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International STEM Students Are Up for Grabs

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EXECUTIVE SUMMARY

If current trends continue, international students will comprise half of U.S. science, technology, engineering, and mathematics (STEM) PhD graduates by 2020.

The proportion of international PhD-level students on temporary visas to study STEM subjects in the United States has doubled over the past thirty years. Further, these students are much more likely than domestic students to major in and graduate with STEM-related doctoral degrees and to pursue careers in high-tech firms. The United States stands to lose its significant investment in these highly qualified students—and their potential contributions to U.S. entrepreneurship and innovation—if they return to their home countries after completing their degrees or post-doctoral work.

We explore why foreign graduate students choose to study in the United States and what compels them to either remain in the country or return home after earning their degrees. We also compare their future plans with those of domestic graduate students.

- The primary factor that attracted foreign students to complete their graduate studies in the United States was higher quality of education (84 percent), followed by future career opportunities (74 percent), wanting to experience living abroad (45 percent), opportunity to work with specific faculty (37 percent), and wanting to live in the United States (22 percent). More than 55 percent of foreign students felt their U.S. academic experiences were much better or very much better as compared to their home countries.
- Most international students (48 percent) wish to stay in the United States after graduation, citing future job opportunities as the key factor influencing the desire to remain. Only 12 percent want to leave, but 40.5 percent are undecided. This latter group represents a sizeable pool of talented scientists and engineers who may—or may not—become part of the skilled U.S. workforce.
- The most important factor in determining whether a foreign graduate student wanted to stay in or leave the United States after graduation was why the individual chose to pursue graduate studies in the United States in the first place. If the student selected future career opportunities as a reason for deciding to study here, there is an 87 percent likelihood he or she wants to stay in the United States.
- Among those who did not select future career opportunities as a motivator for U.S. study, the decision to stay or go is influenced by whether they are aware of programs or policies in their home countries that encourage people to return from abroad. For those who are not aware of such home country incentive programs

[1] Views expressed here reflect the authors' personal perspectives, not the policy positions of their home organizations. This work was supported by the National Science Foundation Grant No. SES 0938099.

or policies, there is a 71 percent likelihood that they will want to stay in the United States.
- Those who plan to return to their home countries after graduation cited family as the most important influence in the decision to leave the United States.
- International graduate students who want to seek employment with a company or start their own companies are significantly more likely to want to remain in the United States (77 percent) than are those who want to remain in academia, work for a governmental agency, or work for an NGO (68 percent).

These findings have important policy implications. In 2014, immigrant entrepreneurs founded 29 percent of all new U.S. startups, nearly twice as much as that of U.S.-born adults. Although the United States remains an innovation powerhouse, it runs the risk of losing its competitiveness unless it changes its legal immigration policies to ease the long and arduous process now required of highly skilled foreign STEM workers.

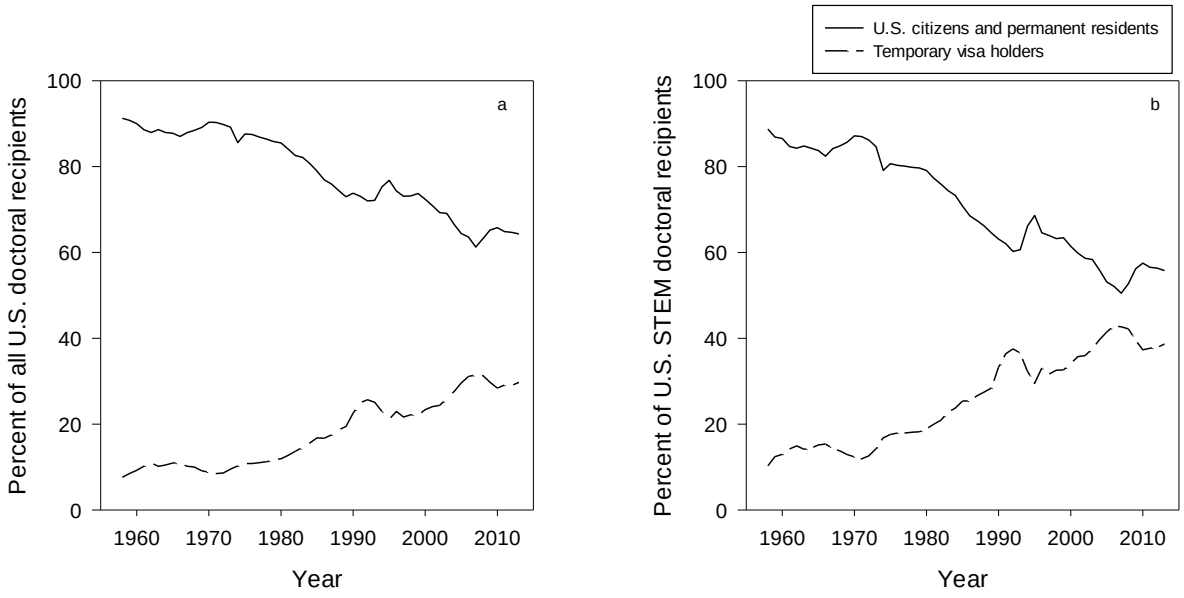
INTERNATIONAL STEM STUDENTS: IMPORTANT TO U.S. INNOVATION

International students studying in the United States on temporary visas accounted for nearly two-fifths (39 percent) of all PhDs in science, technology, engineering, and mathematics (STEM) fields in 2013—a proportion that has doubled over the past three decades (see Appendix for details). Moreover, international doctoral students were significantly more likely than domestic students to major in and graduate from STEM disciplines in the United States.[2]

If these trends continue, we estimate that the majority of STEM PhDs from U.S. universities will go to international students by the year 2020 (Figure 1). This represents a considerable investment of public and private resources, the return on which may well be lost to the United States if the most highly qualified of these students are compelled to leave the country after they complete their degrees or postdocs. Of these international students, 69 percent came from China, India, South Korea, and Taiwan.[2] These are emerging economies that are seen as increasingly challenging to U.S. dominance in science and technology, and which also are building their own research and university systems. Understanding why international students seek U.S. PhDs and what motivates them to stay or leave upon graduation has important implications for the future of U.S. innovation, competitiveness, and economic progress.

[2] NSF and NCSES. 2013. *Doctorate Recipients from U.S. Universities: 2013*. Special Report NSF 15-304. Arlington, Va. Available at http://www.nsf.gov/statistics/sed/2013/.

Figure 1. Domestic and international students as percentages of all U.S. doctoral recipients and STEM doctoral recipients, 1957/58–2012/13



Note: Data from the National Science Foundation Survey of Earned Doctorates.[3]

SURVEY DESIGN AND IMPLEMENTATION

To better understand what motivates foreign STEM graduate students to study in the United States, then stay—or return home—after earning their PhDs, we conducted an email survey of domestic and international graduate students who were enrolled in STEM disciplines at the ten U.S. institutions with the largest total number of enrolled international students (see Table S1).[4] Domestic students were included in our survey to determine whether their future career plans differed significantly from those of international students. Differences in career trajectories, particularly for going into industry or creating startups, may have important consequences to U.S. economic progress and development. Our survey asked about the students' reasons for studying in the United States, perceptions of the U.S. education system, post-graduation goals, and if they planned—or hoped—to remain in the United States after graduation.[5]

Within each institution, only departments that provided a STEM graduate degree as identified by the U.S. Immigration and Customs Enforcement were included in our

[3] National Science Foundation, National Center for Science and Engineering Statistics. 2015. "Science and Engineering Degrees: 1966–2012." Available at http://www.nsf.gov/statistics/2015/nsf15326/pdf/nsf15326.pdf.

[4] Institute of International Education. 2014. "Top 25 institutions hosting international students, 2013/14." *Open Doors Report on International Educational Exchange*. Accessed July 7, 2015. Available at http://www.iie.org/opendoors.

[5] Our survey received Human Subjects approval from the Office of Research's Human Subjects Committee, University of California Santa Barbara. For a full discussion of the methodology and methods of statistical analysis, please see the Appendix.

survey.[6] A total of 114 departments across the ten institutions met our selection criteria. Of these, fifty-seven departments provided public access to their graduate students' contact information. From these, we identified 11,685 email addresses that belonged to both international as well as domestic graduate students. For the remaining fifty-seven departments in which graduate student information was not made public, we contacted the department chair, graduate coordinator, and/or graduate advisors to elicit help in contacting their graduate students through their internal listservs. Twenty-one of the fifty-seven departments agreed to send our email to their graduate students, but we were unable to make contact with students from the remaining thirty-six departments. Based on the number of email addresses we collected from the fifty-seven departments that provided public contact information, we estimated that a department has, on average, 205 graduate students. From this, we calculated that the twenty-one departments that sent emails on our behalf reached approximately 4,305 students. Combined with the email addresses that we collected, we estimate that our survey reached roughly 15,990 students.

A total of 2,810 individuals responded to our survey, a high response rate given the length of the survey and the fact that an unknown number of our emails were filtered as spam. Once we controlled for incomplete surveys and removed individuals who identified themselves as social science majors, we were left with a usable sample of 2,322 responses, giving us a response rate of 14.5 percent. Our statistical analyses are based on the sample of 2,322 completed surveys.

Of the 2,322 respondents, approximately 66 percent (1,535 individuals) were domestic students (i.e., U.S. citizens or permanent residents), while 34 percent (787 individuals) were international students (i.e., temporary visa holders) representing seventy-four nationalities (Table S1). China was the leading country of origin, accounting for 29.9 percent of all international survey respondents, followed by India (25.7 percent), Taiwan (3.7 percent), Turkey (2.9 percent), and the Republic of Korea (2.5 percent; Table S2).

To examine the representativeness of our sample population, we compared our PhD population demographics to that of the Survey of Earned Doctorates (SED), an annual survey since 1957 of all individuals receiving research doctorates from accredited U.S. institutions in a given academic year.[7] As the Survey of Earned Doctorates does not include master's degree-seeking students, we compared our master's degree student population to that of the Integrated Postsecondary Education Data System Completions Survey, conducted by the National Center for Education Statistics, U.S. Department of Education.[8] These data enabled us to calculate the relative percent of international and

[6] U.S. Immigration and Customs Enforcement. 2012. "STEM-designated degree program list. 2012 Revised list: additions are in bold." Accessed July 7, 2015. Available at http://www.ice.gov/sites/default/files/documents/Document/2014/stem-list.pdf.

[7] National Science Foundation, National Center for Science and Engineering Statistics. 2015. "Science and Engineering Degrees: 1966–2012." Available at http://www.nsf.gov/statistics/2015/nsf15326/pdf/nsf15326.pdf.

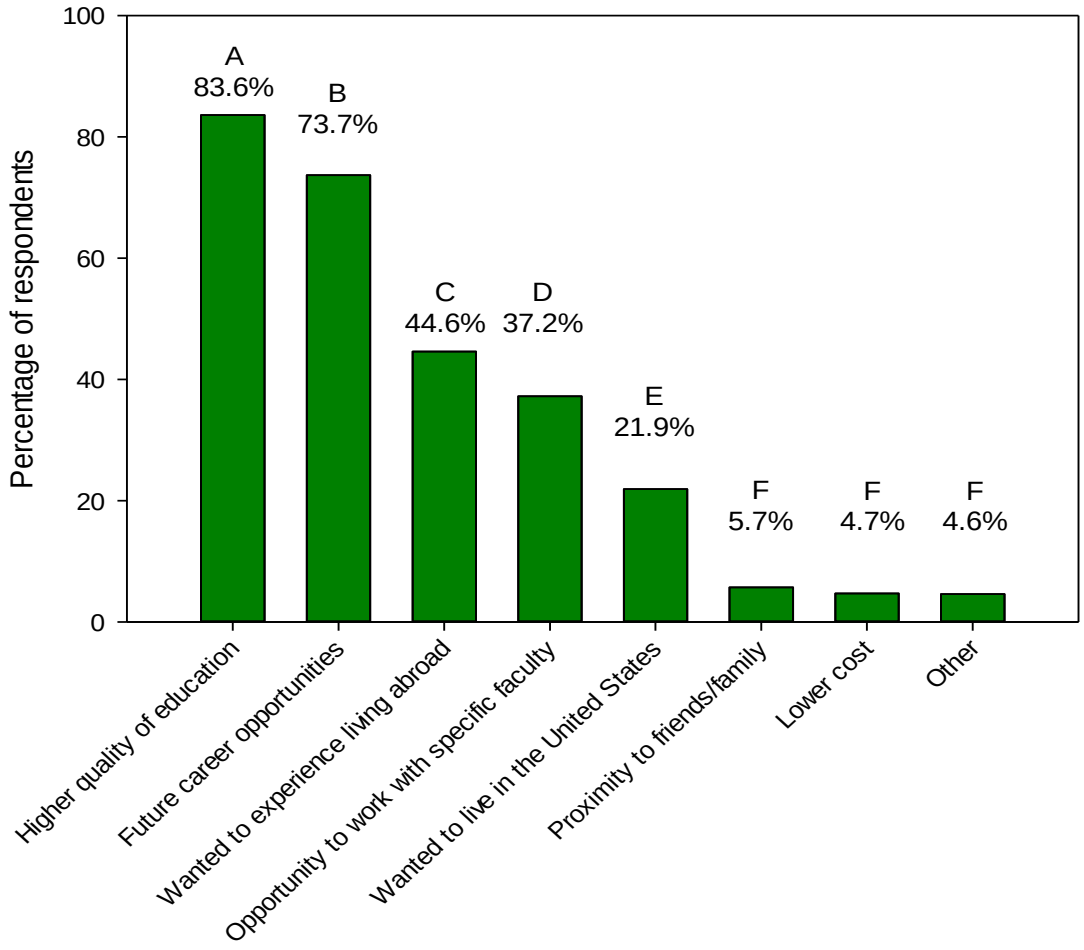
[8] Allum, J. (2014). Graduate enrollment and degrees: 2003 to 2013. Washington, D.C.: Council of Graduate Schools.

domestic doctoral recipients who majored in STEM fields out of all U.S. research doctoral degrees by international and domestic students, respectively. The sample demographics as categorized by citizenship, degree-seeking program, and gender are all within one to two percentage points of the national population, indicating that, overall, our sample population is representative of the national population (Table S3).

