POLICY FORUM

STEM WORKFORCE

Rethinking immigration policies for STEM doctorates

Many Ph.D.'s follow an inefficient path to green cards through visas aimed at entry-level workers

By **Michael Roach**[1] *and* **John Skrentny**[2]

Despite broad consensus that high-skilled immigration can contribute to innovation and economic growth (*1*–*3*), there is considerable controversy regarding how to reform immigration policies, including for workers in science, technology, engineering, and mathematics (STEM) professions. Much attention has centered on entry-level IT workers (*4*, *5*), but less consideration has been given to the visa pathways of STEM doctorates (*6*, *7*) who, unlike entry-level IT workers, can bring firms advanced training at the frontiers of science and technology and contribute disproportionately to innovation and entrepreneurship relative to workers with bachelor's or master's degrees (*3*). We provide new insights on the visa progression, qualifications, and starting salaries of STEM doctorates in the U.S. context from a survey that follows a cohort of 1597 U.S. citizen (69.7%) and foreign-born (30.3%) science and engineering Ph.D.'s from U.S. research universities into their first-time industry R&D employment [see details in the supplementary materials (SM)]. We show that the H-1B visa has become the predominant first step for STEM Ph.D.'s employed in industrial R&D, not because it is legally required or the most suitable visa but because of inefficiencies and delays on the path to permanent residency. Our findings show that the H-1B—a highly contentious visa used primarily for entry-level workers—may be an inefficient pathway for U.S.-trained STEM doctorates and suggest the need to rethink visa policies to retain these highly specialized workers.

Lawmakers of both major U.S. political parties have supported policies that would facilitate retention of U.S.-trained STEM Ph.D.'s. In recent years, however, attention has centered on the H-1B, which is problematic for U.S.-trained Ph.D.'s for two reasons. First, there are widespread concerns that firms use the H-1B to import cheap labor that displaces U.S. workers, especially in entry-level IT jobs (*5*). As a result, some reformers seek a reduction in the number of H-1Bs issued, and recently the Trump Administration tried to suspend issuance of new H-1B visas. However, there is little evidence on whether these concerns also apply to Ph.D.'s. To the extent that the H-1B is used to hire STEM Ph.D.'s, such sweeping reforms could drastically restrict U.S. companies' access to talented Ph.D.'s (*8*).

Second, STEM Ph.D.'s compete with entry-level workers for a limited number of H-1B visas allocated through a lottery system regardless of employer demand, level of occupation, or pay. This has heightened uncertainty for both workers and employers, leading U.S. firms—including Amazon, Google, and Microsoft—to open R&D centers in countries such as Canada where visas favor high-skilled STEM talent (*9*). Visa uncertainties also deter foreign Ph.D.'s from working in startups (*10*), placing young technology companies at a disadvantage in their ability to hire recent doctorates. Congress did not design the H-1B to retain elite workers with advanced degrees from U.S. universities, and visa reforms tailored to foreign-born Ph.D.'s may be warranted.

VISA PROGRESSION

Upon graduation, foreign Ph.D.'s have different visa pathways to industry employment. First, STEM Ph.D.'s may work on their F-1 student visa for up to 3 years without an employment-based visa through the Optional Practical Training (OPT) program. However, to remain in the U.S. long-term, foreign Ph.D.'s need to transition to an employment-based visa. There are two visa paths—one authorizing permanent residency and the other authorizing temporary work.

The Immigration Act of 1990 created a complex series of merit-based permanent resident ("green card") visa categories to attract and retain highly skilled workers. These include the highest category (EB-1) for outstanding researchers and workers with "extraordinary ability." The second category (EB-2) is for workers with advanced degrees or "exceptional ability." The EB-2 also includes a special "National Interest Waiver" (NIW) category to expedite permanent residence for workers with skills deemed especially valuable to the country. STEM doctorates from U.S. universities are qualified upon graduation for EB-2 for advanced degrees, and they may also be qualified for the EB-1 under extraordinary ability, the EB-2 under exceptional ability, or NIW if they can meet specific criteria such as evidence of scientific publications, patents, awards, and commanding a high salary. Although workers must be sponsored by their employers for the EB-2 advanced degree or exceptional ability, they may self-sponsor through either the EB-1 or NIW.

Doctorates are eligible to apply for permanent residency while on OPT and are not required to first transition to a temporary work visa such as the H-1B. The time to secure permanent residency varies depending upon the EB visa type and the worker's nationality, with processing times as short as 6 to 12 months for many Ph.D.'s on EB-1 to as long as 5 to 10 years for Ph.D.'s on EB-2 visas from countries where the high number of applicants has resulted in a wait list, such as India and China.

Another pathway for foreign Ph.D.'s is through the employer-sponsored H-1B, a "non-immigrant" temporary visa that Congress designed to fill short-term labor shortages for workers in specialty occupations with at least a bachelor's degree. Each year, the U.S. Citizenship and Immigration Services (USCIS) allocates 65,000 H-1B visas, plus an additional 20,000 for workers with a master's degree or higher from U.S. universities, for employees of for-profit firms (nonprofits such as universities are exempt from these caps). Unlike EB visas, the H-1B gives little priority to worker qualifications and no special recognition to Ph.D.'s. Given that each year the number of H-1B applications far exceeds the number of visas available, the USCIS randomly selects workers until the quotas are met. Doctorates not selected in a given year may reapply the following year, so long as they have not exhausted their OPT eligibility. The H-1B is valid for 3 years and may be renewed for an additional 3 years. Although the H-1B is not required for permanent residence eligibility, in practice Ph.D.'s may use the H-1B as a bridge between OPT and a green card.

The array of different pathways that doctorates may take through the visa system is complex, and there is little empirical un-

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derstanding of which visas recent doctorates use in their first industry job, nor the sequencing and timing of visa progression. We provide detailed insights on the visa progression of foreign STEM doctorates from 39 leading U.S. research universities who graduated between 2010 and 2016 and transitioned to industry employment (see SM for details of sample by nationality and degree field). The survey provides previously unavailable microdata on STEM doctorates' visa progression, employment qualifications, starting salary and work benefits, and employer characteristics. We complement our survey with administrative data from the Department of Labor (DOL) on 2461 Labor Certification applications for foreign Ph.D.'s sponsored for an EB-2 visa. Our sample represents young, early-career Ph.D.'s who have many years of productivity ahead of them and are the focus of governments around the world seeking to attract and retain leading STEM researchers.

We asked foreign Ph.D.'s to report their first work visa, as well as their current visa after at least 3 years of industry employment. In their first job, two-thirds of Ph.D.'s were sponsored for an H-1B, the same visa used to hire entry-level workers with bachelor's degrees and that is at risk of restriction by Congress (see the first figure). Approximately 10% of foreign doctorates were either employer- or self-sponsored for permanent residency, and 16% remained on OPT without a sponsored work visa.

After at least 3 years of employment, 68% of doctorates have either received or been sponsored for permanent residency (see the first figure). Among Ph.D.'s who were first sponsored on an H-1B, 76% have transitioned to or are being sponsored for permanent residency (table S2). Although our sample does not reflect Ph.D.'s who may have left the United States as a result of visa delays, these patterns illustrate that the majority of Ph.D.'s obtain permanent residency early in their careers and that most do so by passing through the H-1B.

