To Stay or Not to Stay: Location Choice of Foreign Born U.S. Doctorates

Scott Adams, Niloy Bose* and Chandramouli Banerjee†

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Abstract

Over the past few decades, foreign-born U.S. PhDs have play a crucial role in shaping the landscape of U.S. skilled workforce. Not all foreign-born U.S. doctorates choose to remain in the U.S. workforce. This paper uses a newly assembled set of data – the International Survey of Doctoral Recipients (ISDR) – assembled by the National Science Foundation to explore the factors, both at the individual as well as at the country level, that are relevant for the location choice of work for foreign-born individuals receiving their doctorates from the U.S. Our analysis, identifies a number of demographic and country specific factors that have implications for the location choice. Among those one particular factor stands out. We find that foreign-born U.S. PhDs who choose to emigrate are positively selected in terms of skill as measured by the quality of the school they attended. This result deserves attention as it implies that the U.S. may be losing premium talents to global competition.

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*Corresponding Author: nbose@uwm.edu

†Adams, Bose and Banerjee: University of Wisconsin-Milwaukee, Department of Economics, 3210 North Maryland Avenue, Bolton Hall, Milwaukee 53211 USA

1 Introduction

The activity of Science and Engineering (S&E) or Science, Technology, Engineering and Mathematics (STEM) workforce is the main input in the creation and adoption of scientific knowledge which drives economic productivity. According to Census Bureau data, employment in S&E occupation in the U.S. grew from about 1.1 million in 1960 to about 5.8 million in 2011. During the same period, the S&E workforce grew at a rate of 3.3%, which is twice the rate of growth in total employment. This growth is partly driven by an increased participation of foreign-born scientists in the U.S. S&E workforce. Currently, foreign-born scientists represent a large fraction of the S&E workforce. According to the American Community Survey (ACS) and the Scientists and Engineers Statistical Data System (SESTAT), 26-27% of respondents employed in S&E occupations during 2010 were foreign born and the corresponding number for the pool of respondents with a doctoral degree is about 42-44% (see Table 1). Significantly, amongst the foreign-born doctorate holders employed in the S&E workforce in the U.S., many received their doctoral degree from a U.S. institution and this supply pool of U.S. trained foreign-born doctorates has grown rapidly over the last few decades. The share of foreign nationals earning doctorates in Science, Engineering or Health in the United States was about 17% during the decade of 1960. By 2010, this share increased to nearly 40% (See Figure 1),[1] the effect being driven by a large influx of students from low and middle income countries (See Figure 2). The share of doctorates awarded to foreign-born students in the top tier universities has also grown rapidly while the total share of doctorates handed out by these schools has remained fairly constant (See Figure 3). Foreign-born students now also dominate the pool of PhD recipients in many key subject areas.[2] The above stylized facts indicate that over the past few decades, foreign-born U.S. PhDs have shaped and are continuing to shape the landscape of the U.S. S&E higher education and workforce. It is, therefore, crucial to have a deeper understanding of the behaviors of this group of individuals. The primary goal of this paper is to learn about the location choice of work for foreign-born U.S. graduates.

Our goal is meaningful for a variety of reasons. First, there is evidence that a large fraction of foreign born S&E graduates emigrate after graduation. According to 2007 Survey of Earned Doctorates, only 53% of foreign doctorate recipients with temporary visas reported that they have a 'definite plan' to remain in United States. Whereas, 79% of the population expressed their intention in favor of remaining in the U.S. after graduation. Finn (2010, 2014) offers more direct estimates based on Social Security and tax information of foreign doctoral recipients. According

[1] Source: InfoBrief, National Center for Science and Engineering Statistics, NSF-13-300, October 2012.

[2] Bound et al. (2009) report that students from outside the US accounted for 51% of PhD recipients in S&E in 2003, up from 27% in 1973. This trend holds across fields. For example, the same study finds that in 2003, foreign-born individuals accounted for: 50% of degrees in Physical Sciences, 67% of degrees in Engineering, 68% of degrees in Economics.

to Finn (2010), the two year stay rate of foreign students with temporary visas who received their S&E doctorate degree in 2005 is about 67%. In a more recent publication, Finn (2014) reports a slightly higher stay rate among temporary residents receiving S&E doctorates in 2006. Still, nearly 28% of this group have relocated to other countries within two years of graduation and this share rises to 34% within a period of five years.

Second, there is compelling evidence that U.S. trained foreign born graduates make significant contribution to research and innovation. According to Chellaraj et al. (2008), a 10% increase in the size of foreign graduate students in Science and Engineering (S&E) fields leads to 4.5% increase in the university patent applications and 6.8% increase in the university patent grants. Similarly, the estimates by Stuen et al. (2012) suggest that having an additional foreign graduate student in S&E departments translates into an average gain of 5 extra articles in the department over the course of a doctoral student's 6-year graduate career. Using individual level data from the National Survey of College Graduates, Hunt and Gauthier-Loiselle (2008) suggest that foreign-born students not only do not crowd out natives from the graduate school, but a one percentage point increase in the share of immigrant college graduates in the population increases patent per capita by about 15%. Beyond the domain of graduate schools, the contributions of the foreign-born graduates are disproportionately large as well. According to Peri (2007), compared to a foreign-born population of 12% in 2000, 26% of U.S. based Nobel Prize recipients from 1990-2000 were immigrants. Similarly, immigrants are over-represented among members of the National Academy of Science and the National Academy of Engineering (Levin and Stephan, 1999) and non-U.S. citizens account for 24% of international patent applications from the United States.