WHY DO THEY COME?

There were significant differences among the reasons international students chose to conduct their graduate studies in the United States. ($P<0.001$, Figure 2). Pairwise comparisons showed that factors influencing international students' decisions to study in the United States fell into six statistically significantly different categories. *Higher quality of education* was the most important factor, with 84 percent of all respondents indicating that it was a major factor in their decision to study in the United States. (Figure 2). This was followed by *future career opportunities* (74 percent of respondents), *wanting to experience living abroad* (45 percent), *opportunity to work with specific faculty* (37 percent), and *wanting to live in the United States* (21.9 percent). The remaining three factors were not significantly different from one another and together formed the sixth category: *proximity to friends/family* (5.7 percent), *lower cost* (4.7 percent), and *other* reasons (4.6 percent).

Figure 2. Factors for why international students decided to pursue their graduate studies in the United States.



Note: Cochran's Q-test indicated that there were significant differences among the percentage of individuals who selected each factor (P<0.001).[9]

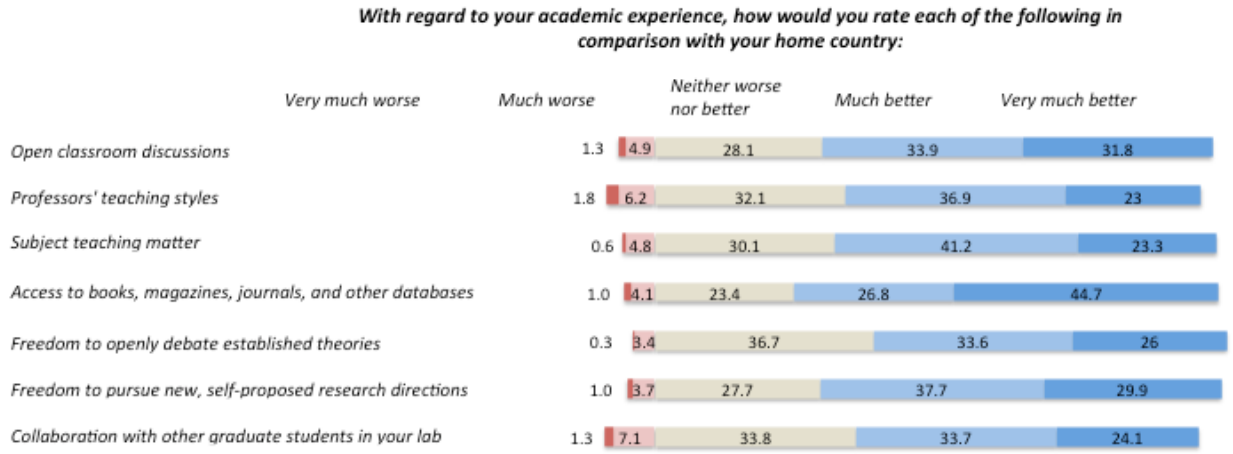
THE IMPORTANCE OF EDUCATIONAL QUALITY

More than 55 percent of all international respondents believed that their academic experiences in the United States are *much* better or *very much better* in comparison to their home countries for each of the seven academic experiences in our survey (Figure 3). There were significant differences on a number of educational quality factors between the percent of students rating their U.S. experience as *much better or very*

[9] Different letters indicate significant differences among factors. In this case, higher quality of education was significantly higher than future career opportunities, which was significantly higher than wanted to experience living abroad, etc. The same letter indicates factors that are not significantly different from one another (i.e., proximity to friends/family, lower cost, and other).

much better than their home country experiences, as opposed to *much worse* or *very much worse*:

Figure 3. U.S. academic experiences, in comparison with that of individuals' home countries.[10]

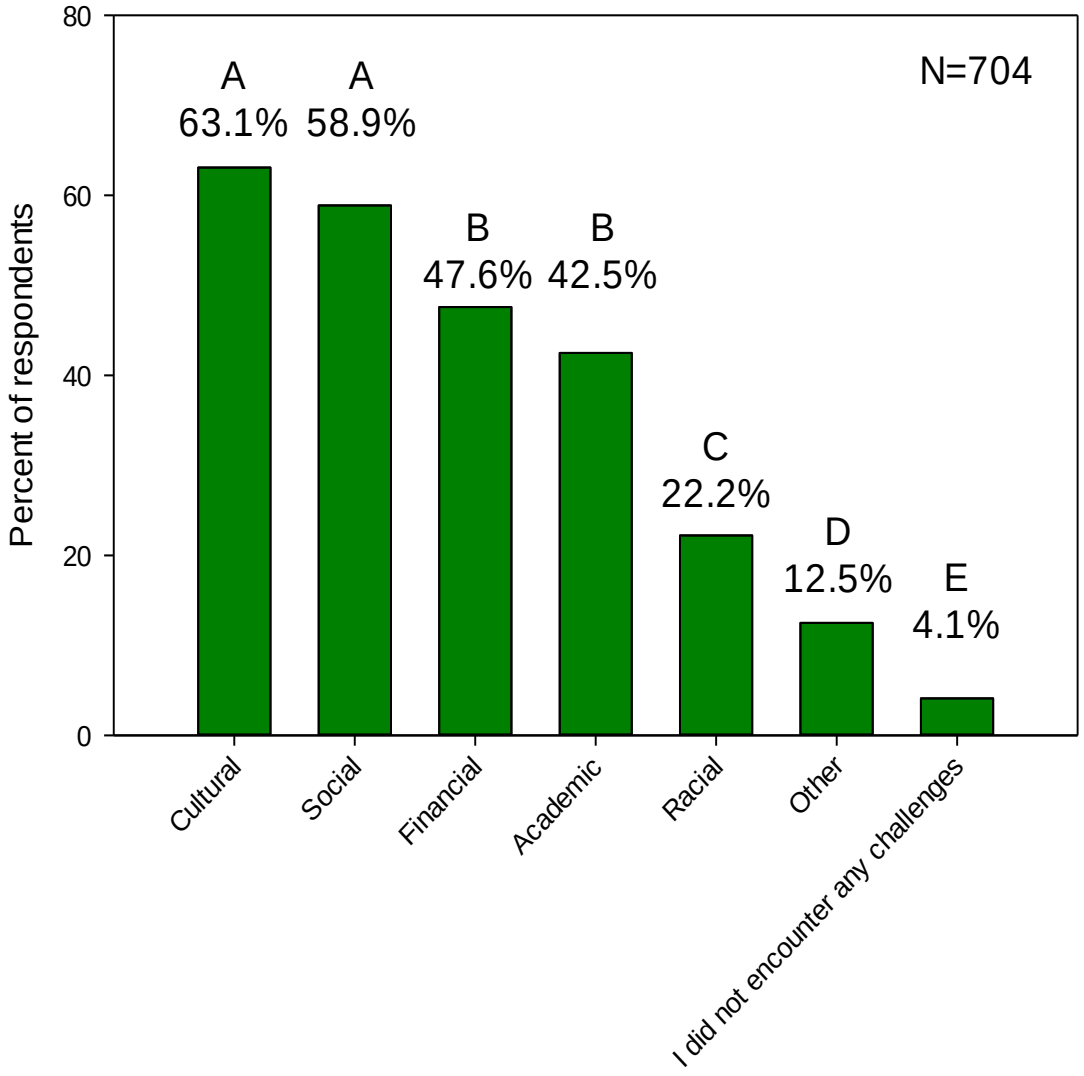


In a similar vein, the percentage of students who feel they are being treated *better or much better* (46.7 percent) by professors and colleagues in the United States in comparison with those in their home countries was considerably higher than the percentage of students (7.0 percent who feel they are being *treated worse* or *much worse* ($P<0.01$). On the other hand, when posed the same question in terms of returning home, a significantly higher percentage of students (49.6 percent) believed they would be *treated better* or *much better* by colleagues and professors in their home countries if they returned than believed their treatment would be *worse* or *much worse* (6.4 percent, $P<0.01$).

All was not perfect for international students, however (Figure 4). A high percentage of international students (87.5 percent) faced one or more challenges during their graduate studies in the United States (Figure 3). The highest percentage of students reported encountering *cultural challenges* (63.1 percent), followed by *social challenges* (58.9 percent), *financial challenges* (47.6 percent), *academic challenges* (42.5 percent), and *racial challenges* (22.2 percent). A small percentage of respondents (4.1 percent) indicated that they have not encountered any challenges in their time in the United States, and 12.5 percent of individuals indicated that they encountered *other challenges* than the ones identified in the survey.

[10] N=787 for each academic category.

Figure 4. Percent of individuals who have experienced cultural, social, financial, academic, racial, other challenges, or no challenges during their time in the United States as graduate students.



Note: Cochran's Q-test indicated that there were significant differences among the percentage of individuals who selected each factor ($P<0.05$). See footnote 8 for explanation.

TO LEAVE OR TO STAY: THAT IS THE QUESTION

We found that, although most international students (47.8 percent of respondents)[11] would like to stay in the United States upon graduation, a large percentage (40.5 percent) is undecided. Only 11.7 percent want to leave, mostly with *family reasons* (cited by 77 percent of those who want to leave) the main factor.

For those who indicated wanting to stay in the United States, there were significant differences among which factors are most important in influencing this decision ($P<0.001$; Figure 5). *Future job opportunities* was the most important factor among individuals who want to stay and was significantly more important than all other factors ($P<0.001$ for all pairwise comparisons). This was followed by *overall quality of life, professional network opportunities*, and *salary*. Social reasons were influential for only 21 percent of those who wish to stay in the United States, while *opportunities for family members, geographic location, family, friends*, and *cultural reasons* accounted for fewer than 20 percent each.

For those who plan to leave the United States after graduation (Figure 6), there were also significant differences among which factors are important ($P<0.001$) with *family* as the most significant factor ($P<0.001$ for all pairwise comparisons) for influencing individuals' decisions to leave.

[11] The NSF Survey of Earned Doctorates (SED) assesses whether an individual will stay in the United States within one year of completing his or her degree. It does not address whether an individual would stay in the United States if given the choice. We compared the stay-rate from the 2014 SED (71.1 percent) to ours (47.8 percent) and found that the stay-rate from the SED is significantly higher than the percentage of individuals who wish to stay from our survey ($X^2_1 = 1931.1$, $P<0.01$). This difference is most likely because we provided individuals in our survey with an additional choice of *do not know/not sure* in their decision to stay in or leave the United States.

Figure 5. Influential factors for staying among individuals who wish to remain in the United States.

