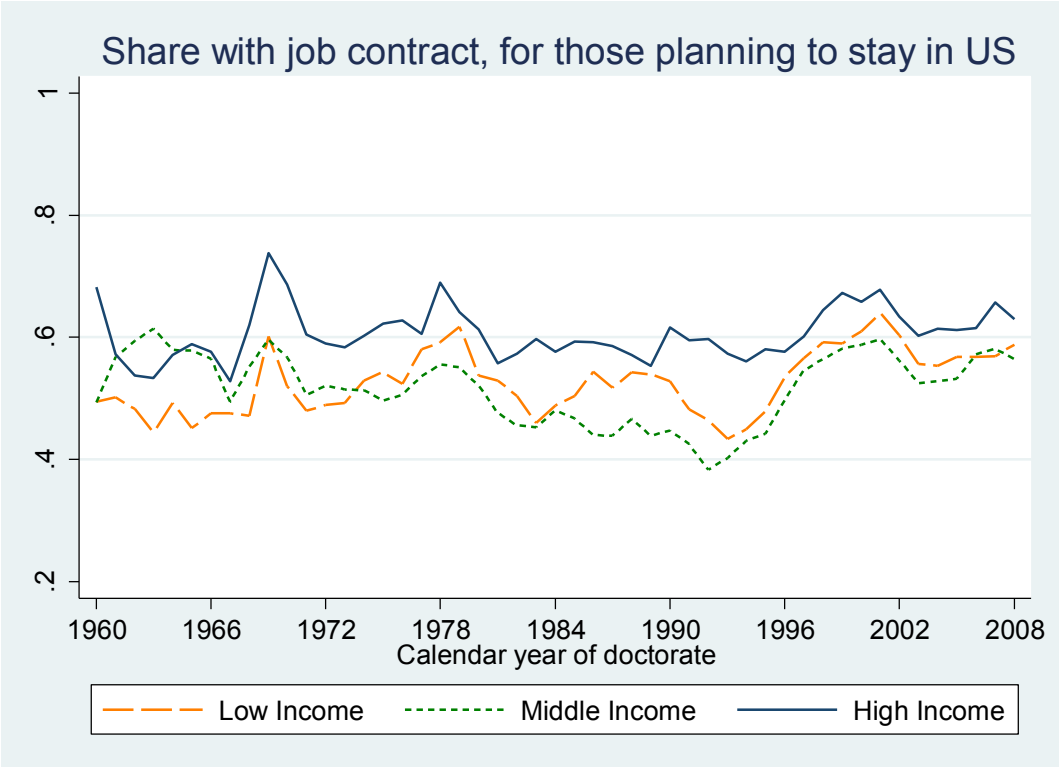


Table A1: Summary statistics

	mean	st. dev.
= 1 if intends to stay in US	0.773	0.419
= 1 if intends to stay in US and has job	0.432	0.495
= 1 if naturalized citizen	0.088	0.284
= 1 if has green card	0.173	0.378
= 1 if earned BA degree in US	0.146	0.353
= 1 if father has BA degree	0.479	0.500
= 1 if mother has BA degree	0.276	0.447
= 1 if had RAship/TAship	0.516	0.500
= 1 if had fellowship, scholarship	0.106	0.307
= 1 if had Fulbright, Ford Foundation, etc.	0.001	0.026
= 1 if had foreign scholarship	0.038	0.192
= 1 if top 20 university	0.260	0.439
= 1 if top 40 university	0.484	0.500
= 1 if top 15 program	0.048	0.213
= 1 if ranked program	0.766	0.424
= 1 if male	0.800	0.400
= 1 if married	0.627	0.483
age at PhD degree	32.089	3.923
age at BA degree	22.791	1.954
birth country log pc GDP growth t-1 to t-5	0.057	0.035
US log pc GDP growth t-1 to t-5	0.033	0.008
birth country average log pc GDP t-1 to t-5	8.859	1.863
currency crisis, t to t-1	0.118	0.270
external debt crisis, t to t-1	0.055	0.215
banking crisis, t to t-1	0.189	0.361
number of natural disasters, t to t-1	7.254	8.875
major natural disasters, t to t-1	0.074	0.140
>25 battle deaths, t to t-1	0.250	0.435
>1000 battle deaths, t to t-1	0.081	0.274

Sample is foreign-born recipients of PhD in a science or engineering field from a US research university over the period 1960 to 2008 (N=262,616 except for birth country measures which have fewer observations owing to inclusion of lagged values in their construction).