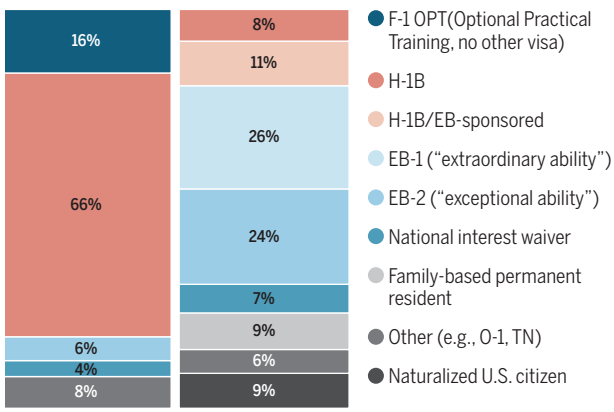
To obtain deeper insights into pathways for Ph.D.'s to gain permanent residency, we use DOL administrative data on EB-2 Labor Certification applications. Among foreign STEM Ph.D.'s employed in industrial R&D and sponsored by their employer for EB-2 visas, 20% progressed directly from OPT, whereas nearly 80% progressed through an H-1B (table S4). The average time from graduation to filing an EB-2 application is 1.1 years under OPT and 2.8 years under H-1B (fig. S2). Although Ph.D.'s on H-1B wait ~18 months longer to be sponsored for permanent residency than Ph.D.'s on OPT, this wait time is much shorter than the full 6-year term of the H-1B visa. This suggests that employers are not using the H-1B as a trial period before sponsoring for a green card.

At the same time, the short duration of OPT work eligibility makes applying for permanent residency without first obtaining an H-1B an often impossible path for doctorates from India and China, who may wait several years to receive their green cards because of per-country quotas. Our survey shows that Indian (78%) and Chinese (67%) doctorates are especially likely to be first sponsored for an H-1B compared to doctorates from other countries (55%) (table S4). Although the longest wait times of 5 to 10 years are for the EB-2, wait times for the EB-1 are just over 2 years (*11*). To examine whether Ph.D.'s differ in their use of EB-1 and EB-2 visas, we asked survey respondents sponsored for permanent residency their EB preference category: 46% reported that they were sponsored for an EB-2, 41% were sponsored for EB-1, and 10% for NIW (table S3). Moreover, a disproportionate share of doctorates from India and China are on EB-1 (50.8% and 54.2%, respectively) compared to doctorates from the rest of the world (20.0%, table S4), likely because of the shorter wait time relative to the EB-2.

Together these findings demonstrate that a meaningful share of doctorates transition directly to permanent residency while on OPT. At the same time, the majority first pass through the H-1B, suggesting that the H-1B may be pressed into service to overcome gaps resulting from an inefficient immigration system.

Visa progression of foreign-born STEM Ph.D.'s

Employment visa in first job is shown at left, current visa after 3 to 9 years of employment is at right. Sample is foreign-born Ph.D.'s who were temporary residents at graduation and required a work visa in their first industrial job (N = 305).



GRAPHIC: KELLIE HOLOSKI/*SCIENCE*

This raises the question of why more doctorates don't transition directly to permanent residency. One possibility is that doctorates sponsored for permanent residence in their first job may be more qualified than those sponsored for H-1B (see SM). In regression analyses that control for demographics and degree field (table S6), we find no significant difference between Ph.D.'s sponsored for EB or H-1B visas in terms of the number of publications or patents prior to industry employment, two evidentiary requirements of a worker's qualifications used in permanent residency applications. We also find no significant difference in starting salary as reported in our survey, nor in the offered wage as reported in the DOL EB-2 applications (see the second figure). Although we lack data to explore why firms sponsor some Ph.D.'s for EB and others for H-1B, these results show that Ph.D.'s sponsored for an H-1B may be qualified for permanent residency when first hired.

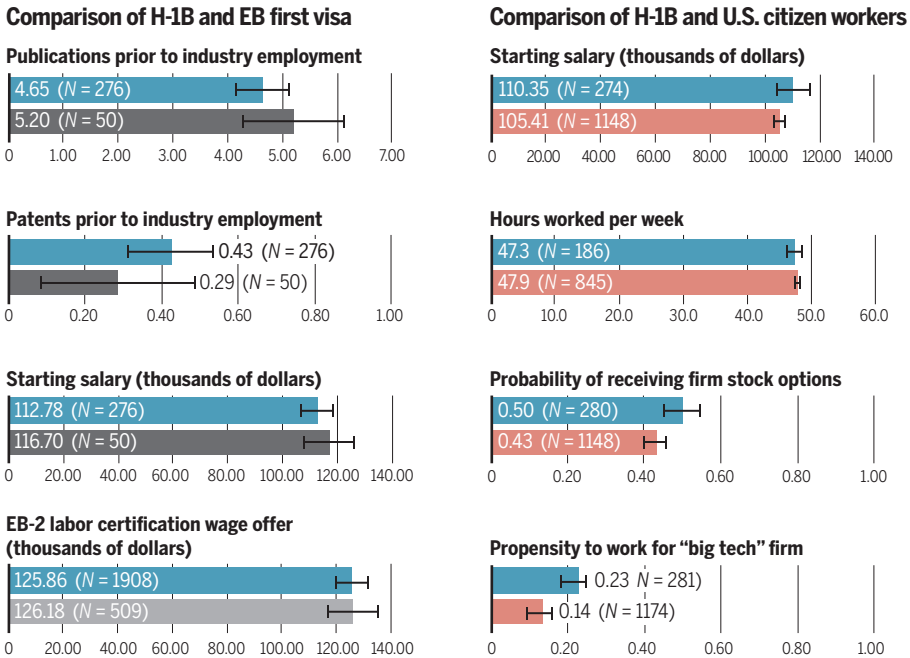
COMPARISON TO U.S. PH.D.'S

Arguably the greatest concern when considering changes in visa policies is potential adverse impacts on U.S. citizens. Though the preponderance of prior research has compared U.S. citizens to H-1B entry-level IT workers (*5*, *12*), there is little existing evidence comparing U.S. and foreign doctorates first-time employees in similar industry occupations. Data from the U.S. Bureau of Labor Statistics show that doctorates have the lowest unemployment and highest salaries of any level of educational attainment, with pre–COVID-19 unemployment of 1.1% and median annual salaries of approximately $100,000 (*13*). Although these numbers do not distinguish between U.S. and foreign doctorates, the tight labor market for highly skilled Ph.D.'s does not suggest crowding out.

To examine possible differences in pay, we use our survey to compare the starting salary of U.S. citizen and foreign Ph.D.'s on temporary resident visas in their first industrial R&D job (see SM). In regression analyses that control for worker ability, demographics, work benefits, job start year, and employer type, we find no significant difference in pay between U.S. citizen and foreign doctorates (see the second figure). Instead, starting salary is driven primarily by degree field and proxies for worker ability (table S7). Though these comparisons do not allow for careful identification of the

Comparing qualifications

Graphs show predicted values from regression analyses (see tables S6, S7, and S9). (Left) Foreign doctorates first sponsored for H-1B (blue) are compared with those first sponsored for permanent residency (EB)(dark gray); EB-2 Labor Certification application wage offer is compared between applicants on H-1B and on OPT (Optional Practical Training, light gray). (Right) Foreign doctorates on H-1B (blue) are compared with U.S. citizen doctorates (red).



causal effects of immigration policies on wages, nor do they rule out the possibility that a greater number of foreign Ph.D.'s in the workforce could drive down wages for native Ph.D.'s (*14*), they provide suggestive evidence that often-cited concerns of foreign entry-level STEM workers being paid less than their native peers do not apply to STEM Ph.D.'s (*5*).