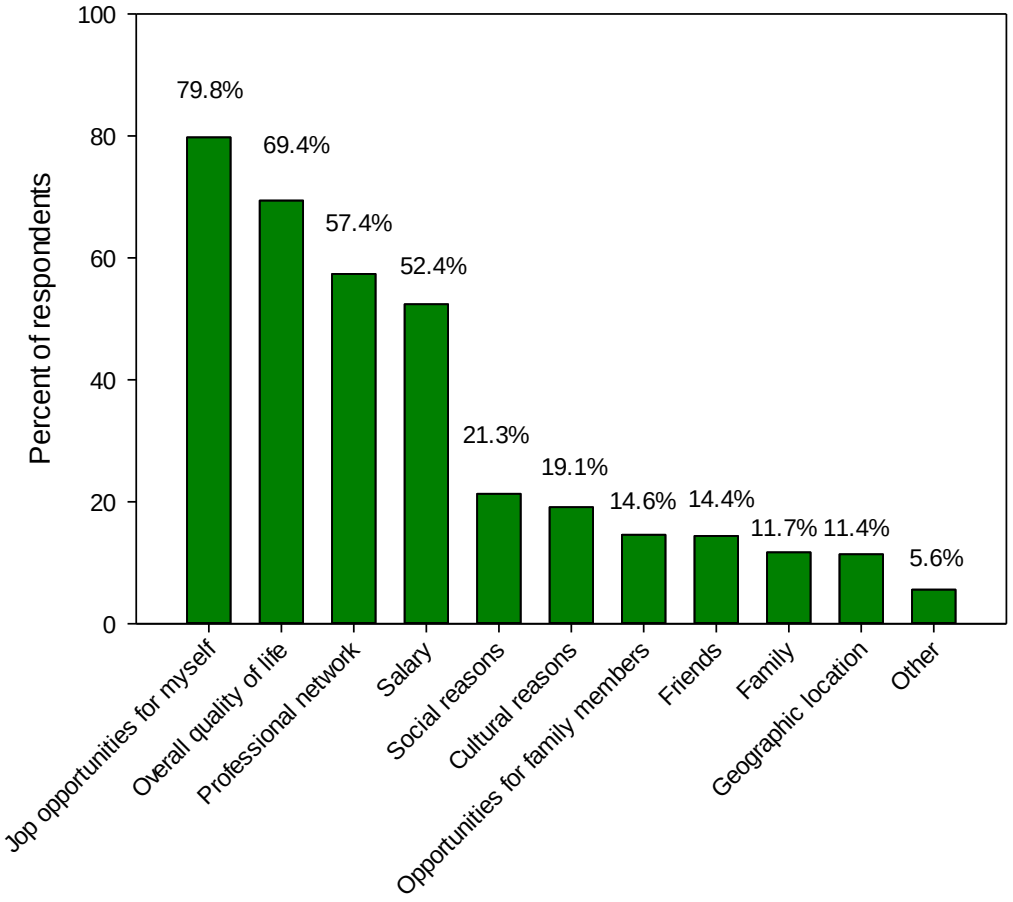
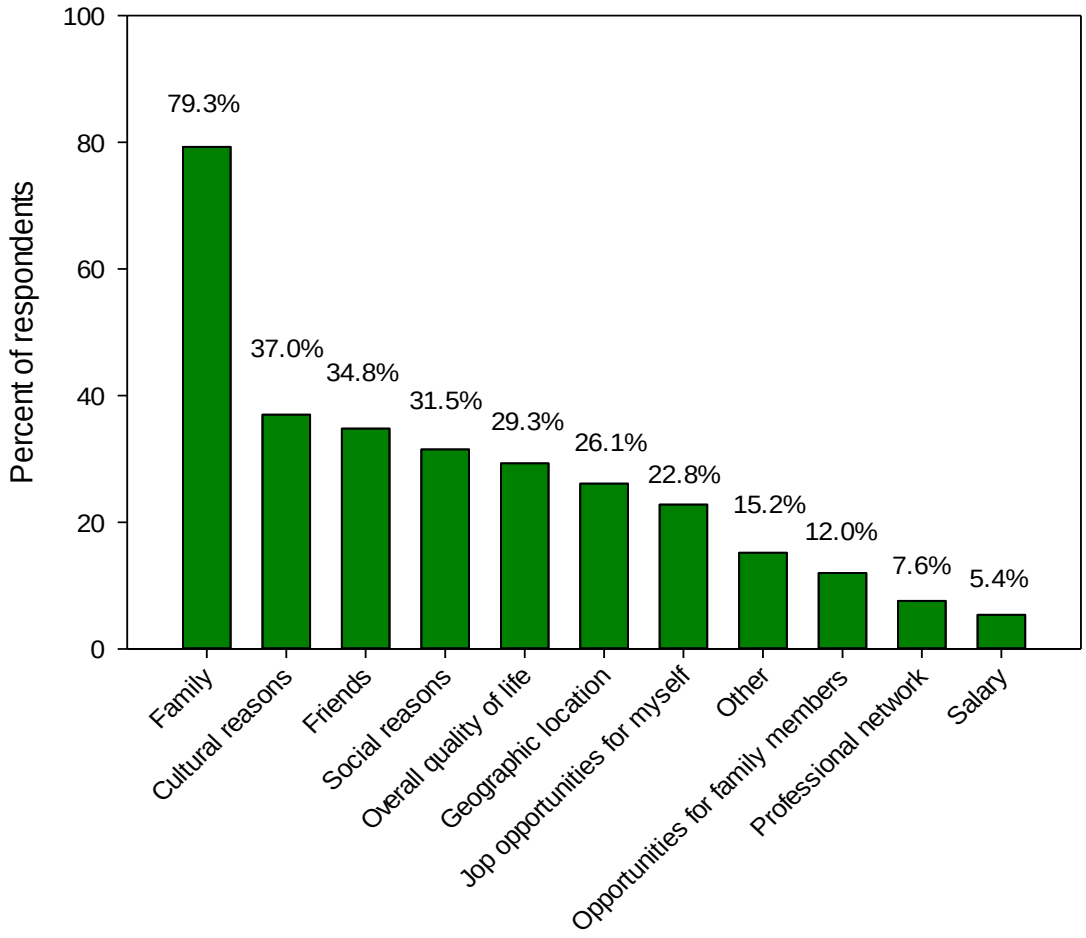


Figure 6. Influential factors for leaving among individuals who wish to leave the United States



We note that the “undecideds” (41 percent) represent a sizeable pool of talented scientists and engineers whose future, at least in the near term, is up for grabs. Will they stay and become part of the skilled, innovative U.S. workforce, or leave for their home or other country? The Chinese government, for example, recognizes the importance of repatriating its many talented expats who are enrolled in top STEM PhD programs throughout the United States, Europe, and Japan and has enacted policies such as the Thousand Talents Program and Thousand Young Talents Program to provide professional and financial incentives to attract returnees. Given that international students are well on their way to becoming a majority of U.S. STEM doctoral students, this trend could have a considerable impact on the U.S. talent pool.

DIFFERENCES IN CAREER PLANS

We found that, among all career options, respondents preferred to stay in academia (39 percent of all individuals), followed by wanting to seek employment with a company (31

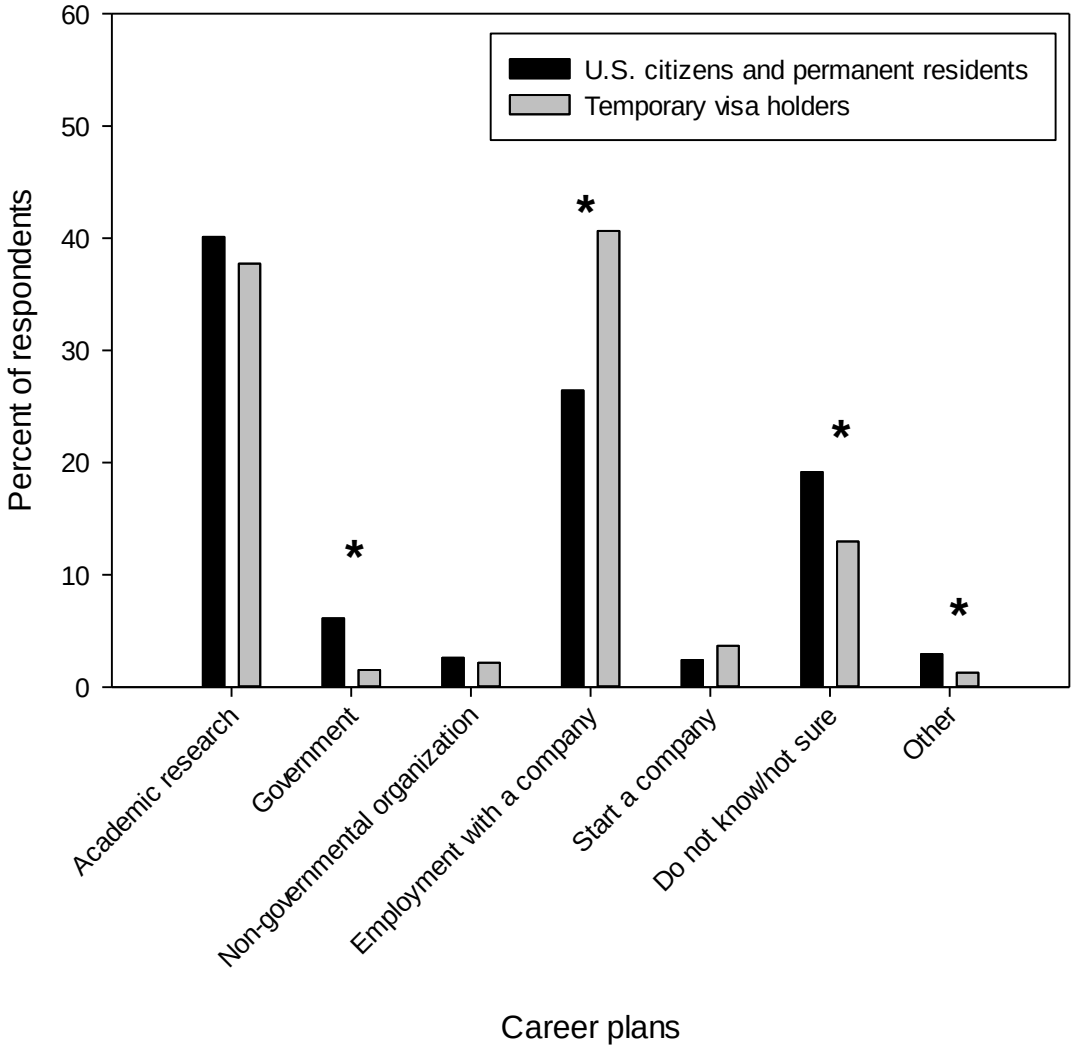
percent). Only a small percentage of individuals wanted to work for governmental agency (4.6 percent), start their own companies (2.8 percent), or work for a non-governmental organization (2.5 percent). A higher percentage of respondents (13 percent) were interested in 'other' career options, and some did not know or were uncertain of their future career plans (6.0 percent; Figure 7).

International students were significantly more likely than their domestic counterparts to seek employment with a company ($P<0.001$); and they are significantly less likely than domestic students to want to work for a governmental agency ($P<0.001$), to be unsure in what they want to do upon graduation ($P<0.001$), and to choose 'other' career plans ($P=0.02$). There were no significant differences between domestic and international students in terms of who wanted to remain in academia ($P=0.28$), start their own companies ($P=0.11$)[12], or work for a non-governmental agency ($P=0.61$). For international students, there was no significant difference in the percentage of respondents who wanted to pursue academic research (38 percent)[13] and those who wanted to seek employment with a company (41 percent; $P=0.26$). Domestic students significantly preferred academic research (40 percent) to seeking employment with a company (27 percent; Figure 7).

[12] Because of the low number of individuals who indicated they would like to *start their own companies* as a post-graduate career plan (N=29 for international respondents, N=37 for domestic students), we could not perform any additional analyses to determine if there were any demographic or disciplinary factors associated with which individuals were likely to *start their own companies*.

[13] A two-sample proportion test showed that the percentage of international graduates who were taking a post-doc position after graduation (44.2 percent from the 2014 SED) is significantly higher than the percentage of individuals who indicated they would like to pursue a post-doc in our survey (37.7 percent; $X^2_1 = 12.5$, $P<0.01$). This difference can be accounted for by the fact that the NSF identifies a "post-doc" as a temporary position for gaining additional education and training in research, usually awarded in academe, industry, government, or a non-profit organization. In our survey, *government* and *non-profit organization* were categorized separately from academic post-docs. When we combine the number of individuals who selected these three categories (41.6 percent), we find that there is no significant difference between our data and that of NSF's ($X^2_1 = 2.2$, $P=0.13$).

Figure 7. Future career plans, U.S. citizens/permanent residents and foreign students



WHO WISHES TO STAY IN THE UNITED STATES (AND WHO DOESN'T)?