Together, the above facts offer prima facie evidence that a large number of U.S. trained graduates relocate to other countries taking human capital and vast potential with them. This location decision has crucial implications for the U.S. S&E workforce and for the U.S. productivity growth.[3] The implication becomes even more compelling if one *chooses* to consider evidence in support of shortages in the STEM workforce. For example, the report by the National Academy of Sciences (National Academy of Sciences and National Academy of Engineering and Institute of Medicine, 2007) highlights troubling issues in a number of areas including low STEM retention rates, a relative decline in the number of U.S. citizens enrolled in Science and engineering graduate school, and a lower percentage of STEM graduates than those of other developed countries (also see Figure 1). These sentiments were echoed in a 2012 report by the U.S. Congress Joint Economic Committee (US Congress Joint Economic Committee and others, 2012). There is also evidence to suggest that professional STEM vacancies take longer to fill now than before the recession, while vacancies for lower-skilled occupations remain much easier to fill (Rothwell, 2014). Many,

[3]For example, Xu (2015) estimates that the impact of doubling the number of immigrants from every non-OECD country would boost U.S. productivity growth by 0.1 percentage points per year.

however, hold a different view that there are no shortages of scientists and engineers (Anft, 2013; Teitelbaum, 2012), while others (Xue and Larson, 2015) are of the opinion that certain STEM disciplines, such as Material Science Engineering, Computer Science, Electrical and Mechanical Engineering, Petroleum Engineering etc., have a shortage of positions at the PhD level. Here we do not partake in this debate. Rather, we would like to point out that if there is indeed a shortage of STEM workers (even if at a sectoral level), then foreign-born U.S. doctorates are a potential source to bridge the gap between the demand and supply of skills. Therefore, from the policy perspective, it is important to understand the behavior of this group of individuals including their choice of location.

Finally, in an era where most nations realize the importance of having a well trained S&E workforce, the competition to attract these highly skilled individuals has become more and more fierce. Many countries are now engaging in the intense global competition to attract internationally mobile human capital by redesigning their immigration regimes. The UN World Population Policies Database reports that in 2013, approximately 40% of the 172 UN member states declared an explicit interest to increase the level of high-skilled migration into their countries either by attracting foreign or retaining native talent, whereas this share was only about 22% in 2005. Highly developed countries lead this global trend – two thirds of OECD nations have implemented or are in the process of implementing policies specifically aimed at attracting high-skilled migrants. Moreover, many countries in the Asia-Pacific region have been investing heavily in R&D and now collectively perform a larger share of global R&D than the United States (National Science Board (NSB), 2014). Since S&E skills are portable, these global changes not only have implications for the location choice, but also have implications for cross-border transmission of knowledge and for the U.S. advantages in S&E.

This paper uses a new set of data - the International Survey of Doctoral Recipients (ISDR) - assembled by the National Science Foundation to learn about the factors – at individual as well as at the country level – that may have contributed to the location choice of foreign born U.S. graduates. This data set is unique in a number of respects and alleviates many challenges facing the research community. For example, in contrast to the previous sets of available information, the data provide information on foreign-born graduates who have left the U.S. workforce, and most importantly, inform us about their current work locations. The ISDR data also offer us an opportunity to pin down the time of departure for a large subset of individuals in the sample. Additionally, the ISDR contains detailed information about the principal job that the respondents currently hold, to which we add demographic and economic information that are available through the Survey of Earned Doctorates (SED). We supplement this with information from other sources to learn more about the economic environment of an individual's choice of his/her country of destination. Together, the information offer a sound platform to conduct the analysis. In Section 2, we outline in more details

about the features of the ISDR data also explain its contributions in meeting the challenges facing the researchers.

Our analysis identifies a number of factors that are relevant for the location choice. For example, at an aggregate level, the relative performance of the destination country vis-a-vis United States in terms of output growth and employment matters for the location decision. For example, at the time of the decision, an individual is more likely to stay back in the U.S. if the U.S. enjoys a relatively faster output growth and lower unemployment. FDI inflows to the destination country also plays a role in the decision. At an individual level, the status of legal residency and the status of graduate funding appear to play an important role. For example, we find that students with stronger ties to the U.S. via legal residency (U.S. Citizenship/Permanent Residence) are more likely to stay back. Similarly, students who have received a RA/TA-ship or received a B.A. in the U.S., are likely to make a decision in favor of staying in the U.S. workforce. The opposite is true for those who have received a Fellowship or funds from a foreign source. Significantly, we find that the students who leave the U.S. are positively selected on the basis of skill, as measured by the quality of the school they attended. Needless to say that this finding deserves attention as it suggests that the U.S. may be losing the best of their talent to other countries in the race to attract the talent.

The rest of the paper proceeds as follows. In Section 2 we expand upon the constraints faced by the academic community in studying the location choice of foreign-born U.S. PhDs using data available previously. In Section 3 we describe in detail how the newly assembled ISDR data serves to alleviate these constraints, and set up the econometric model. In Section 4, we discuss the results. Section 5 concludes with some remarks.

2 Related Literature and Challenges

This paper is certainly not the first to study the population of highly skilled migrants in the U.S. The rapidly changing landscape of U.S. higher education has drawn the attention of researchers. Some have focused on the determinants of changes over time in the representation of foreign born students among doctorate recipients from U.S. universities (Kapur and McHale, 2005; Bound et al., 2009; Freeman, 2010). Others went on to look at the impacts of foreign-born graduates on innovation (Stuen et al., 2012) and on the U.S. labor market conditions (Borjas, 2005; Hunt, 2011). In comparison, little work has been undertaken to understand the factors governing location choice of foreign born U.S. doctoral graduates.[4] When undertaken, the analysis is based on a set of imprecise information. This is not due to the lack of such information, rather the manner in which information were made available to researchers that rendered little scope for conducting a systematic analysis.