Table 1: Intent-to-stay in US among S&E PhD recipients by birth country, 1960-2008

	Intend to stay in US	
Low income	'60-'84	'85-'08
Bangladesh	1.000	0.852
Cameroon	0.582	0.779
China	0.901	0.941
Ethiopia	0.646	0.857
Ghana	0.605	0.833
Guyana	0.794	0.866
India	0.814	0.385
Indonesia	0.389	0.426
Kenya	0.514	0.657
Nepal	0.427	0.759
Nigeria	0.493	0.821
Pakistan	0.636	0.708
Sri Lanka	0.611	0.796
Sudan	0.237	0.549
Tanzania	0.406	0.515
Uganda	0.579	0.561
Vietnam	0.753	0.922
Zimbabwe	0.725	0.662
Middle income		
Argentina	0.660	0.709
Brazil	0.215	0.404
Chile	0.494	0.520
Colombia	0.445	
Egypt	0.618	0.357
Iran	0.741	0.443
Jordan	0.532	0.525
Korea	0.778	0.598
Malaysia	0.463	0.530
Mexico	0.446	0.548
Philippines	0.517	0.769
Poland	0.853	0.857
Romania	0.827	0.898
Russia	0.896	0.896
South Africa	0.622	0.626
Taiwan	0.889	0.640
Thailand	0.360	0.282
Turkey	0.641	0.641

See Table A1 for description of sample.

Table 2: Characteristics, location choices, and employment probabilities of foreign-born S&E PhD recipients

		Intend to stay in US	P(Has job|intent to stay)
US citizen	no	0.700	0.549
	yes	0.957	0.527
US permanent resident	no	0.685	0.556
	yes	0.921	0.512
High school in US	no	0.709	0.543
	yes	0.930	0.567
College in US	no	0.697	0.545
	yes	0.874	0.548
RAship, TAship	no	0.654	0.514
	yes	0.821	0.575
Fellowship, scholarship	no	0.725	0.537
	yes	0.745	0.616
Fulbright, Ford, Rockefeller	no	0.728	0.545
	yes	0.445	0.506
Foreign financial support	no	0.747	0.546
	yes	0.254	0.520
Father has BA degree	no	0.686	0.520
	yes	0.777	0.570
Mother has BA degree	no	0.703	0.528
	yes	0.796	0.588
Top 20 university	no	0.730	0.521
	yes	0.721	0.614
Top 15 department	no	0.741	0.552
	yes	0.720	0.658

See Table A1 for desctiption of sample.

Table 3: Post-PhD employment intentions

Desired sector of employment	Does not intend to stay in US	Intends to stay in US
Government	0.236	0.060
Academia	0.496	0.344
Private industry	0.104	0.328
Non-for profit	0.077	0.141
Other, unspecified	0.087	0.127

The sample is foreing-born PhD recipients in science and engineering fields who are not pursuing further study or a temporary postdoc or trainee position after their degree.

Table 4: Baseline regression estimates
Dependent variable: Intends to stay in US after graduation

Variable\Sample	All	Non-citizen	Non-green card	'85-'08	Big 5
=1 if US citizen	0.209*			0.191*	0.175*
	(0.026)			(0.028)	(0.004)
= 1 if has US green card	0.175*	0.175*		0.156*	0.125*
	(0.032)	(0.032)		(0.037)	(0.002)
= 1 if earned BA in US	0.034~	0.051*	0.064*	0.038~	-0.015*
	(0.013)	(0.012)	(0.013)	(0.015)	(0.004)
= 1 if father has BA	0.015*	0.015*	0.018*	0.017*	0.017*
	(0.005)	(0.005)	(0.005)	(0.005)	(0.002)
= 1 if mother has BA	-0.005	-0.005	-0.004	-0.004	-0.006*
	(0.003)	(0.004)	(0.004)	(0.003)	(0.002)
= 1 if had RAship, TAship	0.085*	0.094*	0.112*	0.069*	0.071*
	(0.015)	(0.017)	(0.017)	(0.016)	(0.003)
= 1 if had fellowship/scholarship	0.045*	0.057*	0.070*	0.028~	0.060*
	(0.011)	(0.013)	(0.013)	(0.011)	(0.003)
= 1 if had Fulbright/Ford/Rockfllr	-0.135*	-0.165*	-0.159*	-0.123*	-0.169*
	(0.037)	(0.043)	(0.047)	(0.035)	(0.048)
= 1 if had foreign support	-0.252*	-0.237*	-0.210*	-0.274*	-0.325*
	(0.032)	(0.032)	(0.029)	(0.031)	(0.012)
= 1 if top 10 in NRC ranking	0.000	0.006	0.009	0.001	0.004
	(0.004)	(0.004)	(0.005)	(0.004)	(0.003)
= 1 if ranked program	0.002	0.002	0.003	0.002	0.002
	(0.003)	(0.004)	(0.004)	(0.004)	(0.002)
= 1 if BA ranked in AWRU	0.009	0.004	0.000	0.005	0.014*
	(0.008)	(0.008)	(0.008)	(0.005)	(0.002)
log GDP growth in birth country	-0.695*	-0.784*	-0.878*	-0.662*	-0.708*
	(0.174)	(0.186)	(0.220)	(0.165)	(0.047)
log per capita GDP in birth country	-0.135*	-0.143*	-0.163*	-0.103*	-0.166*
	(0.045)	(0.047)	(0.049)	(0.030)	(0.006)
log GDP growth in US	2.352*	2.576*	2.517*	3.938*	2.943*
	(0.480)	(0.512)	(0.570)	(0.821)	(0.107)
= 1 if male	-0.007~	-0.008~	-0.010~	-0.002	-0.002
	(0.003)	(0.003)	(0.004)	(0.003)	(0.002)
=1 if married	-0.001	-0.004	-0.01	0.007	0.020*
	(0.009)	(0.010)	(0.011)	(0.007)	(0.002)
Adj. R squared	0.257	0.258	0.252	0.258	0.171
N	219,180	200,351	163,227	176,657	129,799