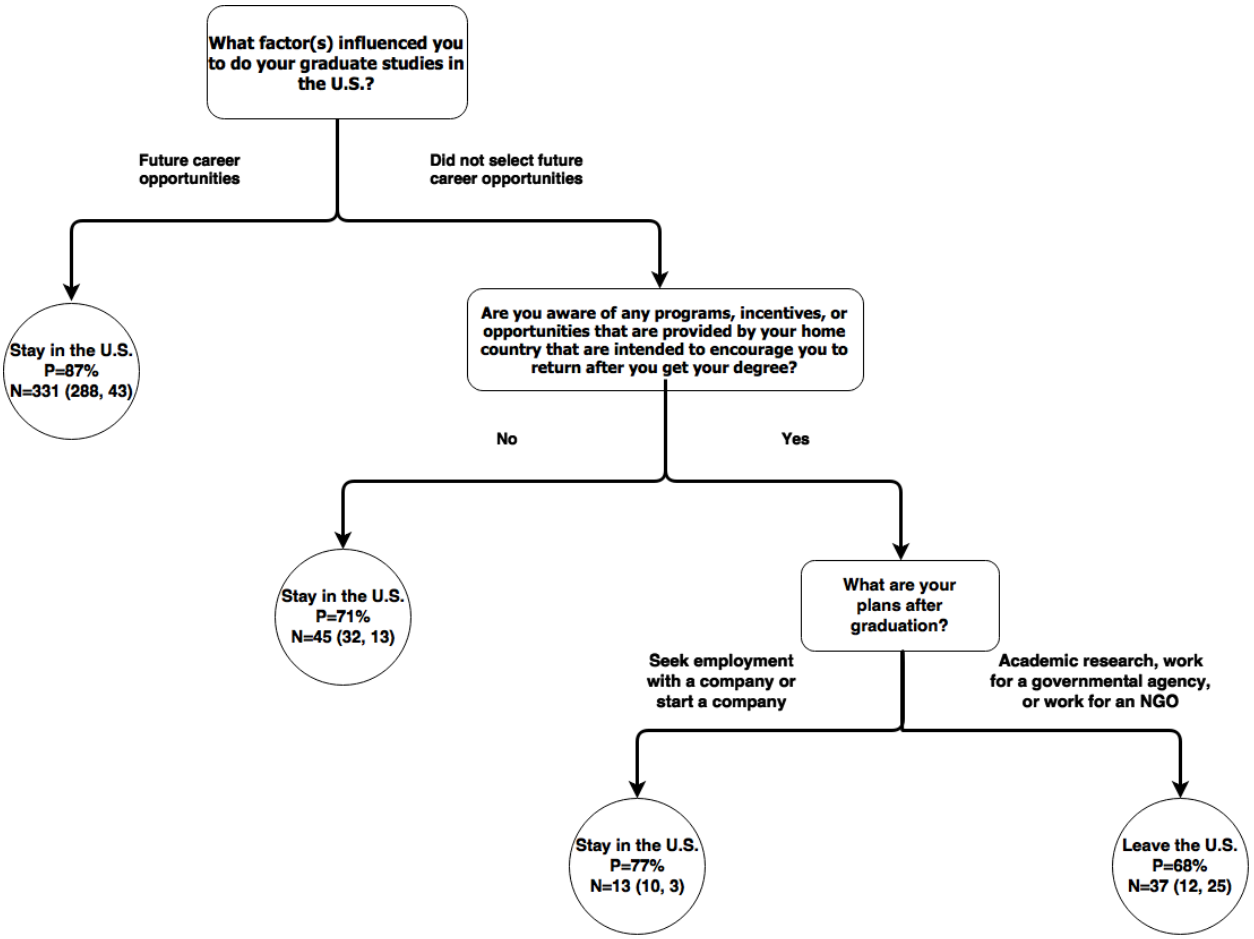
The biggest value added by this study is our assessment of what kinds of students wish to stay (or leave) the United States upon graduation. To better understand what prompts international students to stay or leave upon completing their studies, random forests were used to determine variable importance among thirty-nine variables. Classification trees then were grown and pruned to determine how professional, social, and personal factors interacted to influence their decisions (a full discussion of this methodology is available in the Appendix).

We found that the most important factor[14] determining whether an individual would want to stay in or leave the United States upon graduation was why that individual was motivated to pursue his/her graduate studies in the United States in the first place (Figure 8). If *future career opportunities* was selected as a reason for why an individual decided to study in the United States, then there is an 87 percent likelihood that an individual will want to stay in the United States. For those who did not select *future career opportunities*, their decisions are influenced by whether they are aware of any incentive programs or policies provided by their home countries to encourage people to return from abroad. For those who are not aware of such home country incentive programs or policies, there is a 71 percent likelihood that they will want to stay in the United States.

For those who are aware of home country incentive programs or policies, their decision to stay or leave is influenced by their career plans. Individuals who want to seek employment with a company or start their own companies are significantly more likely to want to remain in the United States (77 percent) than are those who want to remain in academia, work for a governmental agency, or work for an NGO (68 percent).

[14] Thirty-nine total variables were included in the random forest model. Nine variables (i.e., reason for studying in the United States; postgraduate career plan; year of study in graduate program; awareness of policies from home countries that encourage repatriation; whether an individual believes that the United States provided him or her with any kind of advantage over his or her home country; challenges encountered in the United States; whether an individual received any undergraduate education in the United States; and age) were considered to be important by looking at the mean decrease in accuracy associated with each variable. *Year of study* was one of the nine variables to be included in the classification tree analysis, but it was eliminated through the pruning process and did not make it into the final classification tree. A multiple proportions test showed that the percentage of individuals who wish to stay in the United States is not significantly different among different years of study (P=0.08). The final classification tree indicated that the interaction of three main factors (i.e., *future career opportunities* as a reason for studying in the United States, awareness of programs from home countries to enhance repatriation, and plans after graduation) determine whether an individual wishes to stay in or leave the United States upon graduation.

Figure 8. Final classification tree (N=426) showing which factors influence international graduate students' decisions to stay in or leave the United States upon graduation.



N=426. For full explanation, see Appendix.

WHY SHOULD IT MATTER?

If current trends continue, international students will account for half of all PhD students in STEM fields in U.S. universities by 2020. Retaining the "best and the brightest" of these students would contribute to the U.S. innovation system—yet, U.S. immigration policy makes it difficult for such students to remain.[15] Given that nearly two out of five international students in our survey are undecided about whether to stay or leave, and that more than a third are aware of programs or incentives designed to lure them back home, it appears that the United States is in danger of systematically losing a portion of its best-trained STEM graduates. Our findings indicate that, while international and domestic students have roughly equal aspirations to pursue careers in academic research (40 percent v. 38 percent respectively; P=0.28), domestic students significantly

[15] Han, X., G. Stocking, M. Gebbie, and R. P. Appelbaum. 2015. "Will They Stay or Will They Go? International Graduate Students and Their Decisions to Stay or Leave the U.S. Upon Graduation." PLoS ONE. 10(3): e0118183. doi:10.1371/journal.pone.0118183.

preferred a career in academic research to seeking employment with a company (40 percent v. 27 percent respectively; P<0.001). On the other hand, international students were equally likely to want a career in academia or seek employment in industry (38 percent v. 41 percent respectively; P=0.26). International students also were significantly more likely than their domestic counterparts to want to pursue careers in high-tech firms (41 percent v. 27 percent respectively; P<0.001). These differences in career trajectories between academia and industry have important implications to the future of U.S. competitiveness, particularly if the United States loses these highly skilled talents in the global market to competing countries.

Although the United States remains one of—if not the—world's leading innovation centers, many countries now are vying for that role. In 2014, more than two-fifths (42 percent) of all design patents granted by the U.S. Patent and Trademark Office were attributed to a foreign ownership location, representing a significant increase from the period 1977–2000, when foreign-originating U.S. patents accounted for only 31 percent.[16] In 2014, 29 percent of all new U.S. startups were founded by immigrant entrepreneurs, reflecting a startup rate nearly twice as high as that of U.S.-born adults.[17] Immigrants reportedly launched more than half of all startups in Silicon Valley, although the percentage appears to be slowly declining.[18] U.S. immigration policy would do well to consider ways in which at least some of the foreign talent earning U.S. degrees might be able to remain upon graduation.

WHAT SHOULD BE DONE?

Employer-sponsored H-1B visas remain the primary method for international individuals to reside in the United States. The 2015 fiscal year had a regular cap of 65,000 visas, with an additional 20,000 visas reserved for individuals who obtained U.S. master's degrees or higher.[19] Because employment-based immigration visas (i.e., permanent residency) are limited to 140,000 per year, are subject to an approximate 7 percent per-country limit (i.e., ~25,900 visas per country), and are allocated on a preference-based system,[20] the H-1B visa is the most prevalent method for highly skilled individuals who

[16] USPTO. 2015. Retrieved July 7, 2015. "Number of Patents Granted as Distributed by Year of Patent Grant, Breakout by Ownership Location (State/Country)," PART A1- Table A1-1a, Breakout by Ownership Location (State/Country) Number of Patents Granted as Distributed by Year of Patent Grant. Granted: 01/01/1977–12/31/2014. Available at: http://www.uspto.gov/web/offices/ac/ido/oeip/taf/own_cst_dsn2014.htm.

[17] Kauffman. 2015. "The Kauffman Index: Nativity of New Entrepreneurs." Retrieved July 20, 2015. The Kauffman Foundation. Available at http://www.kauffman.org/microsites/kauffman-index/profiles/entrepreneurial-demographics?Demographic=Nativity.

[18] Bluestein, Adam. 2015. "The Most Entrepreneurial Group in America Wasn't Born in America." Retrieved July 30, 2015. *Inc.* Available at http://www.inc.com/magazine/201502/adam-bluestein/the-most-entrepreneurial-group-in-america-wasnt-born-in-america.html.

[19] USCIS. 2015. Retrieved Feb. 17, 2015. Available at http://www.uscis.gov/working-united-states/temporary-workers/h-1b-specialty-occupations-and-fashion-models/h-1b-fiscal-year-fy-2015-cap-season.

[20] The United States Citizenship and Immigration Services (USCIS) recognizes five employment-based immigration preferences. First preference (EB-1) "is reserved for persons of extraordinary ability in the sciences, arts, education, business, or athletics; outstanding professors or researchers; and

wish to stay and work in the United States. The duration that an individual can remain on an H-1B visa prior to receiving permanent residency can vary greatly due to numerical limits based on nationalities and employment preferences.

The per-country limit is implemented to avoid potential monopolization of immigration visas by applicants from few countries. However, there are far more individuals from certain countries, due to large population sizes. For example, Chinese and Indian students accounted for 31 percent and 14 percent of all U.S. STEM doctoral recipients in 2012/13 (see footnote 2). These two countries also happen to have the third- and second-highest employment-based immigration waiting lists by country,[21] resulting in numerous highly skilled workers having to wait an extraordinarily long time to receive permanent residency: Chinese individuals holding advanced degrees or having exceptional ability must wait nearly five years; the wait is approximately ten years for individuals of Indian descent.[22]

Despite the problems associated with the H-1B visa, there are few alternatives for highly skilled immigrants to stay and work in the United States.[23] Until there are other

multinational executives and managers." Second preference (EB-2) "is reserved for persons who are members of the professions holding advanced degrees or for persons with exceptional ability in the arts, sciences, or business." Third preference (EB-3) "is reserved for professionals, skilled workers, and other workers." Fourth preference (EB-4) "is reserved for "special immigrants," which includes certain religious workers, employees of U.S. foreign service posts, retired employees of international organizations, alien minors who are wards of courts in the United States, and other classes of aliens." And fifth preference (EB-5) "is reserved for business investors who invest $1 million or $500,000 (if the investment is made in a targeted employment area) in a new commercial enterprise that employs at least ten full-time U.S. workers." For full details regarding employment-based immigration, see: USCIS. 2016. Permanent workers. Available at https://www.uscis.gov/working-united-states/permanent-workers.

[21] USCIS. 2014. Retrieved Feb. 17, 2015. Annual report of immigration visa applications. Available at http://travel.state.gov/content/dam/visas/Statistics/Immigrant-Statistics/WaitingListItem.pdf.

[22] USCIS. 2015. Retrieved Feb. 17, 2015. Available at http://travel.state.gov/content/dam/visas/Bulletins/visabulletin_February2015.pdf.

