Why foreign STEM PhDs are unlikely to work for US technology startups

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Visa policies to retain United States-trained STEM PhDs are of central importance to national innovation and economic competitiveness. There is also growing interest in "startup" visas that stimulate entrepreneurial activity and job creation, particularly in technology sectors. However, there is little understanding of how visa policies might influence foreign PhDs' employment in technology startups. This study investigates differences between 2,324 foreign and US PhDs from US research universities using a longitudinal survey of individuals' preferences and characteristics during graduate school and their subsequent employment in a startup or established firm. Among PhDs whose first job is industrial research & development, 15.8% of US PhDs work in a startup compared with 6.8% of foreign PhDs. Foreign PhDs are as likely as US PhDs to apply to and receive offers for startup jobs, but conditional on receiving an offer, they are 56% less likely to work in a startup. This disparity is partially explained by differences in visa sponsorship between startups and established firms and not by foreign PhDs' preferences for established firm jobs, risk tolerance, or preference for higher pay. Foreign PhDs who first work in an established firm and subsequently receive a green card are more likely to move to a startup than another established firm, suggesting that permanent residency facilitates startup employment. These findings suggest that US visa policies may deter foreign PhDs from working in startups, thereby restricting startups' access to a large segment of the STEM PhD workforce and impairing startups' ability to contribute to innovation and economic growth.

STEM workforce | entrepreneurial workforce | immigration policy | PhD career paths | industrial R&D

US universities attract talented students from around the world to study at research-intensive science and engineering PhD programs. On graduation, many of these PhDs seek positions in industrial research & development (R&D), where they are among the highest-skilled workers and contribute disproportionately to firm innovation and economic growth (1, 2). However, there are growing concerns that US immigration policies are out of step with the needs of today's innovative firms, giving rise to public debates over ways to revise immigration policies to retain United States-trained STEM PhDs.* While debate has focused on employment in large technology firms and immigrant entrepreneurship, the ways in which US visa policies might influence the employment of foreign STEM PhDs in technology startups are not well understood. As noted in a recent National Academies report (3), there are growing concerns that small firms may experience greater difficulty in securing visas for highly skilled workers, thereby constraining technology startups' ability to tap into a growing segment of the STEM PhD workforce. This may be especially true in computer science and engineering, where half of doctorates from US universities are foreign born (4, 5). Given the importance of high-growth technology startups to American innovation, job creation, and economic growth, understanding how visa policies might constrain startups' ability to hire and grow is essential to entrepreneurship policy.

This study contributes to these timely debates by investigating whether foreign PhDs who require an employer-sponsored work visa are less likely than US PhDs to work in a startup in their first industry job, a career stage when visa concerns are most salient. There are reasons to expect that concerns regarding work visas might influence foreign PhDs' decision to work in established firms over startups. While the Optional Practical Training (OPT) program allows STEM PhDs to work in the United States for up to 3 y on their F-1 student visa, to remain longer foreign PhDs must obtain an employment-based temporary work visa, such as an H-1B. As such, securing a work visa is a major priority for foreign PhDs entering first-time industry employment. Given established firms' resources and stability, foreign PhDs may expect that working in an established firm will increase their chances of obtaining a work visa, especially a highly coveted permanent resident visa. However, foreign PhDs may be concerned that startups are less able to secure a work visa and that startup failure would require them to either restart the visa process at a new employer or lose their eligibility to work in the United States entirely. As a result, current visa policies may deter highly skilled foreign PhDs from working in a startup, thereby making it difficult for startups to attract the talent that they need to innovate and compete against large firms.

There are also reasons why startups may be unable or unwilling to hire foreign PhDs. Startups typically have limited resources and managerial attention, and recruiting talented workers is a major activity for founders. This may be particularly challenging for technology startups seeking to hire highly specialized PhDs, as the number of potential employees with the necessary expertise may be small and difficult to find. In addition, the cost and time to sponsor a visa, which can range from $5,000 to $10,000 for attorney and filing fees and take several months, can be prohibitive for

Significance

We provide insights from a longitudinal survey that follows a cohort of 2,324 STEM PhDs from US research universities to their first industry employment in a startup or established firm. We show that foreign PhDs apply to and receive job offers from technology startups at the same rate as US PhDs but are less than half as likely to work in a startup. We present evidence that this discrepancy is not explained by foreign PhDs' preferences for established firm jobs, risk tolerance, or preference for higher pay. We also show differences in visa sponsorship between startups and established firms, suggesting that visa policies may deter foreign PhDs from working in startups.