Other regressors: age, age squared, age at BA, age at BA squared, married, mother has BA, share primary/secondary/tertiary educated in parents' cohort in birth country, dummy for top 40 university, dummy for whether department is ranked, time trend, narrow PhD field dummies, birth-country dummies. Standard errors in () clustered by birth country.

Table 5: Regression estimates
Dependent variable: employed, given intent to stay

Variable\Sample	All	Non-citizen	Non-green card	'85-'08	Big 5
=1 if US citizen	-0.015			-0.041*	-0.027*
	(0.011)			(0.015)	(0.007)
= 1 if has US green card	-0.034*	-0.032*		-0.053*	-0.038*
	(0.007)	(0.007)		(0.009)	(0.004)
= 1 if earned BA in US	-0.010	-0.011	-0.013	-0.010	0.021*
	(0.014)	(0.015)	(0.011)	(0.014)	(0.007)
= 1 if father has BA	0.006	0.005	0.003	0.005	0.004
	(0.004)	(0.003)	(0.005)	(0.004)	(0.004)
= 1 if mother has BA	0.003	0.002	0.001	0.002	0.006
	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)
= 1 if had RAship, TAship	0.079*	0.073*	0.065*	0.068*	0.086*
	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)
= 1 if had fellowship/scholarship	0.087*	0.082*	0.071*	0.078*	0.091*
	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)
= 1 if had Fulbright/Ford/Rockfllr	0.014	0.03	0.062	0.034	0.016
	(0.037)	(0.039)	(0.047)	(0.035)	(0.074)
= 1 if had foreign support	0.035*	0.028~	0.028~	0.024~	-0.011
	(0.012)	(0.012)	(0.012)	(0.010)	(0.022)
= 1 if top 10 in NRC ranking	0.064*	0.062*	0.063*	0.067*	0.070*
	(0.007)	(0.007)	(0.009)	(0.007)	(0.005)
= 1 if ranked program	0.006	0.006	0.005	0.003	0.002
	(0.004)	(0.005)	(0.006)	(0.004)	(0.003)
= 1 if BA ranked in AWRU	0.023	0.018	0.02	0.025*	0.005
	(0.012)	(0.011)	(0.010)	(0.006)	(0.004)
log GDP growth in birth country	-0.017	-0.07	-0.097	-0.028	-0.003
	(0.131)	(0.147)	(0.185)	(0.145)	(0.071)
log per capita GDP in birth country	-0.059~	-0.069*	-0.081*	-0.036*	-0.055*
	(0.026)	(0.027)	(0.024)	(0.012)	(0.010)
log GDP growth in US	1.863*	1.875*	1.810*	2.847*	2.056*
	(0.445)	(0.488)	(0.524)	(0.309)	(0.176)
= 1 if male	0.056*	0.058*	0.046*	0.049*	0.067*
	(0.008)	(0.010)	(0.009)	(0.009)	(0.004)
=1 if married	0.022*	0.021*	0.019*	0.014*	0.019*
	(0.004)	(0.005)	(0.005)	(0.005)	(0.003)
Adj. R squared	0.059	0.057	0.056	0.065	0.051
N	165,120	147,581	114,152	134,767	107,401

Other regressors: age, age squared, age at BA, age at BA squared, married, mother has BA, share primary/secondary/tertiary educated in parents' cohort in birth country, dummy for top 40 university, dummy for whether department is ranked, time trend, narrow PhD field dummies, birth-country dummies. Standard errors in () clustered by birth country.