[4]To our knowledge two papers precede ours in using a cross section of foreign born U.S. PhDs to investigate the factors determining their location decisions, Black and Stephan (2007) and Grogger and Hanson (2015).

To be precise, a systematic analysis of location choice requires simultaneous access to two sets of information on individuals. The first set includes information about the conditioning variables, such as individual characteristics and the information about the environment. The second set includes information about the true location choice of the individuals. Heretofore, matching these two sets of information has posed a major challenge to the research community. For example, when it is possible to learn a great deal about the intentions of individuals and their characteristics through the Survey of Earn Doctorates (SED), the researchers knew little about the true location choice of the foreign born graduates. On the flip-side, the seminal studies by Michael G. Finn (Finn, 2010, 2014) offer a scientific method for identifying those foreign born graduates who have left the U.S. workforce. However, the reported data are in the aggregate form and the lack of information on individuals and on their choice of destinations makes these studies unsuitable for the analysis on location choice.

The lack of precise information has compelled researchers to make heroic assumptions in the analysis of 'stay versus leave' decisions of the foreign graduates for whom they have individual-level data. Specifically, the existing research has used the temporary visa holders' 'intend to stay' responses in the SED as a proxy for the actual decisions of the foreign born graduates. Perhaps the most prominent examples of this approach are Black and Stephan (2007) and Grogger and Hanson (2015). While the former analyzed the association between the expressed intentions of individuals and their characteristics, the latter extended this analysis by adding country specific measures to the set of controls. However, the assumptions that the authors were forced to make in the above research have limited their ability to truly learn about the factors that contribute to the location choice of foreign born graduates. Take, for example, the case of using 'intend to stay' responses as a proxy for the true actions. In practice, the correlation between intention and action is not perfect. It is true that the percentage of foreign students reporting plan to stay tracks the actual one year stay rate closely. While this makes the 'intend to stay' responses a good predictor for the aggregate behaviors (Finn, 2010), it does not necessarily render itself as a sound predictor of behavior at the individual level. The two aggregates can track each other well even when there is a significant mismatch between the plan and the action at the individual level. The ISDR data offers an opportunity to learn about individuals who have actually left the U.S. workforce. In a sample of about 10,000 individuals, we find that the correlation between 'intend to stay' responses and the 'actual stay' rates is only about 0.67.

Sparse information on location choice and the time of departure also have implications for estimates of other conditioning variables. For example, in exploring the effects of the prevailing macroeconomic conditions on the location choice of foreign-born U.S. PhDs, Grogger and Hanson (2015) are forced to assume that the foreign-born are destined to return to their country of birth since scope of observing the true location choice of the individual were absent. Thus, the

conditioning variables which capture the relative economic environment were constructed with the birth country as the reference country. Needless to say, in the era of globally integrated labor markets, especially so for high skilled workers, it need not be the case that an individual always returns to their country of birth, and the macroeconomic conditions that factor into an individual's decision to move must be those of the true country of location, and not necessarily of the country of birth. Moreover, existing research assume that individuals choose to leave immediately after they graduate. Yet, the two year, five year and ten year stay rates of foreign-born U.S. PhDs. differ significantly, and individuals who move within a few years of graduation and those who move much after presumably represent two very different group of people with a different set of skills. More precise information about the departure dates in the ISDR data creates room to distinguish between these groups of individuals.

The newly available International Survey of Doctoral Recipients (ISDR) data alleviates many of the above constraints. The data provide information on foreign born graduates who have left the U.S. workforce along with their current locations. The ISDR data also offer us an opportunity to pin down the time of departure for a large subset of individuals in the sample. To this, we add information that are available through SED and other sources to learn more about individual characteristics and also about the characteristics of the destination country. Together, they constitute a set of information that is rich enough to render itself suitable for a systematic analysis of location choice.

3 Data and Methods

3.1 Data

For the purposes of our analysis, we make use of the newly available 2010 International Survey of Doctorate Recipients (ISDR) data, along with data contained in the Survey of Earned Doctorates (SED) and the 2010 Survey of Doctorate Recipients (SDR). The 2010 survey was the first such survey issued by the NSF to track individuals who settled outside U.S. borders to ask them the same set of questions typically asked of the domestic SDR sample. We merge the data on the respondents from the SDR and ISDR to corresponding data from the SED, which allows us to observe all the demographic variables contained in the SED in addition to what we observe in the SDR and ISDR.

We limit our analysis to foreign born individuals in the 2010 SDR/ISDR. We also limit our analysis to those individuals for whom we have a complete set of information. This leaves us with a sample of 8430 foreign-born doctoral recipients from U.S. institutions.[5] Of these, 85.72% were

[5]Our sample size is smaller than Grogger and Hanson (2015) because we are limited to the foreign-born who are

in S&E fields. Our first objective is to establish the characteristics that are positively related to emigrating from the U.S. As discussed in the previous section, the key advantage of the new dataset is that it allows us to construct a measure of emigration based on the true location choice of the individual. Our measure for emigration from the U.S. is an indicator of whether one is part of the ISDR survey (current job location is outside the U.S.) or one is part of the SDR (current job location is within the U.S.). Since every respondent of the ISDR lived outside the United States, we assume they chose to leave the U.S. at some point between graduation and their time of interview. Every foreign-born respondent in the SDR currently lives in the U.S. so we assume they have chosen to remain the U.S. The data does not offer any information about circular migration. As a result, we treat all emigrations as permanent. That is, if one is currently outside the U.S., we assume they left the U.S. permanently at one point and remained outside its borders. If one is currently in the U.S., we assume that they never left.