Another frequent concern is that employers may use visa sponsorship as leverage to exploit foreign workers in ways other than salary. For example, employers may require sponsored employees to work longer hours relative to U.S. citizens, or they may offer fewer benefits to offset the high costs of visa sponsorship. In regression analyses (table S9), we find no significant difference between U.S. and H-1B Ph.D.'s in hours worked, with both reporting an average of 47 hours per week (see the second figure). We also find that H-1B Ph.D.'s have a higher probability than U.S. Ph.D.'s of receiving firm stock options (see the second figure), a highly coveted financial benefit. This appears to be due to foreign doctorates' higher propensity to work in "big tech" firms like Google and Amazon that are more likely to give new employees stock options (see SM). H-1B Ph.D.'s are also nearly twice as likely to work for a big tech firm compared to other firms (see the second figure).

IMPLICATIONS

The role of the H-1B as the modal start of a complex path to permanent residency for elite, high-skilled STEM doctorates from U.S. universities is inconsistent with the U.S. government's classification of the H-1B as a guest worker visa for entry-level jobs. However, delays in the processing and wait times for a green card have made the H-1B the de facto first visa for the majority of doctorates, especially individuals from India and China. This inefficient visa path through the H-1B increases not only uncertainty for workers but also the costs for many employers who spend thousands of dollars per employee to first sponsor them for an H-1B and then several thousand more for permanent residency. These inefficiencies suggest that a streamlining of the path from doctorate to permanent residency or changes to the H-1B program may be warranted (*15*).

Visa reforms that specifically target STEM Ph.D.'s from U.S. universities—with oversight to avoid fraudulent dissertations and job offers—could have broad benefits by facilitating and easing doctorates' transitions to permanent residence. A simplified path toward permanent residency could be especially beneficial in leveling the playing field for early-stage technology startups that are at a disadvantage in hiring workers who require visa sponsorship (*10*). In addition, exempting STEM Ph.D.'s from national quotas for green cards would not only facilitate their pathway to permanent residency but could also help U.S. firms to retain top scientists and engineers where they can contribute to innovation and economic growth. Our findings align with the proposed immigration policies of President-elect Biden, who within his first 100 days intends to implement a program that would provide recent STEM doctorates from U.S. universities with a green card that is exempt from national quotas. ■

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SUPPLEMENTARY MATERIALS

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Supplementary Materials for

Rethinking immigration policies for STEM doctorates

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This PDF file includes:

1 Materials and Methods

Our empirical analyses utilize two separate data sources: the Science and Engineering PhD Panel Survey (SEPPS) administered by the authors and the U.S. Department of Labor PERM public disclosure administrative data on Labor Certification applications for EB-2 permanent residency. SEPPS data and Stata code used in this study are available at Dataverse: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/8WCCSB

1.1 Science and Engineering PhD Panel Survey (SEPPS)

The SEPPS is a national longitudinal survey of a cohort of science and engineering PhDs from 39 top-tier U.S. research universities.[1] Respondents were first surveyed in spring 2010 or spring 2013 while in graduate school (PhD survey, 10,781 respondents, 30% response rate) and then again after graduation in 2013, 2016, 2018 and 2019 as they transitioned into post-graduation positions, including postdoctoral positions and full-time employment (employment survey). This longitudinal survey provides detailed micro data on individuals' characteristics and PhD experience while in graduate school, as well as employer characteristics and work activities after graduation. This survey was approved by the Cornell University Institutional Review Board Protocol # 1707007286A003.

To the best of our knowledge, the SEPPS is the only data source that provides detailed insights on the full composition of employment visas, including H-1B, OPT, O-1, permanent residency, etc., for recent STEM doctorates in their first full-time industry R&D position. In addition, the SEPPS provides data on PhDs' transition to other work visas over their early careers, primarily different types of permanent residency. The SEPPS also distinguishes between different types of permanent residency preference categories, specifically the EB-1, EB-2 and National Interest Waiver (NIW). This is important since we have little data on the extent to which PhDs are sponsored by their employers for EB-1 or NIW relative to EB-2.

The SEPPS offers a number of advantages over existing data sources used to examine U.S. immigration policies. First, administrative data are typically organized by visa type, such as the H-1B, and thus allow for detailed comparisons of a wide swath of workers who differ in education, skills, occupation and experience. However, they do not allow for comparisons of similar workers such as PhDs on different visas, nor do they follow workers' visa progression over time from first employment. Moreover, differences in occupation classes make comparisons of wages more difficult as employers may classify foreign workers for lower skilled jobs than the U.S. citizen who they are competing with for jobs. Other frequently used data, such as the NSF *Survey of Doctorate Recipients*, provide nationally representative survey data of science and engineering doctorates from U.S. research universities. Although the SDR allows for comparisons of recent U.S. and foreign doctorates across fields, it reports foreign PhDs as temporary or permanent

[1] The initial survey was developed and administered by Michael Roach and Henry Sauermann.

residents and does not provide information on different visa types, nor the transition between different visas for the same foreign PhDs over time.

Survey Methodology – To obtain the initial survey sample, we identified top-tier U.S. research universities with doctoral programs in science and engineering using the 2009 National Science Foundation's Survey of Earned Doctorates, an annual census of all individuals receiving doctorates from U.S. universities. Our selection of universities was based largely on program size while also ensuring variation in private and public universities and geographic region We collected approximately 30,000 email addresses from department websites and invited PhD students to participate in an online survey in spring 2010. For departments that did not list PhD students' email addresses, we contacted department administrators and requested that they forward a survey link to their graduate students. Overall, 88% of responses for our baseline survey were obtained through direct email and 12% were obtained through administrators. Adjusting for 6.3% undeliverable emails, the direct survey approach yielded an adjusted response rate of 30%. We administered another survey in spring 2013 that was sent to both respondents and non-respondents of the 2010 survey to increase the sample size and to obtain measures of PhDs in later stages of their program, as well as those who may have graduated and transitioned to other positions. Of the 10,781 respondents, 8,508 were PhD students at various stages of their graduate studies and 2,273 were postdoctoral scholars. Given that postdocs are temporary research training positions prior to engaging in full-time employment, we combine postdocs with PhD students and include a control variable for respondents who completed a postdoc prior to full-time employment.

A follow-up employment survey was sent in spring 2013, 2016, 2018 and 2019 to the same PhD students who responded to the PhD survey in 2010 or 2013.[2] The employment survey asked questions about respondents' postdoc experience, if any, their job search, year of first industry employment, first employer age and size, starting salary and, for foreign PhDs, their first and current work visa. The employment surveys also asked respondents to indicate their current employer type (university, national lab or research institute, established firm, startup, founder, or other), as well as whether this was their first full-time job.[3]

We restrict our sample to 1,597 PhDs who responded to both the *PhD survey* and *employment survey,* who graduated between 2010-2016, and who entered full-time employment in the U.S. private sector in R&D occupations between 2010-2019. We used survey responses on work activities (i.e., at least 40% of weekly work activities are basic research, applied research, and/or

[2] We asked respondents of the PhD survey to provide us with a personal email address to contact them in the future. Among respondents who provided us with a personal email address, 64.8% responded to the employment survey in at least one of the years it was administered. For 35.2% of our respondents we only had a university email address that may no longer be active, and thus we were unable to reach some PhD student respondents to participate in the employment survey.