Table 6: Regression estimates by field of study
Dependent variable: Intends to stay in US after graduation

Variable\Field	Phys Science	Life Science	Engineering	Economics	Soc Science	Humanities	Education
=1 if US citizen	0.188*	0.209*	0.221*	0.339*	0.327*	0.355*	0.458*
	(0.022)	(0.027)	(0.034)	(0.031)	(0.019)	(0.020)	(0.024)
= 1 if has US green card	0.150*	0.191*	0.177*	0.283*	0.325*	0.336*	0.384*
	(0.029)	(0.042)	(0.029)	(0.030)	(0.022)	(0.016)	(0.029)
= 1 if earned BA in US	0.038*	0.033	0.032~	0.070*	0.090*	0.085*	0.096*
	(0.011)	(0.018)	(0.014)	(0.014)	(0.014)	(0.010)	(0.013)
= 1 if father has BA	0.014~	0.016*	0.012~	0.01	0.007	-0.005	0.005
	(0.005)	(0.004)	(0.006)	(0.009)	(0.005)	(0.006)	(0.006)
= 1 if mother has BA	-0.005	-0.008	0	0.002	0.007	0.002	0.006
	(0.003)	(0.005)	(0.004)	(0.011)	(0.007)	(0.007)	(0.012)
= 1 if had RAship, TAship	0.061*	0.085*	0.103*	0.094*	0.081*	0.094*	0.132*
	(0.015)	(0.016)	(0.016)	(0.011)	(0.012)	(0.016)	(0.018)
= 1 if had fellowship/scholarship	0.034*	0.039*	0.055*	0.060*	0.000	0.003	-0.024
	(0.011)	(0.012)	(0.016)	(0.009)	(0.010)	(0.016)	(0.024)
= 1 if had Fulbright/Ford/Rockfllr	-0.161*	-0.147~	-0.082	-0.320*	-0.134*	-0.052	-0.191*
	(0.059)	(0.060)	(0.059)	(0.053)	(0.040)	(0.068)	(0.073)
= 1 if had foreign support	-0.215*	-0.222*	-0.284*	-0.147*	-0.171*	-0.158*	-0.114*
	(0.033)	(0.025)	(0.039)	(0.021)	(0.023)	(0.023)	(0.028)
= 1 if top 10 in NRC ranking	0.012~	-0.019~	-0.004	0.078*	-0.01	0.021~	
	(0.006)	(0.009)	(0.007)	(0.012)	(0.012)	(0.009)	
= 1 if ranked program	-0.006	0.012~	-0.002	0.003	-0.008	-0.021~	
	(0.004)	(0.005)	(0.005)	(0.011)	(0.008)	(0.010)	
= 1 if BA ranked in AWRU	0.012	0.011	-0.007	-0.016	-0.006	-0.011	-0.035~
	(0.008)	(0.008)	(0.009)	(0.009)	(0.014)	(0.011)	(0.015)
log GDP growth in birth country	-0.650*	-0.423	-0.637*	-0.719*	-0.707*	-0.426~	-0.247
	(0.192)	(0.235)	(0.183)	(0.269)	(0.269)	(0.209)	(0.314)
log per capita GDP in birth country	-0.118*	-0.144*	-0.088	-0.177*	-0.091~	-0.037	-0.09
	(0.043)	(0.029)	(0.051)	(0.050)	(0.040)	(0.031)	(0.063)
log GDP growth in US	2.168*	1.791*	2.702*	2.760*	2.498*	1.494*	0.872
	(0.486)	(0.396)	(0.625)	(0.881)	(0.448)	(0.434)	(0.463)
= 1 if male	-0.006	-0.002	-0.008~	-0.045*	-0.031*	-0.037*	-0.048*
	(0.005)	(0.006)	(0.004)	(0.010)	(0.009)	(0.009)	(0.010)
=1 if married	0.014	-0.023~	0.006	-0.015	-0.038*	-0.048*	-0.031*
	(0.008)	(0.010)	(0.011)	(0.011)	(0.010)	(0.007)	(0.009)
Adj. R squared	0.191	0.345	0.254	0.249	0.305	0.296	0.371
N	71,563	61,753	85,864	26,415	26,575	26,080	18,275

Other regressors: age, age squared, age at BA, age at BA squared, married, mother has BA, share primary/secondary/tertiary educated in parents' cohort in birth country, dummy for top 40 university, dummy for whether department is ranked, time trend, narrow PhD field dummies, birth-country dummies.
Standard errors in () clustered by birth country.