Table 2 provides descriptive statistics for these determinants for the total sample, those who emigrated, and those who stayed in the U.S. Among the sample of 8430 foreign born PhDs, roughly 75% (6344) stayed and 25% (2086) emigrated. The sample of those who left differ from those who stayed on a number of characteristics. Those who left were more likely to be from a more developed country and more likely to currently be employed in the academic sector. This indirectly means that many who stay back in the U.S do not remain in academics. Another striking difference is that those who emigrate have a higher proportion of graduates from Top 10 schools and also have a higher proportion of those from schools ranked 11-40. We use the National Research Council overall ranking of PhD granting institutions from 1995 to formulate these ranking variables.[6]

The remainder of Table 1 includes descriptions of additional control variables that capture various aspects that might influence the decision to remain or leave. These include citizenship, residency status, parental education, sex, marital status, and whether one also obtained their B.A. in the US. They also include the nature of support, whether it be through research or teaching assistantships (TA/RA), Fellowships or funds from a foreign source. Existing literature (e.g. Grogger and Hanson (2015)) suggest that these variables have explanatory power. Descriptive statistics suggest that individuals with closer ties to the U.S. in terms of citizenship or residence status are among those who stay. Further, those who stay have received a RA/TA. Whereas, those who receive a fellowship or other foreign support are more represented among the leavers. There are little surprises in these results. For example, the close relation between foreign support and the leave decisions is likely due to the fact that many fellowships or foreign scholarships expect the student

also tracked in the 2010 SDR and ISDR. This should affect precision of our estimates but not the parameter estimates themselves.

[6] We use the average of nonzero scores across all 41 ranked programs. See `https://www.stat.tamu.edu/~jnewton/nrc_rankings/nrc1.html#TOP60`. The top 10 are MIT, Berkeley, Harvard, Princeton, Cal Tech, Stanford, Chicago, Yale, Cornell, and UC San Diego.

to return to their home country upon completion of their education. Those who get their B.A. in the U.S. are also more represented among the stayers.

With the ISDR data in hand, we need not assume that a person emigrates to their country of birth. We are also able to identify the time of departure from the U.S. more exactly. The ISDR reports the date at which the individual started working on her principal job. We compare this date to the date at which she received her doctorate, and if she started working at the job within a two year window from graduation, we set the year of departure equal to the year that she started the job.[7] For individuals who started on the job more than two years after graduating, we use a different strategy. A foreign-born graduate who does not have an H1-B visa, permanent residence or U.S. citizenship, is allowed to stay in the U.S. for approximately one year after they graduate. The demographic information contained in the data allow us to observe the legal residence criteria of every individual, and we assume that an individual who does not have a H1-B visa, permanent residence status or US citizenship must have left the U.S. one year after receiving her doctorate. We are therefore able to identify the departure date of 88% of the sample of those who emigrate. We exclude the remaining 12% from the analysis. We are also forced to assume that the individual relocates to her current work location, since there is no way to observe if she had moved to a different country in the period between she received her doctorate and when she is observed in the data set.

Having more exactly identified departure dates and emigration location, we merge macroeconomic variables at those dates for the U.S. and the country to which an individual relocates in order to capture the economic climate relevant for each individual's choice to relocate. For the individuals who have not left the U.S., we simply assume that the relevant comparison country for their location choice other than the U.S. is their country of birth. We draw data on these variables from the World Development Indicators (WDI) published by The World Bank. The macroeconomic variables are each measured relative to the country of actual or potential emigration. For example, in order to capture the effect of economic performance of the two countries in question for a particular individual, we construct the relative GDP growth variable. We first standardize the per-capita GDP growth of countries. We then take the average of this standardized variable for three years preceding the date of departure. The relative GDP growth rate is then defined as the ratio of the averaged standardized U.S. GDP per capita growth rate to the averaged standardized GDP per capita growth rate of the country of emigration. We do the same for unemployment, with averaging done over three years preceding the departure date, no standardization is performed. FDI inflows to the country of relocation serve as a proxy for the economic openness, and is simply defined as the lagged-three year average of FDI inflows (2005 USD).

Finally, in order to capture the effect of earnings potential on the decision of individuals

[7]This mechanism allows us to identify exactly the departure dates of 56% of the individuals who emigrated.

to relocate, we also construct a salary premium variable. The SDR/ISDR questionnaire contains information on the salary that respondents earn in their primary job. In constructing this variable, we first divide these salaries by the PPP conversion factor to exchange rate ratio of the country the individuals reside in, thus giving us the equivalent salary in US terms by purchasing power.[8] We then use these salaries to fit a basic wage regression model and predict the U.S. salaries and birth/home country salaries for everyone.[9] Then, the salary premium variable is defined as the log difference between the predicted birth/work country salary and predicted USA salary.

3.2 Methodology

To assess the role of these factors on emigration decisions, we estimate Linear Probability Models of the form:

$$\mathbb{P}(\text{leave}_{ict}) = \alpha + \boldsymbol{\beta_1}\mathbf{X}_{ict} + \boldsymbol{\beta_2}\mathbf{Z}_c + \delta_c + \tau_t + \epsilon_{ict} \tag{1}$$

Where the dependent variable 'leave' is an indicator for whether one emigrated.