[3] The first question of each wave of the survey asks about the respondents' current status as (1) a PhD student or candidate, (2) postdoctorate or research fellow, (3) working full or part-time, and (4) currently not working. Respondents were presented with unique surveys based on their response to this question. For example, a PhD student in 2010 who was working in 2013 would receive the employment survey, while a one who was still a PhD student would receive the PhD survey.

development) to identify PhDs employed in R&D-related occupations in U.S. firms. To ensure that we compare individuals who are equally likely to work in similar U.S. industrial R&D-related jobs, we exclude from our sample individuals employed outside the U.S., as well as those employed in consulting, finance, and non-R&D occupations, as well as those in non-profit organizations such as universities and research institutes.

We identify foreign PhDs as survey respondents who reported that they were not U.S. citizens during graduate school or their postdoc. We also asked about their visa status during graduate school or postdoctoral training (e.g. F-1, J-1, permanent resident, etc.) to identify temporary residents who would require a visa to work in the U.S. after graduation, whereas permanent residents do not require an employer-sponsored work visa and have the same employment freedom as U.S. citizens. We compare foreign PhDs to U.S. PhDs who reported that they were U.S. citizens during graduate school. Our sample is comprised of 69.7% U.S. citizen, 4.6% permanent resident and 25.7% temporary resident PhDs (Table S1).

Sample Representativeness – We benchmarked our sample of PhDs employed in industrial R&D from the *employment survey* to the 2017 NSF *Survey of Doctorate Recipients (SDR)*, a biennial survey of science and engineering PhDs in the U.S. workforce. Using the NSF online survey tool for the public access data, we constructed a sample that is comparable to our survey sample of PhDs who graduated between 2010 and 2016, are employed in for-profit firms in the U.S., and whose primary work activity is R&D (Table S1). In our sample of foreign PhDs from the *employment survey* the share who are temporary residents (25.7%) is smaller than the share of recent doctorates employed in industrial R&D on temporary resident visas in the SDR sample (39.7%). Among foreign temporary resident PhDs in our sample, 18.8% are from China and 19.8% are from India, compared to 32.7% from China and 15.7% from India in the NSF SDR.[4]

We believe that there are two possible reasons for the lower response rate of foreign PhDs in our survey. First, in the PhD survey we asked respondents to provide us with a personal email account so that we may contact them again to continue participation in the survey. Foreign PhDs were less likely to provide a personal email address, and for many their student university email address is no longer active. Second, our most recent surveys were administered in 2016, 2018 and 2019, and thus the current political environment that is less friendly to immigrants may have had a chilling effect on response rates.

[4] https://www.nsf.gov/statistics/2018/nsf18304/report/who-earns-a-us-doctorate/citizenship-foreign-origins.cfm

Table S1. Comparison of SEPPS to NSF Survey of Doctorate Recipients (row percentages)

	NSF Survey of Doctorate Recipients (N=1,800)			Science & Engineering PhD Panel Survey (N=1,597)		
	U.S. citizen	Permanent resident	Temporary resident	U.S. citizen	Permanent resident	Temporary resident
Life sciences	69.9%	6.4%	23.7%	78.5%	6.5%	15.0%
Chemistry	59.5%	5.9%	34.6%	71.7%	5.4%	22.8%
Physics	58.5%	4.8%	36.7%	71.4%	3.4%	25.2%
Engineering	35.8%	5.4%	58.8%	66.8%	2.1%	31.1%
Computer Science	39.6%	3.5%	56.9%	58.6%	3.3%	38.1%
All fields	**54.7%**	**5.6%**	**39.7%**	**69.7%**	**4.6%**	**25.7%**

Response bias among foreign PhDs is of concern for analyses that directly compare foreign PhDs to U.S. citizens. To account for potential response bias, we constructed proportional sample weights using NSF SDR data by dividing the proportion of temporary resident industrial R&D employees for broad degree fields in our survey (i.e., the "sample proportion") by the proportion observed in the SDR for the same broad field (i.e. the "population proportion"). The public use SDR data do not include specific nationalities, so broad field was the finest level for which we could construct sample weights. We ran separate unweighted and weighted regression analyses with nearly identical results. In all analyses that follow we report results using proportional sample weights (unweighted results available from the authors).

We have no basis for expecting systematic bias among temporary residents by visa type. For example, if respondents sponsored on an H-1B were less likely to respond than those on F-1 OPT or O-1, then our sample might underrepresent the share of PhDs first sponsored on an H-1B. While we have no way to examine this in our sample, we investigated the shares of temporary and permanent visas among SDR respondents as well as changes in these visa statuses over time (see Figure S1 below) and find that the general visa progression in our sample is comparable to the visa progression in the SDR.

U.S. Department of Labor PERM Data

We complement our survey data with administrative data from the U.S. Department of Labor's Labor Certification (LC) applications for a permanent resident EB-2 visa (ETA Form 9089). Employers use LCs to certify their inability to find a U.S. worker for the position and payment of the prevailing wage for that occupation in a given region. LCs are required for most EB-2 filings, but not for National Interest Waivers or EB-1.

The DOL's PERM administrative data include the date of filing, the offered wage and occupation classification, the worker's highest degree type, field, granting university, and year granted, and employer name, age, number of employees, and industry. We identified 2,461 LCs filed by employers between 2013-2016 that correspond to our survey sample of science & engineering PhDs in industrial R&D-related occupations who graduated from a U.S. research university in

2010 or later. This represents the population of EB-2 sponsored STEM PhDs who graduated from 71 U.S. research universities, the majority of whom hold degrees in engineering (62.6%) or computer science (22.1%), with smaller shares in the life sciences (3.2%), chemistry (4.4%) and physics (7.7%).

We use the DOL PERM administrative data to both validate our survey-based findings as well as to provide addition insights into the population of STEM PhDs sponsored for EB-2 visas during the same period of as our survey. More specifically, we examine PhDs' visa type (i.e., entry visa class) at the time of EB-2 application, the duration from graduation to filing, and the offered wage.

2 Methods and Results

2.1 Visa progression

To examine foreign PhDs' visa progression, we asked respondents in the 2018 and 2019 employment survey to report their citizenship or visa status at various stages of their education and career. First, we asked respondents: "At the time you were looking for your first industry job after your PhD or postdoc, what was your citizenship, immigration or visa status?" The response options were: U.S. citizen, F-1, J-1, H-1B, U.S. permanent resident, and other. Although this is a retrospective question, it asks about a specific fact that respondents are likely to recall with high precision and not about their attitudes or beliefs at a given point in time.

Second, respondents who reported that they were temporary residents when searching for their first industry job (i.e., F-1, J-1, H-1B, and "other") were asked: "At the time you started your first job, which of the following work visas did your employer sponsor you for, if any?" The options were: H-1B, employer-sponsored green card (e.g., EB-1 or EB-2), self-sponsored green card (e.g., National Interest Waiver), OPT only (no other visa), and other (text responses included O-1, TN, family-based permanent residency, etc.).

Finally, later in the survey we asked non-U.S. citizens: "Which of the following best describes your current visa, immigrant or citizen status? If you are currently in the process of petitioning for a different visa please report your current visa and not the visa being petitioned." The options were: H-1B, OPT, employer-sponsored green card (e.g., EB-1 or EB-2), self-sponsored green card (e.g., National Interest Waiver), family-based green card (e.g., by marriage), U.S. citizen, and other.