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*We use the term STEM to refer to life sciences, physical sciences, engineering, and computer science.

resource-constrained and inexperienced startups. Resource-rich established firms, however, have specialized human resource functions that mitigate the costs of hiring foreign workers. As such, startups may be faced with the choice between not recruiting foreign PhDs and thus, drawing from a smaller pool of talent and paying significantly more to hire foreign workers.

This study investigates the first-time industry employment of STEM PhDs in 3 ways. First, we consider general supply (worker) and demand (firm) factors by examining whether foreign and US PhDs differ in their likelihood of applying to startup jobs, reflecting PhDs' revealed intentions to work in a startup, and their likelihood of receiving startup job offers, reflecting startup' intentions to hire them. Second, we investigate whether individual characteristics observed during graduate school, such as stated career preferences, risk tolerance, and preferences for financial pay, explain employment outcomes. Third, we report differences in visa sponsorship between startups and established firms as well as the effect of receiving a permanent resident visa on foreign PhDs' subsequent mobility from established firms to startups. Although we do not provide direct causal evidence that visas explain differences in employment outcomes, the body of evidence suggests that visas play a role in deterring foreign PhDs from working in startups early in their careers.

By focusing on recent doctorates from US universities, our study departs from current debates over entry-level information technology workers coming to the United States from other countries on temporary work visas and displacing US workers for lower wages (2). In contrast, the industry labor market for STEM PhDs is characterized by lower unemployment and higher wages relative to STEM workers with undergraduate or master's degrees, indicating strong labor market demand for these highly specialized workers.[†] Foreign STEM PhDs are also of particular policy and economic interest given that their extraordinary skills place them among the highest priority applicants for permanent resident visas. Moreover, our sample represents young, early-career PhDs who have many years of productivity ahead and are arguably the ideal targets for visa policies intended to attract and retain highly skilled STEM workers to contribute to the US economy.

Methods

A particular challenge in examining employment outcomes using administrative data or population-level surveys is that they often lack detailed microdata on how individuals choose jobs. More critically, these data sources typically do not provide measures of individuals' characteristics and preferences before their first employment and thus, cannot identify whether foreign PhDs are, for example, less likely to work in startups by choice or are constrained in their ability to do so. We overcome these limitations through a longitudinal survey that follows a cohort of science and engineering PhD students from their graduate studies at 39 top-tier US research universities to their subsequent employment in the US private sector. By utilizing detailed survey responses on individuals' preferences and characteristics observed 1 to 3 y before seeking their first industry employment, we are able to both limit omitted variable bias and more precisely identify ex ante determinants of PhDs' early employment outcomes, a career stage when visa concerns are most likely to influence job choice for foreign PhDs. This survey was approved by the Cornell University Institutional Review Board. Informed consent was obtained from each respondent as part of an email invitation to participate in the study.

To obtain the initial survey sample, we identified top-tier US research universities with doctoral programs in science and engineering using the NSF's Survey of Earned Doctorates (7). Our selection of universities was based largely on program size while also ensuring variation in private/public status and geographic region. The 39 universities in our sample produced roughly 40% of graduating science and engineering PhDs in 2009 (*SI Appendix*, Table S2 shows the list of fields, and *SI Appendix*, Table S3 shows the list of universities). We collected ∼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 asked 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 through administrators. Adjusting for 6.3% undeliverable emails, the direct survey approach had an adjusted response rate of 30%. Respondents were surveyed again in 2013, 2016, and 2018 as they progressed through the PhD program and transitioned to postgraduate employment, with an average response rate of 73% of the initial 2010 sample.