$\mathbf{X}$ is a vector of individual specific covariates measured at the time of graduating with a PhD or before. These are listed in Table 2. $\mathbf{Z}$ is a vector of country specific (macroeconomic) variables measured at our estimated time of departure for the individual. For those who did not depart, these are macroeconomic conditions at the time of graduation in their country of birth relative to the United States. For those who left, these are conditions in the country to which they emigrate relative to the United States. Additionally, δ_c and τ_t are country of birth and PhD cohort (time) fixed effects, respectively. Finally, we recognize that there are inherent limitations of Linear Probability Models in terms of probability predictions outside the $[0, 1]$ range. However, we do not wish to engage in predictions in this exercise *per se*, and the alternative options – Probit/Logit Models – have the limitation of the incidental parameters problem when fixed effects are included. Moreover, the Linear Probability Model lends itself to easily interpretable parameter estimates.

We repeat the estimation of the model (1) for the full sample and for the subset of individuals who received their doctorate in S&E fields. The results are listed in Tables 3 and 4. We discuss them below.

4 Results

Table 3 presents the regression results from the estimation of (1) for the full sample (all PhD fields). Column (1) includes as covariates only the vector $\mathbf{X}$ of demographic determinants of location choice.

[8] This ratio, also called the national price level, tells us how many dollars would be needed in the country in question to buy a bundle of goods that costs one dollar in the U.S. The ratio trivially equals 1 for the U.S.

[9] Predicted salaries are used for everyone so that we have a standard measure across observations.

Column (2) augments the model by adding vector $\mathbf{Z}$, the macroeconomic conditions at the estimated time of departure for the individual. Column (3) adds τ_t, the time effects, and introduces clustered standard errors, grouped by birth country. In column (4), we include the salary premium variable as a covariate and finally in column (5) we add δ_c, the country of birth fixed effects. Robust clustered standard errors are required since we introduce country specific variables in the regression, and as expected clustering does inflate the standard errors of the estimates.

We find that the effects of demographic variables included in $\mathbf{X}$ are roughly similar in sign and magnitude as those reported in Grogger and Hanson (2015) (in terms of percent reductions). The probability of leaving the U.S. is lower if the individual has a B.A. in the U.S., has U.S. Permanent Residence Status or U.S. Citizenship – all of which capture the effect of stronger ties to the U.S. The opposite effect is noted in the case of Age at Doctorate; individuals who are older when receiving their doctorate are more likely to leave the U.S., presumably because their initial migration to the U.S. to start their PhDs occurred later on in their lifetime and thus they have stronger ties to their home country. As Table 3 shows, the effect of Age at Doctorate is significant and relatively robust across specifications.

We also find that the probability of leaving is lower if the individual is married, a finding consistent with Grogger and Hanson (2015). The effect of either parent having a B.A. is fairly imprecisely measured in all our specifications, so we are unable to say anything about selection of stayers on the basis of parental education. We find that if an individual is male, he is more likely to emigrate, but this effect is significantly different from zero in only a subset of the regression models estimated, even though the magnitude stays robust to the addition of controls.

As for the covariates that capture sources of funding available to the individual, we find that probability of emigration is negatively related to receiving a RA/TA, and positively related to having received a Fellowship or funds from a foreign source. Receiving a RA/TA can be thought to increase the strength of professional networks of an individual, since it typically involves working closely with a member of faculty, and hence they're less likely to leave. On the other hand most graduate fellowships and modes of foreign support mandate that the student return to the home country after receiving her PhD, and hence we see large increases in the probability of emigration if an individual received a fellowship or foreign support.

Perhaps the most striking results that we find relate to the proxy for student ability expressed as the quality of the school the individual completed his/her doctorate from. Specifically, we see that if a foreign-born individual attended a top 10 school the probability that he/she emigrates is 3.7 - 5.9 percentage points higher, and this effect is significant across the various specifications reported in Table 2. Similarly, if an individual attended a school ranked 11-40, the probability he/she emigrates is between 1.4 - 2.2 percentage points higher, although the effect is found to be

significantly different from zero in only one regression specification. This finding is significant as it implies that it is the best among the foreign-born doctorates who are more likely to be leaving the U.S. workforce for opportunities elsewhere, and is also an insight that is different from what the literature (Grogger and Hanson, 2015; Black and Stephan, 2007) suggest except the finding by Finn (2010) who reports that on the aggregate, foreign-born U.S. PhDs from highly ranked institutions have a lower stay rate.

The remaining rows of Table 3 report the impact of the relative macroeconomic climate in the U.S. versus the individuals' country of destination. As mentioned previously, the new data allows us to do away with the assumption that the economic climate of the country (other than the U.S.) that factors in a foreign-born individual's decision to migrate is their home country. The estimates show that if GDP per capita in the U.S. grows faster relative to the other country, the individual is more likely to stay and the opposite effect is seen if the U.S. has a relatively higher unemployment rate. FDI inflows to the home/work country matter as well. If the country attracts more foreign investment, indicating an open economy with strong multinational presence, the more likely the individual is to relocate to that country.[10] These observed impact of business cycle variables on the decision of an individual to emigrate more or less echo the findings of Grogger and Hanson (2015), with the exception of the fact that we find strong and significant effects of FDI inflows to the home/work country indicating that countries with strong economic linkages to the rest of the world do indeed attract the highly talented by expanding the job prospects of U.S. trained PhDs within their borders.[11] Finally, we note that a larger salary premium is positively related to the probability of emigration, however, the standard errors are large. We suspect that the variable itself is quite noisy owing to its construction via predictions and that is a possible reason for the imprecise estimates.

In Table 4 we report the regression results for the specifications discussed above, but we restrict our attention only to S&E doctorates. The results are basically the same even though some estimates are have larger standard errors because of the drop in the sample size. This is not surprising considering that S&E students comprise 86% of our sample of foreign-born PhDs.

5 Concluding Remarks

The functioning of the highly skilled S&E workforce is the main input in the the process of research and innovation. The vast literature on economic growth recognizes this process to be a key factor

[10] Any "Relative" variable χ is defined as the ratio $\chi_{U.S.}/\chi_c$ where c is the relevant country of comparison.