We focus our analysis of visa progression on the 305 foreign doctorates who graduated as temporary residents – primarily F-1 student visa holders – and have been employed in industrial R&D in the U.S. for at least three years. We chose three years since this is the maximum duration of OPT with the STEM extension, and thus PhDs must have transitioned to a temporary or permanent work visa.[5] In addition, in the DOL PERM data the average duration from graduation

[5] Although we do not have data on foreign PhDs who may have left the U.S. due to visa sponsorship, data from the 2017 NSF SDR that correspond to our sample indicate that only 8.8% of all foreign STEM doctorates who graduated between 2010-2014

to EB-2 applications for PhDs who were on an H-1B is 2.8 years, suggesting that three years is a reasonable period of time to observe visa progression.

The first figure in the article reports the shares of first work visa and current work visa over their early career. Table S2 reports the share of foreign doctorates' current visas (columns) by their first work visa in industry employment (rows). Among foreign doctorates who were first sponsored on H-1B, 62.8% have transitioned to an EB permanent resident visa and an additional 13.3% are on H-1B and in the process of being sponsored for permanent residency.

Table S2. Visa progression over time (share of current visa by first visa)

	H-1B	H-1B/EB	EB	Family perm. res.	Naturalized U.S. citizen	Other
OPT	12.8%	10.6%	36.2%	27.7%	8.5%	4.3%
H-1B	8.8%	13.3%	62.8%	5.5%	8.0%	1.5%
EB	n.a.	n.a.	85.2%	n.a.	14.8%	n.a.
Other	0.0%	0.0%	57.7%	15.4%	11.5%	15.4%
Total	**8.0%**	**10.6%**	**57.3%**	**9.6%**	**8.9%**	**5.6%**

NOTES: Rows are visa in first employment and columns are current visa after 3-9 years of employment; row percentages reported; N=305.

Respondents who reported that their current visa status was either permanent resident or being sponsored for permanent residency were asked to also report the EB preference category. Table S3 reports the share of doctorates on different EB preference categories by their first visa.

Table S3. Permanent residency EB preference category

	EB-1	EB-2	NIW	EB-3
OPT	19.0%	52.4%	28.6%	0.0%
H-1B	42.4%	50.3%	4.0%	3.3%
EB	34.8%	26.1%	34.8%	4.3%
Other	61.1%	33.3%	5.6%	0.0%
Total	**40.8%**	**46.5%**	**9.9%**	**2.8%**

NOTES: Rows are visa in first employment and columns are EB preference category for doctorates sponsored for permanent residency; N=213.

Table S4 reports summary statistics of visa progression for foreign doctorates by nationality: China, India, and rest of world (R.O.W). Doctorates from China and India are disproportionately first sponsored on H-1B, and within three years over 80% are either permanent residents or are temporary residents being sponsored for permanent residency. The higher share of doctorates from India and China who are first sponsored for H-1B is likely due to longer green card wait times, which vary depending upon the preference category. Table S3 shows that a much larger share of doctorates from India and China are sponsored for EB-1 visas, which have a current wait time of

are working in industrial R&D outside the U.S. Given that the stay rates for foreign-born PhDs from U.S. universities who are comparable to our sample is approximately 90%, we do not expect this be a significant concern for our analysis.

just over two years compared to 5-9 years for the EB-2 visa. While not reported in the table, doctorates from India and China account for 75% of EB-1 visas and only 38.4% of EB-2 visas. Doctorates from the rest of the world appear to progress earlier and more quickly to permanent residency and to naturalized U.S. citizen.

Table S4. Visa progression by nationality

	First employment visa			
	H-1B	OPT	EB	Other
China	66.7%	19.0%	9.5%	4.8%
India	77.8%	8.6%	7.4%	6.2%
R.O.W.	54.5%	21.6%	12.5%	11.4%

	Current visa after 3-9 years of employment				
	H-1B	H-1B/EB	EB	Naturalized	Other
China	9.3%	8.0%	80.0%	1.3%	1.3%
India	15.0%	26.3%	55.0%	2.5%	1.3%
R.O.W.	5.0%	5.6%	68.9%	13.9%	6.7%

	EB Preference Category			
	EB-1	EB-2	NIW	EB-3
China	54.2%	30.5%	10.2%	5.1%
India	50.8%	32.8%	14.8%	1.6%
R.O.W.	20.0%	58.1%	19.0%	2.9%

We benchmark our visa progression results to the 2017 NSF SDR for comparably matched PhDs. Although the SDR only reports broad classes of temporary resident, permanent resident, and naturalized U.S. citizen, the general patterns are consistent with our more detailed visa progression findings. Figure S1 shows that soon after graduation the majority of foreign PhDs are on temporary resident visas such as H-1B or OPT, and roughly 20% are permanent residents. Over time, the share who are permanent residents or naturalized U.S. citizens increases to over 90% of PhDs who graduated roughly ten years prior.

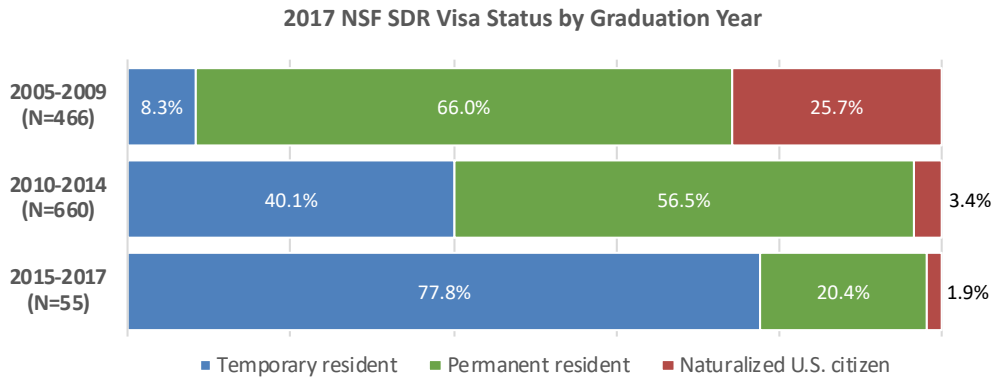

Fig. S1 – Progression from temporary to permanent residency

We compare our findings to administrative data from the U.S. Department of Labor's Labor Certification (LC) applications for a permanent resident visa (PERM). Since the DOL PERM data are employer sponsored EB-2 visas, they are comparable to the 44% of employer-sponsored EB-2 workers in our survey sample, but may not be representative of EB-1 or National Interest Waiver applicants given the higher qualifications required for these visas. We examine 2,461 LCs filed by employers between 2013-2016 for STEM PhDs in industrial R&D-related occupations who graduated from a U.S. research university in 2010 or later. The PERM data report each worker's "class of admission," which is the visa status at the time of filing. Table S5 shows that across all fields, 77.5% of EB-2 PhDs were on an H-1B at filing and 20.7% were on F-1 OPT. The large share of PhDs sponsored for permanent residency while on F-1 OPT indicates that obtaining a green card without first obtaining an H-1B is common.

Table S5. Visa class of admission for U.S. DOL Labor Certification applications (EB-2)

	H-1B	F-1 OPT	Other visa
Life sciences	84.4%	10.4%	5.2%
Chemistry	60.9%	37.3%	1.8%
Physics	77.8%	21.2%	1.1%
Engineering	76.5%	21.5%	1.9%
Computer Science	82.4%	16.3%	1.3%
All fields	**77.5%**	**20.7%**	**1.8%**

NOTES: PERM administrative data (2013-2016) for science & engineering PhDs with degrees from U.S. research universities employed in industrial R&D occupations (N=2,461).