[23] Alternatives to the H-1B visa for highly skilled STEM professionals: (1) the H-2B temporary non-agricultural worker visa, capped at 66,000 visas per fiscal year, designed to allow U.S. employers to hire foreign nationals to fill temporary nonagricultural positions. For more information on the H-2B program, see https://www.uscis.gov/working-united-states/temporary-workers/h-2b-temporary-non-agricultural-workers. (2) The L-1 visa, which is broken into two categories, the L-1A and the L-1B visa. The L-1A visa "enables a U.S. employer to transfer an executive or manager from one of its affiliated foreign offices to one of its offices in the United States. This classification also enables a foreign company, which does not yet have an affiliated U.S. office, to send an executive or manager to the United States with the purpose of establishing one." There is a maximum limit of seven years for a foreign national on an L-1A visa. The L-1B visa "enables a U.S. employer to transfer a professional employee with specialized knowledge relating to the organization's interests from one of its affiliated foreign offices to one of its offices in the United States. This classification also enables a foreign company, which does not yet have an affiliated U.S. office, to send a specialized employee to the United States to help establish one." A foreign national can stay on an L-1B visa for a maximum of five years. There is no numerical cap for the L-1 visas. For more information on the L-1A visa, see https://www.uscis.gov/working-united-states/temporary-workers/l-1a-intracompany-transferee-executive-or-manager. (3) The O-1 visa "is for the individual who possesses extraordinary ability in the sciences, arts, education, business, or athletics, or who has a demonstrated record of extraordinary achievement in the motion picture or television industry and has been recognized nationally or internationally for those achievements." There is no numerical cap for O-1 visas. For the 2015 fiscal year, 23,680 O-1

immigration options for highly skilled STEM individuals, particularly those who have been educated at U.S. institutions of higher education, to stay and work, most individuals have to rely on the H-1B visa as a stepping stone toward permanent residency.

POLICY SUGGESTIONS

We argue that the nearly nine out of ten international STEM students who either would like to remain in the United States after receiving their degrees (48 percent), or who are undecided (41 percent), constitute a valuable resource for future science and technology innovation. Surely, those who are highly qualified and sought after by U.S. firms should be given an opportunity to remain. If not, the United States is at risk of losing its competitive edge in the international arena. A recent study found that within a group of ten developed countries, the United States was ranked second-to-last in terms of global competitiveness in ability to recruit and retain talent.[24]

visas were issued. For more information on the O-1 visa, see https://www.uscis.gov/working-united-states/temporary-workers/o-1-visa-individuals-extraordinary-ability-or-achievement. (4) The E-visa, which is broken into two categories, the E-1 and E-2 visa. The E-1 visa "allows a national of a treaty country (a country with which the United States maintains a treaty of commerce and navigation) to be admitted to the United States solely to engage in international trade on his or her own behalf." For more information on the E-1 visa, see https://www.uscis.gov/working-united-states/temporary-workers/e-1-treaty-traders. The E-2 visa "allows a national of a treaty country (a country with which the United States maintains a treaty of commerce and navigation) to be admitted to the United States when investing a substantial amount of capital in a U.S. business." There is no numerical cap for the E-1 or E-2 visa. For more information on the E-2 visa, see https://www.uscis.gov/working-united-states/temporary-workers/e-2-treaty-investors. Please note that there are other visa options for individuals who are not in STEM professions. For more information on other types of visas, see https://www.uscis.gov/working-united-states/working-us.

[24] Business Roundtable. 2015. "State of Immigration: How the United States Stacked Up in the Global Talent Competition." Accessed July 21, 2015. Available at http://businessroundtable.org/sites/default/files/immigration_reports/BRT%20immigration%20report.pdf.

While the high-tech sector,[25] the Department of Education,[26] the White House,[27] and some researchers[28] argue that there is a serious shortage of skilled STEM workers in the United States, others disagree.[29] It is not our purpose to engage in this debate. We instead argue that, either way, the United States runs the risk of losing its competitiveness in the long run unless it changes its immigration policies. The ability to attract and retain highly skilled STEM workers is crucial if the United States hopes to remain competitive in the global economy. Policymakers have made efforts to remedy this long and arduous immigration process, but the congressional gridlock on immigration has prevented the passing of any bills by either the House or the Senate.

In November 2014, President Barack Obama issued a series of executive orders that would provide some reprieve for H-1B visa holders and their spouses. Specifically, spouses of certain H-1B visa holders can apply for work authorization in the United States.[30] Effective as of May 26, 2015, U.S. Citizenship and Immigration Services and the Department of Homeland Security expect that this new regulation will provide much-needed economic and financial relief for H-1B visa holders and families seeking to transition to lawful permanent resident status.[31]

Several bills aimed at facilitating the immigration process for highly skilled workers have been introduced in the 114th U.S. Congress. All of these measures previously were

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[25] Smith, Brad. 2012. "How to Reduce America's Talent Deficit." *The Wall Street Journal*, October 18. Accessed August 5, 2015. Available at http://www.wsj.com/articles/SB10000872396390443675404578058163640361032; Code.org. 2013. "What Most Schools Don't Teach [Video File]." Available at https://www.youtube.com/watch?v=nKIu9yen5nc; Partnership for a New American Economy, Information Technology Industry Council and U.S. Chamber of Commerce. 2012. "Help Wanted: The Role of Foreign Workers in the Innovation Economy." Accessed August 5, 2015. Available at http://www.renewoureconomy.org/sites/all/themes/pnae/stem-report.pdf.

[26] Department of Education. 2015. "Science, Technology, Engineering and Math: Education for Global Leadership." Accessed August 5, 2015. Available at http://www.ed.gov/stem.

[27] White House. 2013. "Federal Science, Technology, Engineering, and Mathematics (STEM) Education 5-Year Strategic Plan." Accessed August 5, 2015. Available at https://www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf; White House. 2015. "Preparing Americans with 21st Century Skills. Science, Technology, Engineering, and Mathematics (STEM) Education in the 2015 Budget." Accessed August 5, 2015. Available at https://www.whitehouse.gov/sites/default/files/microsites/ostp/Fy%202015%20STEM%20ed.pdf.

[28] Rothwell, J. 2014. "Still Searching: Job Vacancies and STEM Skills." Metropolitan Policy Program, Brookings Institution. Available at http://www.brookings.edu/~/media/research/files/reports/2014/07/stem/job-vacancies-and-stem-skills.pdf.

[29] Salzman, Hal, and B. Lindsay Lowell. 2007. "Into the eye of the storm: Assessing the evidence on science and engineering education, quality, and workforce demand." Urban Institute (October). Available at http://www.urban.org/sites/default/files/alfresco/publication-pdfs/411562-Into-the-Eye-of-the-Storm.PDF; Charette, Robert N. 2013. "The STEM Crisis is a Myth." Spectrum, IEEE 50(9): 44–59. Salzman, Hal. 2013. "What Shortages?" Accessed August 5, 2015. Available at https://www.researchgate.net/profile/Hal_Salzman2/publication/259466494_58_ISSUES_IN_SCIENCE_AND_TECHNOLOGY/links/00b7d52bdd78d4064c000000.pdf.

[30] USCIS. 2015. Retrieved August 3, 2015. Available at http://www.uscis.gov/immigrationaction.

[31] USCIS. 2015. Retrieved August 3, 2015. Available at http://www.uscis.gov/news/dhs-extends-eligibility-employment-authorization-certain-h-4-dependent-spouses-h-1b-nonimmigrants-seeking-employment-based-lawful-permanent-residence.

submitted to Congress and have failed to pass, victims of the current impasse over immigration reform.

- Immigration Innovation Act (or the I-Squared Act): Increases the H-1B annual cap from 65,000 to 115,000–195,000 depending on demand and market conditions.[32]
- Stopping Trained in America PhDs From Leaving the Economy Act of 2015 (or the STAPLE Act): Allows international students who receive PhDs in STEM from U.S. institutions of higher education and who have offers of employment from U.S. employers to be admitted for permanent resident status and be exempted from the numerical limitation on H-1B visas.[33]
- STEM Jobs Act of 2015: Provides up to 55,000 visas each fiscal year to immigrants who received doctorate degrees in STEM from U.S. institutions of higher education.[34]
- Startup Act of 2015: Creates a new visa for up to 50,000 international students per year who graduate with master's degrees or PhDs in STEM from U.S. institutions of higher education. Recipients will have conditional permanent resident status for five years. If a recipient remains active in a STEM field for five years, the conditional status will be lifted and the recipient will become a regular legal permanent resident.[35]
- Fairness for High-Skilled Immigration Act of 2015: Eliminates the country-based restrictions on employment visas and reduces the country-based restrictions on family visas, although the total number of visas given in any fiscal year would remain unchanged.[36]

Meanwhile, other countries have responded to the global supply of skilled talent by strongly incentivizing qualified students to remain after completing their studies.[15] An important step would be to fix the legal immigration process in the United States for highly skilled STEM workers.

Specifically, we propose that Congress immediately enact the I-Squared Act and the STAPLE Act, and give serious consideration to the other measures. Additionally, we recommend that the H-1B visa system be amended to allow all individuals to switch employers/jobs. The current practice provides a strong disincentive for visa holders to maximize their positive economic impact by shifting employment. We also strongly suggest that policymakers avoid lumping illegal immigration with legal immigration in one bill. Policymakers are unlikely to agree on the issue of illegal immigration, which

[32] Congress. 2015. I-Squared Act of 2015. Accessed August 3, 2015. Available at https://www.congress.gov/bill/114th-congress/senate-bill/153/all-info

[33] Congress. 2015. STAPLE Act. Available at https://www.congress.gov/bill/114th-congress/house-bill/2181.

[34] Congress. 2015. STEM Jobs Act of 2015. Available at https://www.congress.gov/bill/114th-congress/senate-bill/98?q=%7B%22search%22%3A%5B%22STEM+immigration%22%5D%7D.

[35] Congress. 2015. Startup Act of 2015. Available at https://www.congress.gov/bill/114th-congress/senate-bill/181.

[36] Congress. 2015e. Fairness for High-Skilled Immigration Act of 2015. Available at https://www.congress.gov/bill/114th-congress/house-bill/213.

should be treated separately. This would greatly increase the likelihood of such a bill passing Congress. We are aware that some of the measures described above failed previously because some members of Congress believed they should be included as part of comprehensive immigration reform. We argue that politics should play no role in an issue so critical to the future of U.S. competitiveness.

APPENDIX

Statistical Analysis

All statistical analyses were performed using R statistical software.[37]

For each of the seven career plans, we used a non-parametric two-sample proportions test to determine whether there were significant differences between the percentage of domestic and international students who were interested in pursuing that career. We also used the non-parametric two-sample proportions test to compare whether there were significant differences in the proportion of international students who wanted to pursue academic careers versus being employed by companies. The same statistical test was used to determine whether there were significant differences in the proportion of domestic students who intend to pursue careers in academia versus wanting to be employed by companies.

To determine which factors affected international students' decisions to study in the United States, we used Cochran's Q-test to determine if there were significant differences among factors. Cochran's Q-test is a non-parametric test that can be used to determine whether there are significant differences in frequencies (or proportions) across multiple dependent samples. We used the *cochran.qtest* function from the *RVAideMemoire* package[38] (version 0.9-45-2) in R to calculate Cochran's Q. Pairwise comparisons using the Wilcoxon sign test were performed post-hoc to determine how factors differed significantly from one another.

We also used the Cochran's Q-test to determine if there were significant differences among factors that influence students' decisions to stay in or leave the United States after graduation. Pairwise comparisons using the Wilcoxon sign test were performed post-hoc to determine which factors differed significantly from one another.

Non-parametric two-sample proportions tests were used to detect differences between the proportion of individuals who hope to stay in the United States with those who want to leave, and to compare those who want to stay with those who currently do not know or are uncertain in whether they want to stay or leave.

Non-parametric two-sample proportions tests were used to assess respondents' perceptions regarding their U.S. academic experiences in comparison with that of their home countries. For this particular analysis, we evaluated if there were significant differences between the proportions of individuals who felt their experience in the United States was *much better* or *very much better* with the proportion of who felt their

[37] R Core Team. 2015. "R: A language and environment for statistical computing." R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

[38] Herve, M. 2015. "Package 'RVAideMemoire'." Available at https://cran.r-project.org/web/packages/RVAideMemoire/RVAideMemoire.pdf.

experience was *much worse* or *very much worse* in comparison to their experiences in their home countries.

Similarly, non-parametric two-sample proportions tests were used to determine how respondents feel they are being treated by their U.S. colleagues and professors in comparison to those in their home countries, and how they feel they would be treated by their colleagues and professors in their home countries if they returned. For these two questions, we compared the proportion of individuals who felt their treatment is *worse* or *much worse* with the proportion who felt their experience was *neither better nor worse* and those who felt it was *better* or *much better*. We also compared the percentage of individuals who felt their treatment was *better* or *much better* with those who believed it was *neither better nor worse*.

Cochran's Q-test was used to determine if there was a significant difference among the proportion of individuals who faced cultural, social, academic, financial, racial, and other challenges. Pairwise comparisons using the Wilcoxon sign test were performed post-hoc to determine how the percentage of individuals who faced each challenge differed significantly from one another.