We supplemented the survey with hand-curated online career profile data gathered in 2014, 2016, and 2018 from LinkedIn, university websites, and a Google search for all respondents in the baseline PhD survey to ensure comprehensive data on employment outcomes. We first searched for respondents by name and university and then, verified the match by comparing the degree field and years in the PhD program reported in the survey. We rely primarily on survey responses to identify employment outcomes, with the online career data being used to validate the survey and supplement missing data. Among the 8,173 PhDs who were employed full time by 2016, 50.1% of US PhDs and 47.0% of foreign PhDs were still in academia (i.e., postdoctorate, tenure-track faculty, or nontenure track university), while 41.8% of US PhDs and 46.8% of foreign PhDs were employed in the private sector. While prior studies have shown that visa concerns may influence international students' decisions regarding employment (8) or returning to their home country (9), in our sample we do not observe differences between foreign and US PhDs in the rate at which they leave academia to enter industry employment (*SI Appendix* has details).

To focus our investigation on how visa sponsorship might explain differences between foreign and US PhDs' industry employment in a startup or an established firm, we restrict our sample to PhDs employed in the US private sector.[‡] The sample used in this study consists of 2,324 PhDs who graduated and entered industry employment in the United States in R&D-related occupations between 2010 and 2016. We focus on R&D-related occupations, since these are the most prevalent first industry jobs for science and engineering PhDs (82.5% of industry occupations in our sample) as well as to ensure that our comparison is between PhDs choosing between similar jobs in startups and established firms. R&D-related occupations are identified either by survey-reported work activities (i.e., at least 40% of their work activities are basic research, applied research, and/or development) or by LinkedIn job title (e.g., research scientist, research engineer, software engineer, etc.). We exclude other industry occupations, such as consulting and finance, which are uncommon in startups, as well as startup founders and executives, which are uncommon first-time jobs in established firms.

We asked respondents to the initial PhD survey whether they were a US citizen as well as their visa status during the PhD program if they were not a US citizen. We use these responses to distinguish between US PhDs and foreign PhDs who graduated on a temporary student visa (e.g., F-1) and require a visa to work in the United States.[§] In select analyses, we also include foreign-born PhDs who obtained a permanent resident visa (i.e., a green card) before entering industry employment and do not require a work visa as a comparison with temporary resident foreign PhDs who do require a work visa. For the sample used in this study, 65.4% of PhDs are US citizens, 30.8% are foreign temporary residents, and 3.8% are permanent residents.[¶] Among foreign temporary resident PhDs in our sample, more than half are from 2 countries: China (31.5%) and India (23.7%). The share of foreign PhDs is highest in computer science (49.8%) and engineering (37.8%) and lowest in the life sciences (16.4%).

To identify whether a PhD's first industry job was in a startup or an established firm, we rely on both survey and LinkedIn data on employer age and the number of employees. In the employment survey, we asked respondents to report the approximate number of employees at their employer using a dropdown menu with number ranges as well as whether their employer was founded in the past 5, 6 to 10, or more than 10 y. LinkedIn

[†]Unemployment rates for STEM PhDs in the United States were ∼2% or lower during the period of our study (6).

[‡]In *SI Appendix*, we examine for selection bias by replicating our main analyses using a sample that includes PhDs who remained in academia with substantively identical results. In additional analyses, we find no difference between foreign and US PhDs in the likelihood of remaining in academia or transitioning to industry.

[§]OPT is an extension of the F-1 student visa allowing eligible STEM graduates from US universities to work in their field of study for up to 29 mo during the period of our study (the duration was increased to 36 mo in 2016). Foreign PhDs use the OPT as a bridge to an H-1B or permanent residency. Recent graduates may work on their OPT without employer sponsorship and are in effect "self-sponsored." However, given that it may take several years to obtain an H-1B or permanent residence, foreign PhDs likely prefer jobs that offer these longer-term visas over jobs that require them to work solely on their OPT.

[¶]We benchmarked our survey to the NSF's SDR (18) for early-career PhDs in the private sector. The SDR sample represents all doctorate-granting universities, while our sample is drawn from top-tier research universities where the share of foreign-born PhDs may be lower. In the SDR sample, 43.9% are US citizens, 51.4% are foreign temporary residents, and 4.7% are permanent residents. Authors' calculations are based on the public use SESTAT Data Tool: https://ncsesdata.nsf.gov/sestat/sestat.html.

employer profiles provide information on a similar range of the number of employees as well as the firm founding year. We code employers as startups if they were founded within 5 y and had 100 or fewer employees at the time that a PhD started employment.[#] All other employers are coded as "established" firms, including fast-growing young companies that had over 100 employees (e.g., 23andMe, Uber, etc.) and corporate spinoffs that are typically young and large (e.g., Google Life Sciences spinoff Verily). For PhDs for whom we observe both survey and LinkedIn data, the correspondence between employment types is 95.8%.