To consider when in their careers STEM PhDs are sponsored for an EB-2, we calculated the number of years between PhD graduation year and the year of LC filing. The PERM data do not indicate when the PhD started industry employment, nor whether they did a postdoc between graduation and industry employment. Thus, these data may reflect the upper bound of the duration from first industry employment to green card sponsorship. Figure S2 presents the average number of years to sponsorship by admission visa (H-1B or OPT) and field. Across all fields the average time from graduation to filing is 1.1 years for workers on OPT and 2.8 years for workers on H-1B, illustrating the longer pathway to permanent residency through an H-1B.

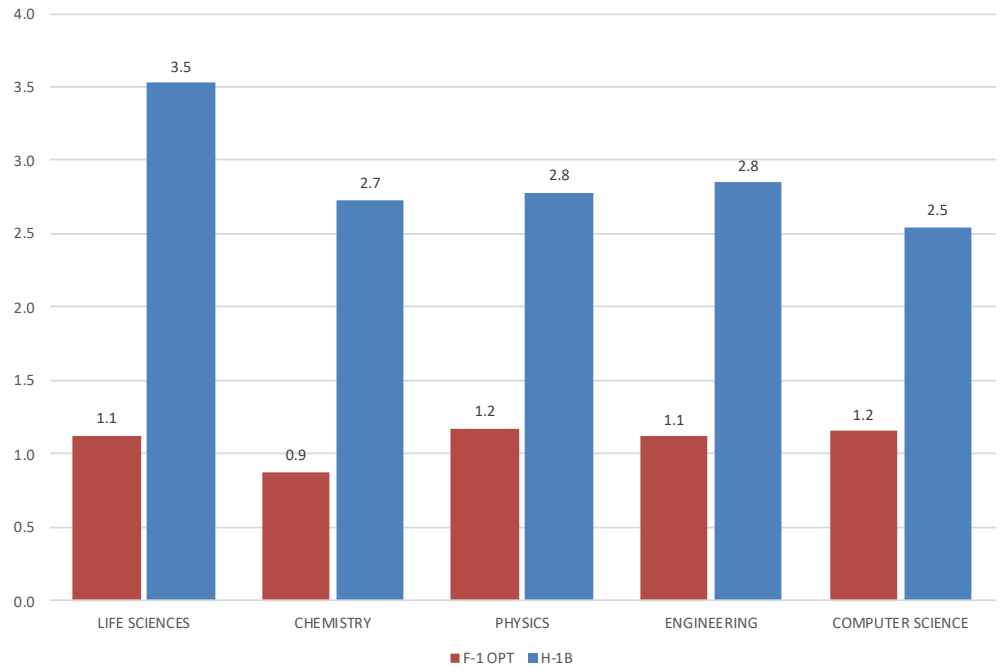

Fig. S2 – Average number of years from graduation to EB-2 sponsorship by visa type
Data source is Department of Labor's Labor Certification applications (PERM); sample of applicants with STEM PhDs from U.S. universities in industry R&D occupations between 2013 to 2016 (N=2,461)

2.2 Comparing H-1B and Permanent Resident (EB) qualifications

We investigate whether there are observable differences in qualifications between PhDs who were sponsored for permanent residency while on OPT versus those who were sponsored for an H-1B.[6] We do this through a series of linear regression analyses using our survey data on observable variables of worker qualifications required for the EB-1, EB-2 and NIW visas including the number of publications and patents at graduation, and starting salary. These are the highest preference categories for permanent residency and thus have the highest worker qualification requirements. The sample for these analyses includes 326 respondents in their first industry job who reported that their first visa status as either (1) sponsored by their employer for permanent residency – while on OPT – or (2) sponsored for an H-1B visa. Since this analysis examines PhDs' first visa status and not their visa progression over time, we are able to expand the slightly to include individuals who responded only to the first employment survey and not both waves of the employment survey. At the same time, this sample excludes foreign PhDs who were not sponsored for permanent residency or an H-1B in their first job, such as individuals on TN or O-1 visas, or who were sponsored for permanent residency by marriage to a U.S. citizen.

[6] Common qualifications for the EB-1 or EB-2 preference category include an advanced degree such as a PhD relating to ability, high salary that demonstrates extraordinary or exceptional ability, recognitions of achievement, and contributions including patents and publications. https://www.uscis.gov/working-united-states/permanent-workers/employment-based-immigration-second-preference-eb-2

We asked respondents in the employment survey "Thinking back to when you completed your PhD, at that time how many publications or patents listed you as an author or inventor?" For respondents who did a postdoc before transitioning to industry we asked them to report their number of publications and patents at the end of their postdoc. Together we consider these the number of publications or patents while in academia before transitioning to an industry job. Among foreign doctorates the average number of publications is 4.5 and the average number of patents is 0.39 (77.8% reported zero patents).

Table S6 reports OLS regression analyses that compare the qualifications of foreign PhDs sponsored for an EB permanent residency visa while on OPT in their first job (1) to those sponsored on an H-1B (0), regardless of whether they are being sponsored for permanent residency or not. All models control for gender and marital status, degree field and job start year. All models report robust standard errors clustered on university.

Models 1 and 2 report the number of publications and patents while in academia and prior to industry employment, respectively, and show no significant difference between EB and H-1B PhDs. Model 3 shows no significant difference in starting salary between EB and H-1B PhDs. These results suggest that PhDs sponsored on an H-1B have similar qualifications as PhDs who are sponsored for an EB while on OPT, and thus could possibly be qualified for EB sponsorship as well.

Model 4 use the DOL PERM data on Labor Certification applications. Although these data do not have the same level of granularity as our survey and do not report starting salary, they are administrative data of the population of EB-2 applications that report the wage offered at the time of sponsorship between 2013-2016 for 2,417 foreign-born STEM doctorates from U.S. universities. The PERM data also provide the visa class at entry – OPT (1) or H-1B (0) for this analysis – as well as the year of graduation, university, degree field, and employer characteristics. Since doctorates on H-1B are sponsored approximately 18 months later from the date of graduation compared to doctorates sponsored while on OPT, we include a variable to reflect work experience – years since completing the PhD – to capture differences in work experience that might predict wage offered. We find no difference in the wage offered between doctorates sponsored while on OPT and those who first go through the H-1B.

Table S6. Comparison of foreign doctorates sponsored on H-1B vs. Permanent Residency

Dependent variable	ln(patents prior to ind. empl.)	ln(pub. prior to ind. empl.)	ln(starting salary)	ln(PERM wage offer)
Method	OLS	OLS	OLS	OLS
Model	(1)	(2)	(3)	(4)
Sponsored for EB while on OPT	0.07	-0.04	0.03	0.01
	(0.09)	(0.06)	(0.04)	(0.01)
Male	-0.03	0.01	0.13***	
	(0.11)	(0.05)	(0.03)	
Married	-0.42***	-0.11+	-0.09*	
	(0.11)	(0.06)	(0.04)	
Children	-0.12	0.00	-0.02	
	(0.20)	(0.07)	(0.05)	
Work in startup			-0.10*	-0.70***
			(0.05)	(0.02)
Work experience				0.00
				(0.00)
Constant	1.40***	0.13	4.37***	11.72***
	(0.18)	(0.08)	(0.08)	(0.05)
Job start year FE	Y	Y	Y	Y
Degree field FE	Y	Y	Y	Y
R^2	0.18	0.14	0.34	0.12
Obs.	326	326	326	2,417

NOTES: Data source for Models 1-3 is Science and Engineering PhD Panel Survey; Data source for Model 4 is the Department of Labor PERM file for EB-2 labor certification applications 2013-2016; robust standard errors clustered on university reported in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

2.3 Comparing H-1B and U.S. citizen starting salaries

While there is broad concern that foreign workers, especially on H-1B, are paid below market wages that undercut American workers, little evidence exists regarding the starting salaries for foreign PhDs and U.S. PhDs in the same jobs. To examine this, we use our survey to compare the starting salary of 1,597 U.S. citizen (69.7%), foreign permanent resident (4.6%), and foreign temporary resident (25.7%) STEM PhDs in their first industrial R&D job. We asked respondents a series of questions about their first industry job, including their total starting annual compensation (in US dollars, including base salary and bonuses) as well as whether they received employee stock options as part of their compensation. The median reported starting salary for STEM PhDs between 2010-2019 was $96,000 for U.S. citizens and $105,000 for temporary resident PhDs. However, these numbers do not take into consideration that foreign PhDs are concentrated in engineering and computer science where industry salaries are higher.