Classification tree analysis and variable selection using random forests

To determine how personal, professional, and social factors interact to influence students' decisions to stay in or leave the United States upon graduation, we used random forests for variable selection, which were then used in a series of classification tree analyses. Decision trees generated from classification and regression tree (CART) analyses are based on recursive partitioning[39] and, like many algorithms, are prone to overfitting.[40] A common approach to avoid overfitting is to grow a tree to its maximum size and then prune it back using some type of pruning algorithm.[41]

Random forests provide a robust method against overfitting. They are able to handle large quantities of data and predictor variables and deal with missing and unbalanced data, as well as provide estimates on variable importance.[42] A random forest is an ensemble approach in which a forest of standard classification (or regression) trees is

[39] De'ath, G., and K. E. Fabricius. 2000. "Classification and regression trees: a powerful yet simple technique for ecological data analysis. "*Ecology* 81(11): 3178–3192; Strobl, C., J. Malley, and G. Tutz. 2009. "An introduction to recursive partitioning: rationale, application, and characteristics of classification and regression trees, bagging and random forests." *Psychology Methods* 14(4): 323–348; Loh, W-Y. 2011. "Classification and regression trees." *WIREs data mining and knowledge discovery* 1: 14–23.

[40] Breiman, L., J. H. Friedman, R. A. Olshen, and C. J. Stone. 1984. "Classification and regression trees." CRC Press: Wadsworth, Monterey, CA.

[41] Esposito, F., D. Malerba, and G. Semeraro. 1997. "A comparative analysis of methods for pruning decision trees." *IEEE transactions on pattern analysis and machine intelligence* 19(5): 476–493; Mehta, M., J. Rissanen, and R. Agrawal. 1995. "MDL-based decision tree pruning." *KDD* 21(2): 216–221; Bradford, J. P., C. Kunz, R. Kohavi, C. Brunk, and C. E. Brodley. 1998. "Pruning decision trees with misclassification costs." *Machine Learning: ECML-98*: 131–136.

[42] Breiman, Leo. 2001. "Random forests." *Machine Learning* 45: 5–32; Liaw, A., and M. Wiener. 2002. "Classification and regression by randomforest." *R News* 2/3: 18–22

grown.[42] Random forests use a bagging method in which each tree is not only un-pruned, but is also constructed using a different bootstrap sample of the original data. Through bagging alone, the same full set of predictors is used to determine each split. In random forests, however, a second round of randomization is used in which a random subset of the predictor variables is selected to determine each split. Because each tree grown only uses a bootstrap sample of the data, the data not used in this, referred to as the out-of-bag (i.e., OOB) data, can then be used to estimate the amount of error associated with that respective tree. Variable importance then can be calculated by looking at the increase in prediction error that occurs when the observed values of a variable are randomly permuted in the OOB samples.[43]

To determine variable importance, we used the package *randomForest* (version 4.6-10)[44] to determine which factors were important in determining whether an international graduate student intended to stay in or leave the United States upon graduation. Two random forests were constructed, both limited to individuals who were definitive in whether they wanted to stay in or leave the United States upon graduation. Individuals who were uncertain were removed from the random forests because our research goal is to determine which factors are important for those who are definitive in their decisions. Individuals who are 'on the fence' may have very different factors affecting their future decisions, which our survey may not be equipped to answer.

We generated a random forest model where we limited our sample size to those who knew definitively whether they would like to stay in or leave the United States upon graduation (i.e., those who "do not know/not sure" were excluded) and to those who were definitive on their future career options (i.e., "do not know/not sure" responses for future career options were excluded) (N=426; Table S4). Ten thousand trees were generated for the random forest model. The random forest model consisted of thirty-nine variables and spanned the range of personal, social, professional, and cultural factors that could influence an international student's decision to stay in or leave the United States upon graduation (Table S4). The mean decrease in accuracy computed from permuting OOB data was used to determine variable importance. As there is no standard rule on how much decrease in accuracy would indicate a variable is important, we looked for large breaks in the mean decrease in accuracy between variables to decide how many variables we used as explanatory variables to generate a classification tree.

Classification trees were generated by using the package *rpart* (version 4.1-10)[45] with variables identified from the random forests as explanatory variables and the choice to

[43] Genuer, R., J.-M. Poggi, and C. Tuleau-Malot. 2010. "Variable selection using random forests." *Pattern Recognition Letters* 31(14): 2225–2236. For a review, see Therneau, T., B. Atkinson, and B. Ripley. 2015. "Recursive partitioning and regression trees." Available at http://cran.r-project.org/web/packages/rpart/rpart.pdf.

[44] Liaw, A., and M. Wiener. 2002. Classification and Regression by randomForest. R News 2(3): 18–22.

[45] Therneau, T., B. Atkinson, B. Ripley. 2015. "Recursive partitioning and regression trees." Available at http://cran.r-project.org/web/packages/rpart/rpart.pdf.

stay in or leave the United States as the dependent variable. The resulting classification trees were pruned using the cross-validation method with the 1-S.E. rule.

Long-term data analysis of the Survey of Earned Doctorates

The SED has been conducted annually since 1957 and includes all individuals who have received research doctorates from accredited U.S. institutions in a given academic year. We contacted the National Center for Science and Engineering Statistics (NCSES) for the complete annual counts of doctoral recipients from 1957–2013 by major disciplines (i.e., science and engineering, social sciences), and citizenship status (i.e., U.S. citizen and permanent resident, or temporary visa holders). From this data, we calculated (1) the percent composition of international and domestic doctoral recipients for all disciplines (i.e., including social science disciplines); (2) the percent composition of international and domestic doctoral recipients for STEM only-disciplines (i.e., STEM disciplines were considered to be the following SED categories: Science and Engineering fields, biological/biomedical sciences, agricultural sciences, health sciences, engineering fields, mathematics/computer sciences, and physical sciences); (3) and the relative percent of international and domestic doctoral recipients who majored in STEM fields out of all U.S. research doctoral degrees by international and domestic students, respectively.

We used a Mann-Whitney U-test to determine whether international students were more likely than domestic students to major and graduate from STEM disciplines. Citizenship status was the explanatory variable, and the relative percent of international and domestic students who received doctoral degrees in STEM out of all U.S. research doctoral degrees was the dependent variable.

We fitted simple linear regressions with *year* as the independent variable and *percent of U.S. STEM doctoral recipients* as the dependent variable for both international and domestic students to estimate when international students would account for more U.S. STEM PhDs than domestic students would. The best-fit model for percent of domestic students as total of all U.S. STEM doctoral recipients was given by: *Percent of domestic students = 1476 – 0.71*year*. The best-fit model for the percent of international student as a total of all U.S. STEM doctoral recipients was: *Percent of international students = -1199 + 0.62*year*. We calculated the year in which the percent of international students would overtake the percent of domestic students for U.S.-granted STEM PhDs by finding the intercept of the two models.

Random forests and classification tree analysis

Using mean decrease in accuracy as a form of variable selection, nine variables (i.e., reason for studying in the United States; postgraduate career plan; year of study in graduate program; awareness of policies from home countries that encourage repatriation; whether an individual believes that the United States provided him or her with any kind of advantage over the home country; challenges encountered in the United States; whether an individual received any undergraduate education in the

United States; and age) were selected as important factors from the random forest model and then were used in the classification tree analysis (Table S4, Figure S1). The thirty remaining variables were not considered to be influential factors in determining whether an individual will stay in or leave the United States upon graduation. Because *degree type* (i.e., master's vs. PhD) was not an influential factor, all respondents were combined together for the classification tree analysis.[46] The final decision tree from the classification analysis is explained in the main text of the paper.

Long-term data analysis of the Survey of Earned Doctorates

Averaging across time, we found that the mean (±SE) relative percent of international (68 ± 0.58 percent) and domestic students (43 ± 0.59 percent) who majored and received U.S. doctoral degrees in STEM fields out of all disciplines differed significantly between the two groups (P<0.001; Figure S2).

Table S1. Top ten U.S. institutions hosting international students in the 2013/14 academic year broken down by rank, institution name, location (city and state), and number of enrolled international students (i.e., undergraduate, graduate, and non-degree-seeking students). *Source of data*: International Institute of Education, Open Doors Report on International Educational Exchange. Retrieved from http://www.iie.org/opendoors.

Rank	Institution	City	State	Total number of international students in 2013/14
1	New York University	New York	NY	11,164
2	University of Southern California	Los Angeles	CA	10,932
3	University of Illinois - Urbana-Champaign	Champaign	IL	10,843
4	Columbia University	New York	NY	10,486
5	Purdue University - Main Campus	West Lafayette	IN	9,988
6	University of California - Los Angeles	Los Angeles	CA	9,579
7	Northeastern University	Boston	MA	9,078
8	Arizona State University	Tempe	AZ	8,683
9	Michigan State University	East Lansing	MI	7,704
10	University of Washington	Seattle	WA	7,469

[46] A two-sample, non-parametric proportion test also indicated that there was no significant difference between the percent of individuals who wish to stay in the United States based on degree type (X^2_1 = 0.49, P=0.48).

Table S2. Country of origin for international survey respondents ordered by decreasing number of individuals. A total of 787 international students from seventy-four countries/regions participated in the survey.

Country of origin	Number of respondents	Percentage of total respondents
China	235	29.9%
India	202	25.7%
Taiwan	29	3.7%
Turkey	23	2.9%
Republic of Korea	20	2.5%
Canada	19	2.4%
Brazil	15	1.9%
Iran	15	1.9%
Colombia	13	1.7%
Germany	11	1.4%
Mexico	11	1.4%
Italy	9	1.1%
Bangladesh	8	1.0%
Lebanon	8	1.0%
Pakistan	8	1.0%
Singapore	8	1.0%
Egypt	7	0.9%
France	7	0.9%
Indonesia	7	0.9%
Malaysia	7	0.9%
Thailand	7	0.9%
Greece	6	0.8%
Israel	6	0.8%
Russia	6	0.8%
Nepal	5	0.6%
Hong Kong	4	0.5%
United Kingdom	4	0.5%
Afghanistan	3	0.4%
Argentina	3	0.4%
Australia	3	0.4%
Chile	3	0.4%
Croatia	3	0.4%
Ghana	3	0.4%
Japan	3	0.4%
Kenya	3	0.4%
Nigeria	3	0.4%
Panama	3	0.4%
Philippines	3	0.4%
Saudi Arabia	3	0.4%
Spain	3	0.4%
Sri Lanka	3	0.4%
Costa Rica	2	0.3%
Ireland	2	0.3%
Jordan	2	0.3%

Kuwait	2	0.3%
Netherlands	2	0.3%
Peru	2	0.3%
Portugal	2	0.3%
Romania	2	0.3%
South Africa	2	0.3%
Uganda	2	0.3%
Venezuela	2	0.3%
Vietnam	2	0.3%
Albania	1	0.1%
Austria	1	0.1%
Azerbaijan	1	0.1%
Bahamas	1	0.1%
Belgium	1	0.1%
Benin	1	0.1%
Cyprus	1	0.1%
Denmark	1	0.1%
Ethiopia	1	0.1%
Finland	1	0.1%
Hungary	1	0.1%
Iceland	1	0.1%
Jamaica	1	0.1%
Kyrgyzstan	1	0.1%
Mongolia	1	0.1%
New Zealand	1	0.1%
Poland	1	0.1%
Slovakia	1	0.1%
St. Lucia	1	0.1%
Trinidad & Tobago	1	0.1%
Zimbabwe	1	0.1%

Table S3. Population versus sample demographics. Population demographics taken from data provided by the Survey of Earned Doctorates**Error! Bookmark not defined.** and by the Integrated Postsecondary Education Data System Completions Survey.[8]

Individuals	Degree	Parameter	Population demographic	Sample demographic
Total (temporary visa holders and U.S. citizens and permanent residents)	Master's-degree-seeking students	Male (% of total population)	54.4%	53.8%
		Female (% of total population)	45.6%	44.7%
		Other/do not wish to disclose (% of total population)	0%	1.2%
	PhD-level-seeking students	Male (% of total population)	53.8%	52.2%
		Female (% of total population)	46.2%	46.0%
		Other/do not wish to disclose (% of total population)	0%	1.7%
International students (i.e., temporary visa holders)	PhD-level-seeking students	Male (% of total population)	64.4%	61.2%
		Female (% of total population)	35.6%	36.8%
		Other/do not wish to disclose (% of total population)	0%	2.1%
Domestic students (i.e., U.S. citizens and permanent residents)	PhD-level-seeking students	Male (% of total population)	48.7%	48.3%
		Female (% of total population)	51.3%	50.2%
		Other/do not wish to disclose (% of total population)	0%	1.6%

Table S4. Coding scheme describing all variables used in the random forest model and a description of the survey question asked for each respective variable. Asterisks indicate variables that resulted in high mean decreases in accuracy from the random forest model and were selected and used in the classification tree analysis.