Results

The majority of employers in our sample are technology firms, especially among startups, where 31% are computer and information technology, 27% are biotechnology or biomedical, and 15% are R&D services. Leading technology firms, such as Google, Genetech, and Qualcomm, account for a large share of established firm employees. Across industries, 15.8% of US PhDs are startup R&D employees compared with 6.8% of foreign PhDs, illustrating a lower incidence of foreign PhDs working in startups than we might expect given their prevalence in the private sector workforce. This disparity is illustrated in Fig. 1, which presents the percentage of US and foreign PhD industry R&D employees working in startups by degree field.

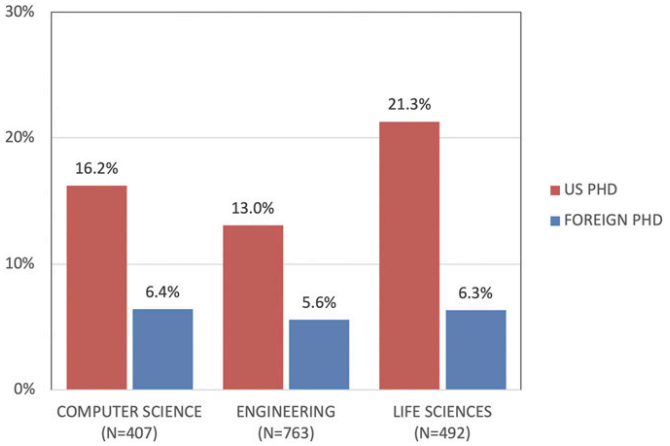

Fig. 1. Share of US and foreign PhD industrial R&D employees working in a startup by field.

Job Applications and Job Offers. We first consider whether foreign PhDs differ from US PhDs in their likelihood of applying to and receiving an offer for a startup job in the United States. Examining job applications and offers provides insights into supply- and demand-side explanations for why foreign PhDs are less likely to work in startups. On the supply side, foreign PhDs may be less likely to apply to startup jobs if they expect that startups are unlikely to sponsor them for a work visa or if they think that startups' greater risk of failure may jeopardize their ability to obtain a visa. On the demand side, startups may be less likely to make offers to foreign PhDs given the time, expense, and uncertainty of sponsoring them for a work visa.

To investigate startup job applications and offers, we sent respondents to the initial PhD survey a follow-up employment survey after graduation ($n = 1{,}336$ for those employed in industrial R&D; 57% response rate) that asked a range of questions about their job search, including whether they applied to a startup job and whether they received at least 1 startup job offer (*SI Appendix* has details). We did not define the age or size of startups in our question, and responses reflect PhDs' own perceptions of whether the job was in a startup. Overall, 40.5% of foreign and 47.3% of US PhDs applied for at least 1 startup job, and conditional on applying, 62.1% of foreign and 58.2% of US PhDs received at least 1 startup job offer.[‖] For comparison, 97.7% of foreign and 94.5% of US PhDs applied for at least 1 established firm job, and conditional on applying, 95.1% of foreign and 92.7% of US PhDs received at least 1 established firm job offer.

One limitation of observed job search behavior is that it conflates career preferences that lead individuals to apply to a job with constraints, such as visa sponsorship, that may deter them from applying. For example, a lower rate of foreign PhDs applying to startup jobs may reflect visa concerns deterring them from applying or a lower interest in working in a startup. To disentangle these effects, we examine whether stated work interests before entering the labor market predict job applications and job offers. To measure work interests, we asked respondents while in graduate school and before their job search to rate the attractiveness of a range of occupations, including working in a startup and working in an established firm. Each occupation was rated independently on a 5-point Likert scale that ranged from "extremely unattractive," 1, to "extremely attractive," 5.** We created a simplified measure that reflects whether individuals were interested in a particular occupation or not, dichotomizing this response with "attractive," 4, and "extremely attractive," 5, coded as 1 and other responses coded as 0 (i.e., "not attractive"). As with the job application and job offer questions, responses reflect PhDs' own perceptions of startup employment. Among our sample of STEM PhDs, 74% of foreign PhDs and 64% of US PhDs reported during graduate school an interest in working in a startup after graduation, and this difference is significant (t statistic = –4.60, P value = 0.000).