[11] We have expanded the analysis by adding other macroeconomic variables that may impact location decisions such as the relative average forecasts of GDP and unemployment to capture any forward looking behavior by these individuals. However, the impact of these variables are imprecisely measured.

in driving the long run economic productivity of nations. The U.S. has long been a forerunner in this area, and part of the sustained advantage that it has had in international R&D has been driven it's ability to attract talent from the rest of the world. The representation of the foreign-born in U.S. S&E education system and workforce has grown rapidly in the past few decades. However, in an increasingly globalized economy, many other countries who recognize the value of having a highly skilled S&E workforce have been rapidly tailoring their policies to attract talent from abroad. Against the backdrop of this global scenario, it becomes very important for researchers to understand the behaviors of this pool of scientists and engineers, specifically with respect to where they choose to locate and work. This understanding is critical towards learning about the extent to which transmission of scientific knowledge is taking place across international borders through the vehicle of emigration and is essential for informing the design of policies directed towards the U.S. S&E workforce in order to maintain the long-standing advantages that the U.S. has enjoyed in scientific innovation and research. This paper uses a new dataset – the International Survey of Doctoral Recipients (ISDR) – assembled by the National Science Foundation to explore the factors, both at the individual and at the country level, that impact the location choice of foreign born U.S. doctorates.

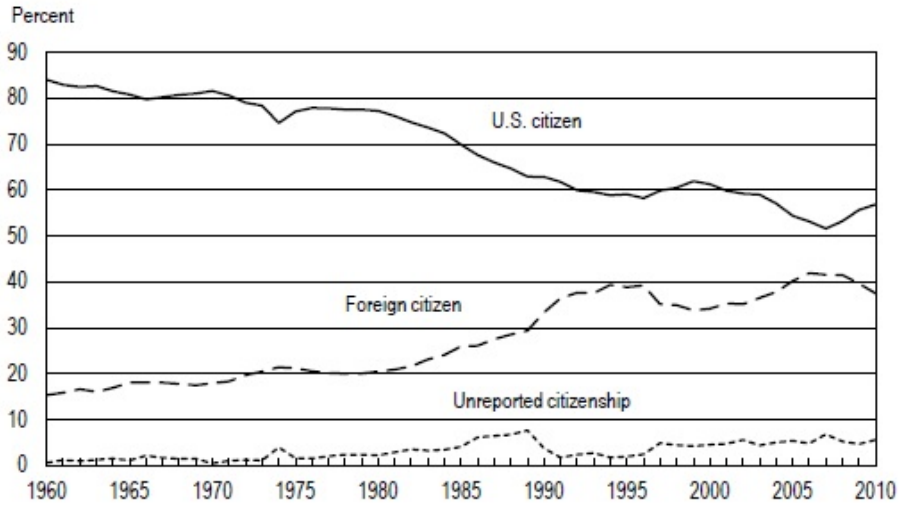
Among the results, one result stands out in particular. We find that foreign-born U.S. doctorates who leave the U.S. are positively selected in terms of skill, as measured by the quality of the school they attended. This trend has potentially damning consequences for U.S. skilled S&E workforce and competitiveness in global research and innovation, particularly when S&E skills are portable and many countries have chosen to take an active role in attracting best talents. The loss is magnified further when one considers the fact that top universities at the graduate level allocate more resources toward subsidizing education and training of doctoral students.

We recognize that our preliminary analysis omits a number of variables that are potentially significant for the analysis. Examples include the availability of research funding in the U.S. relative to other countries, the quality of patenting environments in the country of destination, a measure of social and political stability, the availability of H-1B visa in the U.S. etc. We intend to include these variables in the conditioning set so that the analysis can offer a deeper understanding of the 'stay versus leave' decisions and also create a better platform to guide policy. There is also a need to learn more about the pattern of emigration with respect to whether foreign-born U.S. graduates from developing (developed) countries are returning to developing (developed) countries or not. This issue is important particularly when the influx of foreign students are often from the same set of countries (e.g. China, South Korea, Brazil) which have been investing heavily in higher education and R&D.[12] Finally, we intend to take the analysis to a much more disaggregated level to learn about the potential impact of the current trend in the emigration pattern on U.S. S&E

[12]National Science Board (NSB) (2014)

workforce at a sectoral level. For now, we have left these issues as part of our immediate research agenda.

Figures and Tables



SOURCE: National Science Foundation/National Center for Science and Engineering Statistics, Survey of Earned Doctorates.

Figure 1: U.S. research doctorates awarded in science, engineering, or health, by citizenship: 1960 - 2010