Code	Question description
Study_career*	Future career opportunities: did this factor influence your decision to do your graduate studies in the United States?
Career_plans*	What are your plans after graduation?
Year*	What year are you in your graduate studies?
Policy*	Are you aware of any programs, incentives, or opportunities that are provided by your home country that are intended to encourage you to return after you get your degree?
Advg_notsure*	Do not know/not sure: did you feel a United States education provided you with any advantage in comparison with your home country?
No_challenge*	I did not encounter any challenges: did you encounter any challenge(s) while adjusting to American life?
Undergrad*	Did you study in the United States for any part of your undergraduate degree?
Age*	Please select your age.
Study_US*	Wanted to live in the United States: did this factor influence your decision to do your graduate studies in the United States?
Exp_access	Access to books, magazines, journals, and databases: how would you rate this in comparison with your home country with regard to academic experience?
US_entry	When did you first enter the United States for your studies?
Study_faculty	Opportunity to work with specific faculty: did this factor influence your decision to do your graduate studies in the United States?
Discipline	Please select the discipline in which you are currently pursuing your graduate degree.
Advg_educ	Better education/knowledge of your field: did you feel a U.S. education provided you with this advantage in comparison with your home country?
Exp_teach	Professors' teaching styles: how would you rate this in comparison with your home country with regard to academic experience?
Cultural	Cultural challenges: did you encounter this challenge while adjusting to American life?
Advg_none	None: did you feel a U.S. education provided you with no advantage in comparison with your home country?
Financial	Financial challenges: did you encounter this challenge while adjusting to American life?
Adjustment	How successfully do you feel you have adjusted to American educational culture?
Racial	Racial challenges: did you encounter this challenge while adjusting to American life?
Study_abroad	Wanted to experience living abroad: did this factor influence your decision to do your graduate studies in the United States?
Advg_job	Better job opportunity: did you feel a U.S. education provided you with this advantage in comparison with your home country?
Exp_debate	Freedom to openly debate established theories: how would you rate this in comparison with your home country with regard to academic experience?

Trmt	How do you feel you are treated by your colleagues and professors in the United States in comparison with those in your home country?
Social	Social challenges: did you encounter this challenge while adjusting to American life?
Degree	What degree are you currently pursuing?
Study_cost	Lower cost: did this factor influence your decision to do your graduate studies in the United States?
Study_educ	Higher quality of education: did this factor influence your decision to do your graduate studies in the United States?
Exp_subject	Subject teaching matter: how would you rate this in comparison with your home country with regard to academic experience?
Trmt_return	How do you feel you would be treated by your colleagues and professors in your home country if you returned?
Exp_disc	Open classroom discussions: how would you rate this in comparison with your home country with regard to academic experience?
Exp_collabor	Collaboration with other grad students in your lab: how would you rate this in comparison with your home country with regard to academic experience?
Advg	Will your U.S. education give you any advantages in your career?
Advg_adv	Better advisors/mentorship: did you feel a U.S. education provided you with this advantage in comparison with your home country?
Study_proximity	Proximity to friends/family: did this factor influence your decision to do your graduate studies in the United States?
Advg_ntwk	Better professional network: did you feel a U.S. education provided you with this advantage in comparison with your home country?
Exp_research	Freedom to pursue new, self-proposed research directions: how would you rate this in comparison with your home country with regard to academic experience?
Academic	Academic challenges: did you encounter this challenge while adjusting to American life?
Gender	What is your gender?

Figure S1. Random forest for the whole dataset of variables (*n*=39). Relative variable importance measured in terms of mean decrease in predictive accuracy of the model. The mean decrease in model accuracy is a feature of random forests and is calculated by how much the permutation of each variable decreases the accuracy of the model. Unimportant variables will have little to no effect on model accuracy while the permutation of important variables will result in large decreases of model accuracy. Important variables, therefore, are those with values in mean decrease in accuracy. Codes listed on the y-axis correspond to coding schemes in Table S4.

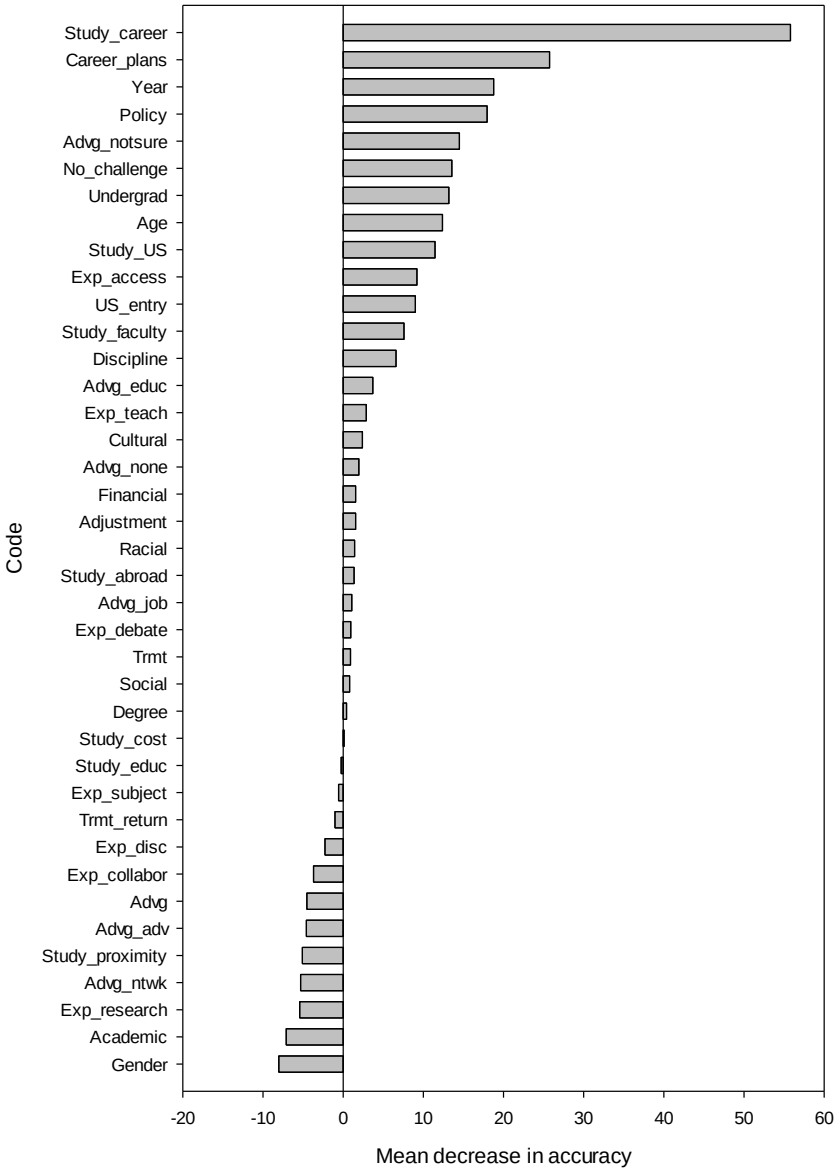
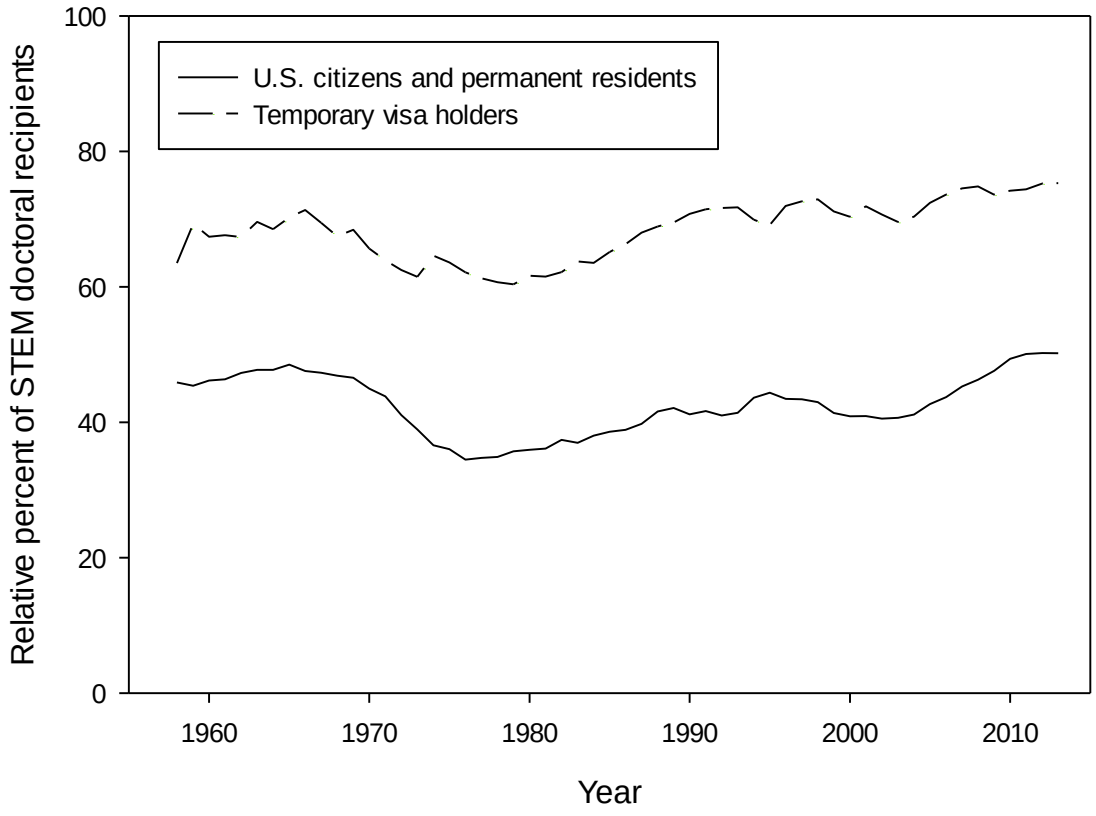


Figure S2. Based on data from the NSF Survey of Earned Doctorates. The percent of STEM doctorates received by domestic and international graduate students relative to all U.S. doctorates received (i.e., including social science disciplines) by domestic and international graduate students. International students were significantly more likely than domestic students to major in and graduate with doctoral degrees in STEM (P<0.001).



Survey

The cover email, survey questions, and a link to the raw survey results follow. Two reminder emails were sent at weekly intervals from the initial contact date to individuals whom we were able to contact directly

Cover email:

> Dear [university name] graduate student,
>
> We are researchers from the NSF-funded Center for Nanotechnology in Society at the University of California, Santa Barbara (www.cns.ucsb.edu). We are contacting you in an effort to assist us with our data collection for a research project regarding STEM graduate students in the United States. We are contacting all STEM graduate students at [university name] to take part in our survey.
>
> [The survey link, now inactive, was provided here.]
>
> Research summary:
> We are conducting a national survey on both international and domestic STEM graduate students studying in the U.S. This study replicates one we have already completed of STEM students at UCSB; we would be most happy to share those results with you, if that would be helpful.
>
> For international students, we are interested in which factors influenced their decision to study in the U.S. and which factors play a role in their decision to stay or leave the U.S. upon graduation. For domestic students, we are hoping to understand the factors that are involved in determining an individual's career path after graduation. The survey should take approximately 10 minutes to complete, please follow this link to begin the survey: [survey link].
>
> Data from this study will not only contribute to academic publications and conferences but will also be used to prepare a Congressional policy brief regarding international graduate STEM students and the implications to the current immigration policy in the U.S. This study is part of a larger set of research that compares the national innovation capacity of the United States with its peers in Asia, Latin America, and Europe.
>
> Questions/Contact information:
> [IRB email address and contact information for authors]
>
> Kind regards,

Individuals who clicked on the hyperlink were then redirected to the survey (the full survey can be found in Appendix S1).

We have made our raw survey data publicly available at openICPSR: http://doi.org/10.3886/E43668V1.[47]

Graduate Students in Science Survey

You are being asked to participate in a short survey that is part of a larger study of Science, Technology, Mathematics, and Engineering (STEM) graduate students in the United States. UCSB's NSF-funded Center for Nanotechnology in Society is conducting this research, which is part of a larger project that compares the national innovation capacity of the United States with its peers in Asia, Latin America, and Europe. We will ask you questions about your reasons for choosing your field of study, your educational background, and your future career aspirations.