We perform a series of OLS regression analyses that examine possible differences in starting salary between U.S. citizen and foreign PhDs while controlling for degree field, year of first employment, and individual characteristics such as gender, marital status, postdoctoral experience and proxies for ability including NRC department ranking and the number of publications and patents while in academia (Table S7). All regressions include sample weights to adjust for the lower representation

of foreign PhDs in our sample, and all models include robust standard errors clustered on university. Model 1 includes a variable reflecting all temporary resident PhDs, while Model 2 includes a variable reflecting those on H-1B visas. Models 3 and 4 report the salary regressions for U.S. citizen and H-1B PhDs, respectively, to investigate differences in the predictors of starting salary for the two subsamples. We find no significant differences between U.S. and temporary resident PhDs in starting salary, indicating that temporary resident PhDs are indeed paid the same market wage as their U.S. counterparts. Instead, starting salary is driven largely by field differences and variables of worker ability (e.g., ranking of the degree-granting department and number of publications and patents at graduation). Table S8 reports OLS regressions of starting salary by broad degree field.

Table S7. Starting salary for PhDs in industrial R&D occupations

Dependent variable: ln(starting salary)				
Sample	**Full**	**U.S. & H-1B**	**U.S.**	**H-1B**
Method	OLS	OLS	OLS	OLS
Model	(1)	(3)	(4)	(5)
All temporary resident PhDs	0.02			
	(0.02)			
Foreign PhDs: H-1B visa		0.01		
		(0.02)		
NRC univ. dept. ranking	0.06***	0.06***	0.06***	0.06*
	(0.01)	(0.01)	(0.01)	(0.02)
ln(publications prior to ind. empl.)	0.03**	0.03*	0.03*	0.03
	(0.01)	(0.01)	(0.01)	(0.03)
ln(patents prior to ind. empl.)	0.08***	0.08***	0.10***	0.03
	(0.01)	(0.02)	(0.02)	(0.03)
Prior postdoc	-0.00	0.00	0.01	-0.02
	(0.02)	(0.02)	(0.02)	(0.04)
Male	0.08***	0.07***	0.06***	0.11**
	(0.01)	(0.01)	(0.01)	(0.04)
Married	-0.02	-0.03	-0.01	-0.07
	(0.02)	(0.02)	(0.02)	(0.04)
Children	-0.00	0.01	0.01	-0.02
	(0.02)	(0.02)	(0.02)	(0.05)
Work in startup	-0.19***	-0.18***	-0.18***	-0.24***
	(0.02)	(0.03)	(0.03)	(0.06)
Received firm stock options	0.15***	0.15***	0.13***	0.17***
	(0.02)	(0.02)	(0.02)	(0.03)
Constant	4.52***	4.50***	4.52***	4.42***
	(0.04)	(0.05)	(0.05)	(0.14)
Job start year FE	Y	Y	Y	Y
Degree field FE	Y	Y	Y	Y
R^2	0.40	0.38	0.36	0.47
Obs.	1597	1442	1169	273

NOTES: Data source is Science and Engineering PhD Panel Survey; all models use proportional sample weights to account for underrepresentation of foreign PhDs in our sample; robust standard errors clustered on university reported in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table S8. Starting salary for PhDs in industrial R&D occupations by degree field

Dependent variable: ln(starting salary)					
Sample	**Life sciences**	**Chemistry**	**Physics**	**Engineering**	**Computer Science**
Method	OLS	OLS	OLS	OLS	OLS
Model	(1)	(2)	(3)	(4)	(5)
Foreign PhDs: H-1B visa	0.00	0.09	-0.00	-0.00	-0.00
	(0.08)	(0.04)	(0.05)	(0.03)	(0.05)
NRC univ. dept. ranking	0.07**	0.05***	0.09***	0.04**	0.08**
	(0.02)	(0.01)	(0.02)	(0.01)	(0.03)
ln(publications prior to ind. empl.)	0.03	0.03	0.05	-0.01	0.06**
	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)
ln(patents prior to ind. empl.)	0.08	0.04	0.04	0.06**	0.15**
	(0.05)	(0.03)	(0.09)	(0.02)	(0.04)
Prior postdoc	0.03	0.01	-0.04	-0.00	-0.05
	(0.04)	(0.04)	(0.04)	(0.02)	(0.09)
Male	0.08**	0.08*	0.04	0.07***	0.05
	(0.03)	(0.03)	(0.04)	(0.02)	(0.04)
Married	-0.06	-0.03	-0.03	-0.03	0.00
	(0.04)	(0.04)	(0.05)	(0.02)	(0.04)
Children	0.01	-0.07	0.03	-0.02	0.03
	(0.04)	(0.06)	(0.05)	(0.04)	(0.05)
Work in startup	-0.21***	-0.12***	-0.16***	-0.20***	-0.17*
	(0.04)	(0.02)	(0.04)	(0.05)	(0.08)
Received firm stock options	0.18***	0.14**	0.22***	0.10**	0.11*
	(0.04)	(0.04)	(0.04)	(0.03)	(0.05)
Constant	4.60***	4.40***	4.64***	4.48***	4.78***
	(0.09)	(0.07)	(0.10)	(0.08)	(0.07)
Job start year FE	Y	Y	Y	Y	Y
Degree field FE	Y	Y	Y	Y	Y
R^2	0.26	0.27	0.31	0.33	0.22
Obs.	350	179	201	470	221

NOTES: Data source is Science and Engineering PhD Panel Survey; all models use proportional sample weights to account for underrepresentation of foreign PhDs in our sample; robust standard errors clustered on university reported in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Another important concern is that employers may use visa sponsorship as leverage to exploit foreign workers in ways other than salary. For example, employers may offer fewer benefits to sponsored foreign workers, or they may require them to work longer hours relative to U.S. citizens. However, as reported above, the average duration of time spent on the H-1B visa is less than half the legally allotted time of six years, suggesting that employers are not finding value by having some workers on the H-1B longer before sponsoring them for permanent residency.

To further investigate this possibility, we use questions in the SEPPS employment survey to examine for differences between U.S. and H-1B PhDs in terms of both their qualifications prior to industry employment, as well as their productivity, financial benefits and work hours in industry employment. Specifically, in the employment survey we asked respondents if they had received employee stock options, an especially coveted financial benefit, in their first job. Since big tech firms may be more likely to offer stock options than other firms, we include a dummy variable that is 1 if the respondent works for Apple, Amazon, Facebook, Google, Intel, LinkedIn, Microsoft, or Qualcomm (12.3% of our sample). In our sample, 86% of employees in "big tech" firms report receiving company stock, compared to 39% of other respondents. We also asked respondents to report how many hours they work in a typical week in one of six categories: less than 30 hours, 30-39 hours, 40-49 hours, 50-59 hours, 60-69 hours, and more than 70 hours. These categories were coded to the midpoint (e.g., 45 for 40-49 hours) to approximate continuous values.