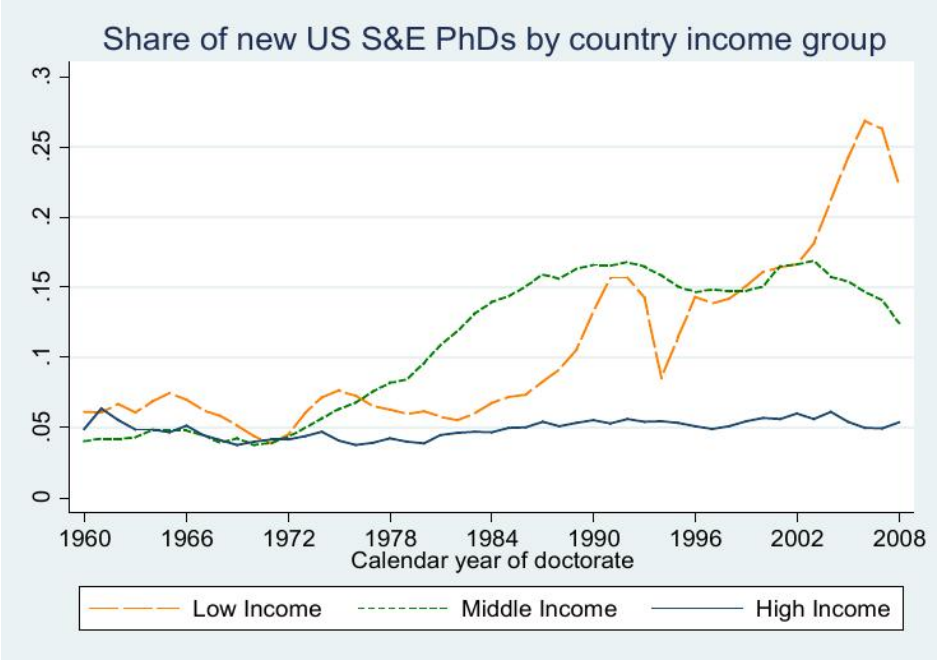


Figure 2: Foreign Born S&E PhDs by Birth Region (Grogger and Hanson, 2015).

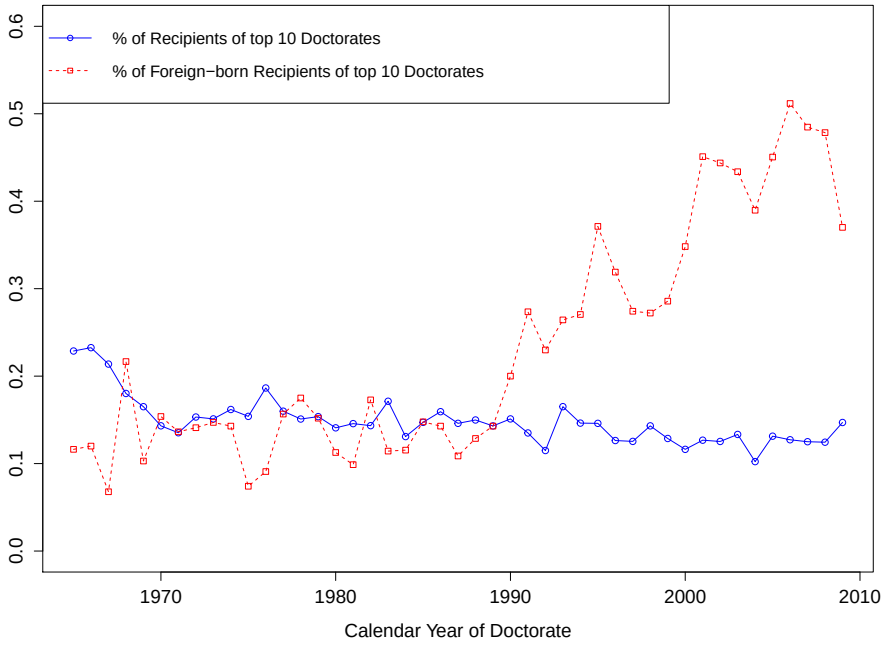


Figure 3: Trend in Doctorates from Top 10 Schools

Table 1: Foreign-born workers in S&E Occupations, by Education Level: Selected Years, 2000 - 11

Education	2000	2003		2006		2008		2009	2010		2011
	Decennial census	SESTAT	ACS	SESTAT	ACS	SESTAT	ACS	ACS	SESTAT	ACS	ACS
All college educated	22.4	22.6	24.2	23.8	25.3	24.6	24.9	25.2	27.4	26.5	26.2
Bachelors	16.5	16.4	17.7	17.3	18.1	17.2	18.4	18.3	20.1	19.0	19.0
Masters	29.0	29.4	32.0	31.7	33.5	32.7	32.7	33.4	34.9	35.0	34.3
Doctorate	37.6	36.4	37.8	36.6	41.8	37.8	40.9	41.6	41.5	44.2	43.2

ACS = American Community Survey; SESTAT = Scientists and Engineers Statistical Data System.

Notes: This table is reproduced from , Chapter 3, Table 3-27. The data from the ACS and the Decennial Census include all S&E occupations except postsecondary teachers because these occupations are not separately identifiable in the 2000 Census or ACS data files. SESTAT 2006 and 2008 data do not include foreign workers who arrived in the United States after the 2000 Decennial Census and also did not earn an S&E degree in the United States.

Sources: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (2003-10), `http://sestat.nsf.gov`; Census Bureau, 2000 Decennial Census Public Use Microdata Sample (PUMS), and ACS (2003, 2006, 2008, 2009, 2010, 2011).

Table 2: Descriptive Statistics

Proportions for Variables of Interest (%)	Total Sample (n = 8430)	Emigrated (n = 2086)	Stayed (n = 6344)
From a S&E Field	85.72	78.19	88.19
From a Developed Country	52.67	61.27	42.75
From a Non-Developed Country	47.33	38.73	57.25
Currently in an Academic Job	48.33	62.32	43.73
Currently in a Non-Academic Job	51.67	37.68	56.27
Covariates			
Bachelors' in the US	20.68	7.91	24.87
Either Parent has a Bachelors'	56.81	55.61	57.20
Male	66.32	68.74	65.53
Married	62.09	53.36	64.96
US Permanent Resident	14.25	2.30	18.17
US Citizen	14.69	1.97	18.87
Received RA/TA	60.19	52.92	62.58
Received Fellowship	17.32	22.72	15.54
Received Foreign Support	5.16	12.27	2.82
Attended a Top 10 School	12.88	13.85	12.56
Attended a School Ranked 11-40	31.73	32.45	31.49