Logistic regression results of the likelihood of applying to and receiving an offer for a startup while controlling for demographic characteristics, year of employment, and degree field are presented in Fig. 2 (*SI Appendix*, Table S6 shows full results). Fig. 2, *Left* shows that both US and foreign PhD students who reported during graduate school an interest in working in a startup are most likely to apply to startup jobs (50.3 and 49.1%, respectively) and are not significantly different from one another ($\chi^2 = 0.05$, P value = 0.825). Foreign PhDs not interested in working in a startup are significantly less likely to apply (31.0%) than foreign PhDs who are interested in working in a startup. Fig. 2, *Center* illustrates that, conditional on applying to a startup job, there is no significant difference between US and foreign PhDs in the likelihood of receiving a startup job offer. However, Fig. 2, *Right* shows that, conditional on receiving a startup job offer, US PhDs interested in working in a startup are most likely to work in a startup (53.9%), while foreign PhDs interested in working a startup are significantly less likely to do so (35.1%). Foreign PhDs not interested in working in a startup are the least likely to work in a startup (10.6%). We examined for selection bias using a sample that includes PhDs who remained in academia with substantively identical results (*SI Appendix* has details).

Although not presented in Fig. 2, we also included in our analyses foreign PhDs who entered industry employment with a permanent resident visa (i.e., green card) and did not require visa sponsorship to work in the United States. If visa sponsorship

[#]We calculate firm age at the time that an employee joined the firm by subtracting the firm founding year from the year of a PhD's first employment. Since firm size was based on the number of employees observed either at the time of the survey or at the time that LinkedIn profiles were obtained, we manually searched for public information on the number of employees at the time that the PhD started employment for firms under 5 y of age and over 100 employees to confirm firm size.

[‖]To investigate potential selection bias in our sample of PhDs in industrial R&D, we examined startup job search and employment outcomes for a sample that also included PhDs who remained in academia. We find no evidence of differences between foreign and US PhDs in the likelihood of applying to startups jobs or remaining in academia. We do find, however, compelling evidence of PhDs' ex ante stated career preferences predicting ex post employment, with PhDs who prefer faculty careers significantly more likely to remain in academia and significantly less likely to work in a startup or an established firm. Given that selection seems to be based on preferences and not citizenship, restricting our sample to PhDs employed in industrial R&D does not bias our comparison of foreign and US PhD employment in startups.

**Our measures of career attractiveness are not mutually exclusive, and thus, individuals could report that working in a startup and in an established firm are both attractive.

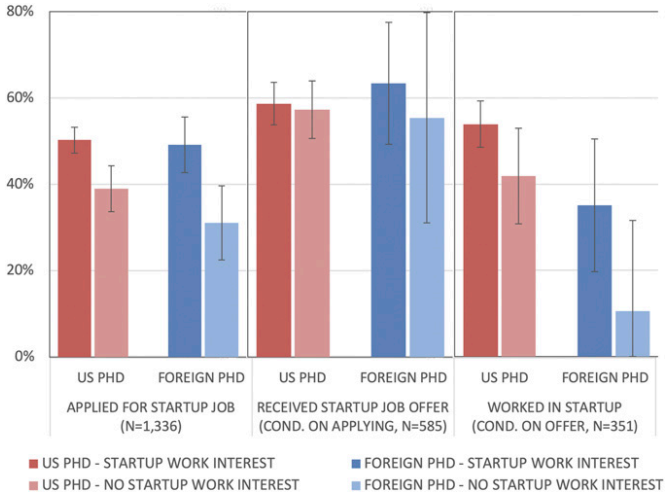

Fig. 2. Estimated likelihood of applying to a startup job (*Left*), receiving a startup job offer conditional on applying (*Center*), and working in a startup conditional on receiving an offer (*Right*) with robust 95% confidence intervals (*SI Appendix*, Table S5 has full results). Startup work interest was measured during graduate school and before the job search.