Table S9 reports OLS regression results comparing U.S. citizen and H-1B PhDs controlling for degree field, year of first employment, and individual characteristics such as gender, marital status, postdoctoral experience and proxies for ability including NRC department ranking and the number of publications and patents at graduation. All regressions include sample weights to adjust for the lower representation of foreign PhDs in our sample, and all models include robust standard errors clustered on university. Model 1 shows no difference in the average number of hours worked per week, with both U.S. and H-1B PhDs reporting an average of 47 hours per week.

Model 2 reports linear probability regression coefficients predicting whether a worker received stock options or not. H-1B PhDs exhibit a significantly higher probability to receive stock options relative to U.S. citizen PhDs, although the effect is much smaller than for employees who work for a big tech firm. To examine this result further, Model 3 restricts the sample to only employees at big tech firms and the difference between H-1B and U.S. PhDs in receiving stock options is no longer significant.

Given that big tech firms are among today's leaders in cutting-edge research on artificial intelligence and electronic devices, we also examine whether there are differences between U.S. and H-1B PhDs working in big tech firms. In addition, given that big tech firms hire a large number of foreign STEM workers and are strong proponents of immigration reforms that enable hiring more foreign workers, they likely have HR departments adept at sponsoring foreign workers and may be attractive employment options for foreign doctorates. Model 4 reports results form a linear probability model that shows that H-1B PhDs have a significantly higher probability of working in a big tech firm. Model 5 shows that there is no difference in the starting salaries of U.S. and H-1B doctorates. Not only does this suggest that big tech firms are not exploiting foreign doctorates who require employer visa sponsorship, both U.S. and foreign doctorates enjoy much higher starting salaries – $140.9 for U.S. doctorates and $139.8 for foreign doctorates – than our overall sample.

Table S9. Comparison of foreign PhDs sponsored on H-1B to U.S. citizens

Dependent variable	**Hours worked per week**	**Firm stock options**	**Firm stock options**	**Work for "big tech" firm**	**ln(starting salary in "big tech")**
Method	OLS	OLS	OLS	OLS	OLS
Model	(1)	(2)	(3)	(4)	(5)
Foreign PhDs: H-1B visa	-0.70	0.07*	0.07	0.09**	-0.01
	(0.72)	(0.04)	(0.05)	(0.03)	(0.04)
"Big tech" employer	1.86*	0.46***			
	(0.80)	(0.04)			
Work in startup	1.64*	0.45***			
	(0.73)	(0.03)			
ln(starting salary)	3.72**	0.31***	0.18	0.35***	
	(1.19)	(0.06)	(0.11)	(0.05)	
NRC univ. dept. ranking	0.28	-0.00	-0.01	-0.02*	0.08
	(0.26)	(0.01)	(0.04)	(0.01)	(0.04)
ln(publications prior to ind. empl.)					0.04
					(0.02)
ln(patents prior to ind. empl.)					-0.00
					(0.06)
Prior postdoc	0.08	-0.00	-0.03	-0.03	0.02
	(0.41)	(0.03)	(0.08)	(0.02)	(0.08)
Male	0.86	-0.02	-0.09	-0.03	0.04
	(0.59)	(0.02)	(0.05)	(0.02)	(0.04)
Married	0.97*	-0.02	0.10*	-0.00	0.06
	(0.44)	(0.03)	(0.04)	(0.02)	(0.04)
Children	-0.50	-0.05	-0.02	0.02	0.08
	(0.84)	(0.04)	(0.11)	(0.03)	(0.06)
Constant	31.02***	-0.99**	0.01	-1.66***	4.74***
	(5.01)	(0.29)	(0.62)	(0.21)	(0.11)
Job start year FE	Y	Y	Y	Y	Y
Degree field FE	Y	Y	Y	Y	Y
R^2	0.09	0.27	0.13	0.26	0.31
Obs.	1000	1428	200	1455	201

NOTES: Data source is Science and Engineering PhD Panel Survey; all models use proportional sample weights to account for underrepresentation of foreign PhDs in our sample; robust standard errors clustered on university reported in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table S10. Variable description and measure

Variable name	Description	Values
Visa variables		
visa_progression	Respondents observed twice in industry employment used to construct visa progression figure	1 if in sample
visa_first_broad	First employment visa (broad classification)	1 = OPT, 2 = H-1B, 3 = EB, 4 = Other
visa_first_detailed	First employment visa (detailed classification)	20 different temporary and permanent visa classifications
visa_current	Detailed current visa in last survey	19 different temporary and permanent resident visa categories
visa_at_job_search	Visa status at job search	Temporary resident, permanent resident, U.S. citizen
visa_foreign	Temporary work visa at time of first job	Temporary visa = 1, U.S. citizen or permanent resident = 0
visa_h1b_vs_eb	First sponsored visa was H-1B or EB	H-1B = 0, EB = 1
visa_h1b	First sponsored visa was H-1B	H-1B = 1, all others = 0
nationality	Nationality	1 = Rest of world, 2 = China, 3 = Indian, 4 = US
nat_china	Nationality is China	yes = 1, no = 0
nat_india	Nationality is India	yes = 1, no = 0
nat_other	Nationality if other foreign, rest of world	yes = 1, no = 0
Other variables		
starting_salary	Starting total annual compensation (including bonuses) for first industry job	$50 to $500 (in thousands)
hrswork	Average number of hours worked per week (6 categories)	25 to 75
firm_stock	Received firm stock options in first job	yes = 1, no = 0
emplr_big_tech	First employer was startup, defined as <=5 years and <=50 employees at time of employment	1 if employer is Apple, Amazon, Facebook, Google, Intel, LinkedIn, Microsoft, or Qualcomm
pre_patents	Number of patents prior to industry job	0 to 8 or more
pre_publications	Number of peer-reviewed publications prior to industry job	0 to 8 or more
male	Gender is male	male = 1, female = 0
pre_married	Married during graduate school	yes = 1, no = 0
pre_children	Children during graduate school	yes = 1, no = 0
nrc_dept_rank	National Research Council, reverse coded and logged	-4.6 to 0.0
pre_postdoc	Did postdoc prior to industry employment	yes = 1, no = 0
field	Degree field	(1) Cellular/molecular, (2) Microbiology, (3) Development/Genetics, (4) Immunology, (5) Neuroscience, (6) Biochemistry, (7) Chemistry, (8) Physics, (9) Bioengineering, (10) Chemical eng., (11) Electrical eng., (12) Mechanical eng., (13) Materials science, (14) Computer science
mainfield	Main degree field	(1) Other field, (2) life sciences, (3) chemistry, (4) physics, (5) engineering, (6) computer science
broadfield	Broad degree field	(1) Life sciences, (2) Chemistry & Physics, (3) Engineering & Computer science
university	PhD university	Confidential
emplr_startup	First employer was startup, defined as <=5 years and <=50 employees at time of employment	Startup = 1, Established firm = 0
job_tenure	Number of years In industry employment at time of survey	1 to 11 years
job_year	Year of first job	2010-2016
sample_weight_SDR_field	Proportional sample weights for foreign PhDs by broad field using NSF SDR data	