While investigators will have access to individual-level data, reports will be shared only in the aggregate. There are no foreseeable risks to your participation.

Your participation is entirely voluntary. The survey will last approximately 10 minutes. Your response is confidential, and will not be associated in any way with your identity. Summary of results may be presented to a wider public in the form of future presentations and publications; however, data will be reported only in the aggregate.

There are no right or wrong answers. You are free to skip any question you do not wish to answer, and you may terminate the survey and your participation in the study at any time. You may change your mind about being in the study and quit after the study has started.

If you have any questions about this research project or if you think you may have been injured as a result of your participation, please contact: [contact information of authors].

If you have any questions regarding your rights and participation as a research subject, please contact the Human Subjects Committee at [IRB contact information].
Thank you for your participation.

Q1 Please select the option that best describes your status.

❍ I am a U.S. citizen or permanent resident

❍ I am an international student

[47] Han, X., R. Appelbaum, G. Stocking, and M. Gebbie. 2015. "International STEM graduate student in the United States Survey 2015." Ann Arbor, MI: Inter-university Consortium for Political and Social Science Research [distributor]. http://doi.org/10.3886/E43668V1.

Q2 Please select your age
- ❍ < 18
- ❍ 18–25
- ❍ 26–30
- ❍ 31–35
- ❍ 36–40
- ❍ 41–45
- ❍ 45+

Q3 What is your gender?
- ❍ Male
- ❍ Female
- ❍ Other
- ❍ I do not wish to respond

Q4 What degree are you currently pursuing?
- ❍ Master's level
- ❍ PhD level

Q5 Please select the discipline in which you are currently pursuing your graduate degree.
- ❍ Life sciences
- ❍ Physical sciences
- ❍ Engineering
- ❍ Mathematics
- ❍ Computer science
- ❍ Other (please specify): _____

The next question was only asked of those who answered "PhD level" on question 4.

Q6 Have you advanced to candidacy?
- ❍ Yes
- ❍ No

Q7 What year are you in your graduate studies?

- ❍ 1st year
- ❍ 2nd year
- ❍ 3rd year
- ❍ 4th year
- ❍ 5th year
- ❍ 6th year
- ❍ > 6 years

Q8 What field is your father employed in?

- ❍ Government party officials (e.g., state-owned enterprise heads, agency heads, high-ranking party officials)
- ❍ Professionals (e.g., engineers, lawyers, accountants)
- ❍ Educators and researchers (e.g., teachers, university professors, scientific researchers)
- ❍ Service workers (e.g., administrative office staff, firefighters, policemen, post office workers)
- ❍ Commercial and retail workers (e.g., sales, restaurant servers, nurses, caretakers, social workers)
- ❍ Agriculture (e.g., farmers, fishermen, foresters)
- ❍ Technical workers (e.g., miners, production line workers, mechanics, electricians, construction workers)
- ❍ Retired/currently not working
- ❍ NA
- ❍ Other (please specify): _____

Q9 What is the highest level of education that your father received?

- ❍ Up through high school
- ❍ High school graduate
- ❍ Some college
- ❍ Bachelor's degree
- ❍ Professional degree (e.g., MA, JD)
- ❍ PhD
- ❍ NA

Q10 What field is your mother employed in?

- ❍ Government party officials (e.g., state-owned enterprise heads, agency heads, high-ranking party officials)
- ❍ Professionals (e.g., engineers, lawyers, accountants)
- ❍ Educators and researchers (e.g., teachers, university professors, scientific researchers)
- ❍ Service workers (e.g., administrative office staff, firefighters, policemen, post office workers)
- ❍ Commercial and retail workers (e.g., sales, restaurant servers, nurses, caretakers, social workers)
- ❍ Agriculture (e.g., farmers, fishermen, foresters)
- ❍ Technical workers (e.g., miners, production line workers, mechanics, electricians, construction workers)
- ❍ Retired/currently not working
- ❍ NA
- ❍ Other (please specify): _____

Q11 What is the highest level of education that your mother received?

- ❍ Up through high school
- ❍ High school graduate
- ❍ Some college
- ❍ Bachelor's degree
- ❍ Professional degree (e.g., MA, JD)
- ❍ PhD
- ❍ NA

The next four questions were only asked of those who answered "I am a U.S. citizen or permanent resident" on question 1.

Q12 What are your plans after graduation? (Please choose only one of the following)

- ❍ Continue conducting research and/or teach through a post-doc or other academic position
- ❍ Work for a government
- ❍ Work for a non-governmental organization
- ❍ Seek employment with a company
- ❍ Start a company
- ❍ Do not know/not sure
- ❍ Other (please specify): _____

The next question was only asked of those who answered "Continue conducting research and/or teach through a post-doc or other academic position" on question 12.

Q13 You told us in the previous question that you plan to conduct research after graduation. In which country do you plan to do so?

❍ [218 country choices]

Q14 We would welcome the opportunity to have a brief follow-up interview. Please let us know if you are willing to do so.

❍ Yes

❍ No

The next question was only asked of those who answered "Yes" on question 14.

Q15 Please fill in the following information

❑ First name _____

❑ Last name _____

❑ Email _____

All remaining questions were only asked of those who answered "I am an international student" on question 1.

Q16 Did you study in the United States for any part of your undergraduate degree?

❍ Yes

❍ No

The next four questions were only asked of those who answered "Yes" on question 16.

Q17 How long did you study at an American university during your undergraduate career?

❍ Less than 1 year

❍ 1 year

❍ 1-2 years

❍ 3+ years

Q18 Did you receive your undergraduate degree in the United States?

❍ Yes

❍ No

The next two questions were only asked of those who answered "Yes" on question 18.

Q19 What university did you complete your undergraduate degree at?

Q20 If you completed any other degrees, what degrees did you complete and at which universities did you do so?

Q21 When did you first enter the United States for your studies?

- ❍ Before elementary school
- ❍ To attend elementary school (grades 1–5)
- ❍ To attend middle school (grades 6–8)
- ❍ To attend high school (grades 9–12)
- ❍ To attend college
- ❍ To attend graduate school
- ❍ Other (please specify): _____

Q22 What is your home country?

- ❍ [218 country choices]

Q23 What visa are you currently on?

- ❍ F1
- ❍ J1
- ❍ Other (please specify): _____

Q24 How did you apply to the graduate program at your current university? (Please choose only one of the following)

- ❍ Applied through an agency
- ❍ Applied through a governmental program in your home country
- ❍ Self-application
- ❍ Transferred from another graduate program in the United States
- ❍ Other (please specify): _____

Q25 What factors influenced your decision to do your graduate studies in the United States? (Please check all that apply)

- ❑ Higher quality of education
- ❑ Lower cost
- ❑ Opportunity to work with specific faculty
- ❑ Future career opportunities
- ❑ Wanted to live in the United States
- ❑ Proximity to friends/family
- ❑ Wanted to experience living abroad
- ❑ Other (please specify): _____

Q26 What are your plans after graduation? (Please choose only one of the following)

- ❍ Continue conducting research and/or teach through a post-doc or other academic position
- ❍ Work for a government
- ❍ Work for a non-governmental organization
- ❍ Seek employment with a company
- ❍ Start a company
- ❍ Do not know/not sure
- ❍ Other (please specify): _____

The next question was only asked of those who answered "Continue conducting research and/or teach through a post-doc or other academic position" on question 26.

Q27 You told us in the previous question that you plan to conduct research after graduation. In which country do you plan to do so?

- ❍ [218 country choices]

Q28 Do you hope to remain in the United States after graduation?

- ❍ Yes
- ❍ No
- ❍ Do not know/not sure

The next two questions were only asked of those who answered "Yes" on question 28.

Q29 Why do you want to stay in the United States? (Please select all that apply)

- ❑ Job opportunities for myself
- ❑ Opportunities for family members
- ❑ Salary
- ❑ Overall quality of life
- ❑ Geographic location
- ❑ Family
- ❑ Friends
- ❑ Professional network
- ❑ Cultural reasons
- ❑ Social reasons
- ❑ Other (please specify): _____

Q30 How long do you plan on staying in the United States?

- ❍ 0–2 years
- ❍ 3–4 years
- ❍ 4–6 years
- ❍ 6–8 years
- ❍ 8–10 years
- ❍ > 10 years
- ❍ Don't know/not sure

The next three questions were only asked of those who answered "No" on question 28.

Q31 Why do you wish to leave the United States? (Please select all that apply)

- ❑ Job opportunities for myself
- ❑ Opportunities for family members
- ❑ Salary
- ❑ Overall quality of life
- ❑ Geographic location
- ❑ Family
- ❑ Friends
- ❑ Professional network
- ❑ Cultural reasons
- ❑ Social reasons
- ❑ Other (please specify): _____

Q32 Do you know which country you plan to go to after graduation?

- ❍ Yes
- ❍ No/not sure

The next question was only asked of those who answered "Yes" on question 32.

Q33 Which country do you plan to go to after graduation?

- ❍ [218 country choices]

Q34 Will your U.S. education give you any advantages in your career?

	Definitely yes	Probably yes	Maybe	Probably not	Definitely not
Please choose the appropriate response for the given question	❍	❍	❍	❍	❍

Q35 In comparison with your home country, what advantages, if any, do you feel a U.S. education provides? (Please select all that apply)

- ❑ Better education/knowledge of your field
- ❑ Better advisors/mentorship
- ❑ Better professional network
- ❑ Better job opportunity
- ❑ None
- ❑ Do not know/not sure
- ❑ Other (please specify): _____

Q36 Are you aware of any programs, incentives, or opportunities that are provided by your home country that are intended to encourage you to return after you get your degree?

- ❍ Yes
- ❍ No

The next two questions were only asked of those who answered "Yes" on question 36.

Q37 What kinds of programs, incentives, or opportunities are you familiar with? Please briefly list:

Q38 Please list any programs you have considered.

Q39 With regard to your academic experience, how would you rate each of the following in comparison with your home country:

	Very much worse (1)	(2)	(3)	(4)	Very much better (5)
Open classroom discussions	❍	❍	❍	❍	❍
Professors' teaching styles	❍	❍	❍	❍	❍
Subject teaching matter	❍	❍	❍	❍	❍
Access to books, magazines, journals, and databases	❍	❍	❍	❍	❍
Freedom to openly debate established theories	❍	❍	❍	❍	❍
Freedom to pursue new, self-proposed research directions	❍	❍	❍	❍	❍
Collaboration with other grad students in your lab	❍	❍	❍	❍	❍

Q40 How do you feel you are treated by your colleagues and professors in the United States in comparison with those in your home country?

	Treated much worse (1)	(2)	(3)	(4)	Treated much better (5)
Please choose the appropriate response for the given question	❍	❍	❍	❍	❍

Q41 How do you feel you would be treated by your colleagues and professors in your home country if you returned?

	Treated much worse (1)	(2)	(3)	(4)	Treated much better (5)
Please choose the appropriate response for the given question	❍	❍	❍	❍	❍

Q42 How successfully do you feel you have adjusted to American educational culture?

	Did not adjust well (1)	(2)	(3)	(4)	Adjusted well (5)
Please choose the appropriate response for the given question	❍	❍	❍	❍	❍

Q43 Please select any challenges you may have encountered while adjusting (select all that apply):

- ❑ Cultural challenges
- ❑ Social challenges
- ❑ Academic challenges
- ❑ Racial challenges
- ❑ Financial challenges
- ❑ I did not encounter any challenges
- ❑ Other (please specify): _____

The next six questions were only asked of those who answered "China" on question 22.

Q44 Did you take the Chinese College Entrance Exam (Gaokao)?

- ❍ Yes
- ❍ No

The next three questions were only asked of those who answered "Yes" on question 44.

Q45 What year did you take the Gaokao? Each answer must be between 1900 and 2013.

Q46 What was your TOTAL score? (If you do not remember, please enter 0)

Q47 What did you score in each of the following subsections? (If you do not remember, please enter 0)

- ❑ Chinese _____
- ❑ Mathematics _____
- ❑ English _____

Q48 Did you take the TOEFL?

- ❍ Yes
- ❍ No

The next question was only asked of those who answered "Yes" on question 48.

Q49 What were your scores in the following sections? (If you do not remember, please enter 0)

- ❑ Reading _____
- ❑ Listening _____
- ❑ Speaking _____
- ❑ Writing _____

Q50 We would welcome the opportunity to have a brief follow-up interview. Please let us know if you are willing to do so.

- ❍ Yes
- ❍ No

The next question was only asked of those who answered "Yes" on question 14.

Q51 Please fill in the following information

- ❑ First name _____
- ❑ Last name _____
- ❑ Email _____

End of survey.