is a key factor explaining why foreign PhDs on a temporary visa are less likely to work in a startup, then we would expect that permanent resident PhDs, who are foreign but already have a work visa, will not differ from US PhDs in their likelihood of working in a startup. However, if other factors associated with being foreign, such as English language proficiency, cultural differences, or discriminatory hiring practices, constrain all foreign PhDs from working in a startup, then we would expect permanent resident PhDs to also be less likely to work in a startup. As reported in *SI Appendix*, Table S5, we find that permanent resident PhDs do not differ significantly from US PhDs in their likelihood of applying to startup jobs, receiving startup offers, or working in a startup. Moreover, conditional on receiving a startup job offer, permanent resident PhDs are more likely to work in a startup than foreign PhDs, indicating that temporary visa status, rather than being foreign per se, is a factor in startup employment outcomes.

Together, these results indicate that foreign PhDs interested in startup employment apply to and receive job offers from startups at the same rate as US PhDs, but among those who receive a startup job offer, roughly 3/4 work instead in an established firm. We examine differences in visa sponsorship between startups and established firms that may influence job choice in the visa progression analysis below.

Determinants of Working in a Startup. We now examine possible explanations for why foreign PhDs are less likely to work in a startup. To do this, we exploit a unique feature of our survey that combines ex ante responses from PhDs while in graduate school and their observed ex post employment using LinkedIn career data for our full sample of PhDs employed in industrial R&D (n = 2,324), including PhDs who may not have responded to the follow-up employment survey. While not exhaustive, we focus on 4 factors that might influence foreign PhDs' decision to work in a startup that are of particular relevance for visa policies: 1) work interests for employment in a startup or established firm, 2) risk tolerance, 3) preferences for higher pay, and 4) worker ability.

First, if foreign PhDs prefer to work in established firms over startups, then reducing visa constraints may have little effect on increasing foreign PhD employment in startups. Prior research, however, shows that, relative to US PhDs, foreign PhDs are more likely to start companies (10) and are more interested in both founding companies and working in startups after graduation (11, 12). Thus, if visas deter foreign PhDs from accepting startups jobs, especially early in their careers, then we would expect that work interests will have less influence on employment outcomes for foreign PhDs, while US PhDs will choose jobs that align with their work interests. Fig. 3 illustrates odds ratios from logistic regressions for separate samples of US and foreign PhDs (*SI Appendix*, Table S7 shows full results). We see that US PhDs who were interested in working in a startup during graduate school are more likely to work in a startup after graduation, while foreign PhDs with the same ex ante startup work interest are not significantly more likely to work in a startup. We also note that US PhDs who were more interested in working in an established firm are less likely to work in a startup (i.e., more likely to work in an established firm), providing additional evidence that US PhDs choose jobs that align with their work interests while foreign PhDs who require a temporary work visa do not.

Second, we examine whether risk tolerance explains differences between US and foreign PhDs' startup employment. Prior entrepreneurship research has emphasized that individuals with a higher risk tolerance are more likely to participate in entrepreneurship (13), and greater risk tolerance has been put forth as one explanation for immigrants' higher rates of entrepreneurship (10). A recent study also shows that foreign PhDs are more risk tolerant while in graduate school than their US counterparts (14). However, if visa policies deter foreign PhDs from working in startups, then risk tolerance should play less of a role in explaining startup employment relative to US PhDs. To measure risk tolerance, we asked respondents during graduate school to report their preference between 2 gambles—a sure bet with a lower payoff and a lower probability bet with a higher payoff—on a 10-point scale that ranged from "strongly prefer a 100% chance to win $1,000" to "strongly prefer a 50% chance to win $2,000." Higher values reflect a greater willingness to choose a riskier outcome with a higher potential payoff, which we interpret as a greater risk tolerance. The average risk tolerance values are 2.05 for US PhDs compared with 2.62 for foreign PhDs (t statistic = −4.78, P value = 0.0001) and 2.22 for established firm employees compared with 2.52 for startup employees (t statistic = −1.98, P value = 0.048). Fig. 3 illustrates that US PhDs who are more risk tolerant are more likely to work in a startup, while there is no effect for more risk-tolerant foreign PhDs. Thus, despite foreign PhDs on average being more risk tolerant than US PhDs, it seems that risk tolerance does not explain why foreign PhDs are less likely to work in a startup.