Table 3: Regression Results for Full Sample

	(1)	(2)	(3)	(4)	(5)
B.A. in US	–.04369***	–.03944**	–.04599	–.04737	–.11149***
	(.01304)	(.01550)	(.03029)	(.03050)	(.02239)
Parent has B.A.	–.00048	.00203	.00045	–.00116	–.01364*
	(.00894)	(.01038)	(.01901)	(.01768)	(.00776)
Male	.00138	.02358**	.02896	.02749	.02532*
	(.00914)	(.01015)	(.01815)	(.01820)	(.01371)
Married	–.08177***	–.08930***	–.08668**	–.08649**	–.04310**
	(.00967)	(.01094)	(.03954)	(.03890)	(.02097)
Age at Doctorate	.00804***	.00765***	.00688***	.00675***	.00421***
	(.00090)	(.00104)	(.00218)	(.00216)	(.00109)
US Permanent Resident	–.27043***	–.28366***	–.23356***	–.23469***	–.19998***
	(.00932)	(.01100)	(.05596)	(.05662)	(.05312)
US Citizen	–.29172***	–.31999***	–.28819***	–.28782***	–.25512***
	(.01386)	(.01669)	(.03959)	(.03997)	(.03553)
Received RA/TA	–.02223**	–.05664***	–.08813***	–.08744***	–.03556***
	(.01122)	(.01493)	(.01838)	(.01833)	(.01355)
Recieved Fellowship	.11583***	.08467***	.02957	.02881	.03844**
	(.01467)	(.01771)	(.02356)	(.02343)	(.01737)
Received Foreign Support	.32604***	.30240***	.25064***	.25014***	.13013***
	(.02297)	(.02496)	(.05969)	(.06032)	(.03204)
Attended a Top 10 School		.05173***	.05908***	.05840***	.03698**
		(.01635)	(.01937)	(.01984)	(.01565)
Attended a School Ranked 11-40		.01977*	.02257	.02131	.01458
		(.01110)	(.01582)	(.01599)	(.01109)
Relative GDP Growth		–.00039***	–.00040***	–.00041***	–.00027***
		(.00011)	(.00013)	(.00014)	(.00009)
Relative Unemployment		.04913***	.05754**	.05727**	.04684**
		(.00710)	(.02794)	(.02857)	(.02180)
FDI Inflows (Home/Work Country)		.01269***	.01051***	.01109***	.01861***
		(.00134)	(.00379)	(.00389)	(.00442)
Salary Premium				.01002	.00930
				(.02082)	(.01199)
Time Fixed Effects	No	No	Yes	Yes	Yes
Birth Country Fixed Effects	No	No	No	No	Yes
Clustered Std. Errors	No	No	Yes	Yes	Yes
R^2	.156	.176	.212	.213	.349
No. of Observations	8430	6865	6865	6815	6815

Table 4: Regression Results for Science and Engineering Only, Weighted

	(1)	(2)	(3)	(4)	(5)
B.A. in US	–.03181**	–.02472	–.03291	–.03372	–.10304***
	(.01392)	(.01671)	(.03444)	(.03470)	(.02394)
Parent has B.A.	–.00290	.00310	.00153	.00041	–.00958
	(.00941)	(.01096)	(.01996)	(.01849)	(.00805)
Male	.00051	.01936*	.02408	.02197	.02271*
	(.00974)	(.01084)	(.01645)	(.01640)	(.01200)
Married	–.08206***	–.09255***	–.09003**	–.09062**	–.04368**
	(.01028)	(.01169)	(.03874)	(.03825)	(.01923)
Age at Doctorate	.00709***	.00649***	.00580***	.00581***	.00334***
	(.00099)	(.00115)	(.00189)	(.00192)	(.00103)
US Permanent Resident	–.25236***	–.26617***	–.22107***	–.22220***	–.18752***
	(.00928)	(.01116)	(.05518)	(.05580)	(.05218)
US Citizen	–.27511***	–.30728***	–.27691***	–.27692***	–.25016***
	(.01468)	(.01796)	(.03893)	(.03925)	(.03576)
Received RA/TA	–.00860	–.04625***	–.07945***	–.07878***	–.03097*
	(.01174)	(.01612)	(.02112)	(.02143)	(.01576)
Recieved Fellowship	.12567***	.09280***	.03629	.03533	.03970**
	(.01603)	(.01957)	(.02559)	(.02547)	(.01955)
Received Foreign Support	.33475***	.30986***	.25719***	.25677***	.12330***
	(.02532)	(.02746)	(.06166)	(.06250)	(.03265)
Attended a Top 10 School		.04873***	.05700***	.05641***	.03513**
		(.01785)	(.01786)	(.01794)	(.01424)
Attended a School Ranked 11-40		.01040	.01351	.01244	.01226
		(.01175)	(.01423)	(.01439)	(.01034)
Relative GDP Growth		–.00040***	–.00041***	–.00042***	–.00024**
		(.00010)	(.00012)	(.00014)	(.00010)
Relative Unemployment		.05233***	.06200*	.06177*	.06499*
		(.00818)	(.03436)	(.03519)	(.03742)
FDI Inflows (Home/Work Country)		.01390***	.01170***	.01228***	.01912***
		(.00140)	(.00435)	(.00444)	(.00419)
Salary Premium				.00753	.00083
				(.02104)	(.01232)
Time Fixed Effects	No	No	Yes	Yes	Yes
Birth Country Fixed Effects	No	No	No	No	Yes
Clustered Std. Errors	No	No	Yes	Yes	Yes
R^2	.144	.168	.204	.205	.352
No. of Observations	7226	5854	5854	5809	5809

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