Third, we consider whether foreign PhDs' preference for financial pay might influence their decision to work in established firms. Prior studies have shown that resource-constrained startups pay lower salaries to their employees in exchange for equity (15, 16). Indeed, in our survey, the average reported starting salary in a startup is $95,537 compared with $108,761 in an established firm, and 75% of startup employees received company equity

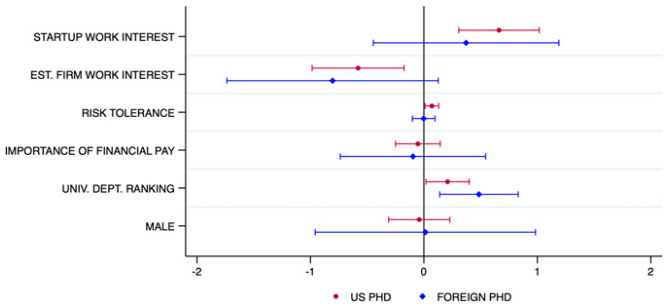

Fig. 3. Odds ratios of working in a startup for US and foreign PhDs with robust 95% confidence intervals (*SI Appendix*, Table S6 has full results). Control variables include degree field fixed effects, job start year fixed effects, marital status, children, and postdoctorate before working in industry.

compared with 40% of established firm employees.[††] To the extent that startups offer lower starting salaries, then PhDs for whom financial pay is more important will likely choose jobs in established firms that pay more. If so, then changes in visa policies may have little effect on foreign PhDs' employment in startups if they are still lured to established firms by higher pay. We use a survey question that asked respondents during graduate school about the importance of a range of attributes regarding their "ideal" job. Specifically, we asked how important financial income is to them on a 5-point Likert scale that ranged from "not at all important," 1, to "extremely important," 5. Fig. 3 shows that the importance of financial pay is not associated with the likelihood of working in a startup for either foreign or US PhDs.

Fourth, an important consideration for entrepreneurship policy is whether visa concerns might deter high-ability foreign PhDs from working in a startup, thereby further constraining startups' access to highly skilled workers. Fig. 3 shows that National Research Council university department rank (17), a signal of PhD ability that is observable to prospective employers, is significantly associated with the likelihood of working in a startup for both foreign and US PhDs, and the effect is significantly stronger for foreign PhDs.[‡‡] Thus, while foreign PhDs are less likely to work in startups, those who do are more likely to come from higher-ranked university departments. Fig. 3 shows no gender difference for foreign or US PhDs in the likelihood of working in a startup.

One may be concerned that our results are driven in part by foreign PhDs from universities outside entrepreneurial regions experiencing greater difficulty in finding startup jobs. For example, in our sample, 87% of foreign PhDs graduated from universities outside of the San Francisco (i.e., Berkeley, Stanford, or the University of California, San Francisco) and Boston (i.e., Harvard or Massachusetts Institute of Technology) entrepreneurial regions compared with 76% of US PhDs. As reported in *SI Appendix*, Table S8, we find that US PhDs from universities in these 2 entrepreneurial regions are more likely to work in a startup, but foreign PhDs are not. Thus, even foreign PhDs who were embedded in entrepreneurial regions during graduate school are less likely than US PhDs to work in a startup.

Visa Progression. Although the previous analyses suggest that startups attempt to hire foreign and US PhDs at similar rates, the significantly lower rate of foreign PhDs working in startups may be attributable to differences in the types of visa sponsored between startups and established firms. To investigate this, we asked foreign PhDs to report the type of visa that they were sponsored for in their first job (n = 321 established firm employees; n = 38 startup employees). The small number of observations for foreign startup employees reflects the relative rare incidence of the phenomenon under investigation and is comparable with numbers from the NSF's nationally representative survey of doctorate recipients (SDR) (18).[§§] Nevertheless, the small sample for foreign PhD startup employees does limit our ability to draw strong comparisons regarding differences in the visa patterns between startups and established firms.

As illustrated in Fig. 4, 24% (9 of 38) of foreign PhDs in startups were not sponsored for a visa and worked on their own OPT, 34% (13 of 38) were sponsored for an H-1B, 26% (10 of 38) were sponsored for a permanent resident visa, and 8% (3 of 38) self-petitioned their own permanent resident visa (e.g., National Interest Waiver). In established firms, 12% of foreign PhDs worked on their own OPT without employer sponsorship, 61% were sponsored for an H-1B, 8% were sponsored for a permanent resident visa, and 10% self-petitioned their own permanent resident visa. Although based on a small number of observations, these findings suggest important differences in visa sponsorship between startups and established firms.

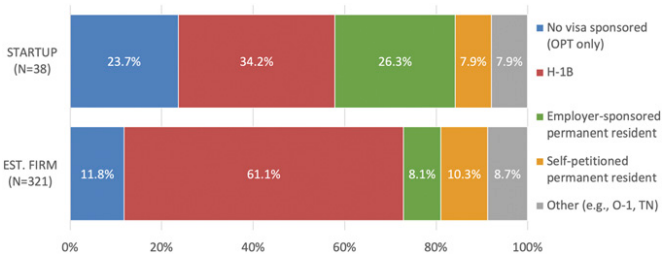

Fig. 4. Share of first work visa type between startups and established firms.

To examine visa progression over foreign PhDs' early careers, we explored current visa status at the time of the survey. We focus on foreign PhDs who were employed in industry for at least 4 y (n = 233) to allow time for progression from OPT, which is valid for up to 29 mo after graduation for STEM PhDs during the period of our study, to another visa type. Roughly 63% of foreign PhDs have received a permanent resident visa within 4 y of working in industry: 45% employer sponsored, 9% self-petitioned (e.g., National Interest Waiver), and 9% by marriage or family relations. An additional 13% of foreign PhDs are on an H-1B and being sponsored by their employer for a permanent resident visa. Of all permanent resident visas that are employment based, 52% are EB-1, the highest preference category for individuals with extraordinary ability or outstanding researchers, and 48% are EB-2, the second highest preference category for individuals with advanced degrees or exceptional ability, with the majority being employer sponsored.[¶¶]

We also examined whether receiving a permanent resident visa is related to employee mobility from established firms to startups. Multinomial regression analyses (*SI Appendix*, Table S9) indicate that foreign PhDs who first worked in an established firm and subsequently received a green card are more likely to move to a startup rather than to another established firm or to stay with their first employer. This result holds even after controlling for whether the PhD has been in the workforce for at least 3 y. Moreover, US PhDs who have been working at least 3 y are more likely to move to another established firm but not a startup. These results suggest that permanent residency facilitates foreign PhD employment in startups.[##]

Policy Analysis. Although we are unable to provide causal evidence that US visa policies directly influence foreign PhD job choice, the body of evidence suggests that visa concerns may deter foreign PhDs from working in startups, even among PhDs who are most interested in working in a startup. To examine whether foreign PhDs might be responsive to reforms that reduce visa constraints to working in a startup, we estimated the counterfactual probability of foreign PhDs working in a startup based on observable characteristics, such as ex ante career interests. If visa sponsorship deters foreign PhDs who are interested in working in a startup from doing so, then we would expect that, in the counterfactual situation where visas do not constrain employment choice, a greater share of foreign PhDs would work in a startup. This may occur, for example, if STEM PhDs with degrees from US universities were eligible for permanent residency on graduation.

[††]OLS regressions predicting starting salary controlling for job year and degree field fixed effects confirm that startups pay 10.4% ($11,290) less than established firms, and the difference is significant.

[‡‡]A seemingly unrelated test comparing coefficient estimates for foreign and US PhDs shows that they are significantly different from one another ($\chi^2 = 4.83$, P value = 0.028).

[§§]We benchmarked our number of observations to publicly available data from the NSF's SDR for PhDs corresponding to our survey respondents by field, graduation year, and work type. The corresponding SDR data include 1,941 responses compared with 2,324 responses in our survey. In the SDR, 59 temporary resident PhDs work in startups compared with 49 in our survey, indicating that foreign PhDs working in startups are a rare occurrence and lower than we might expect given the prevalence of STEM foreign PhDs in the private sector workforce.

[¶¶]Eligibility for EB-1 is typically demonstrated through major scientific contributions, publications, patents, international awards, and a high salary commensurate with extraordinary ability. EB-2 eligibility is often demonstrated through an advanced research degree, such as the PhD, and a salary commensurate with exceptional ability.

[##]We thank the editor for suggesting this analysis, which we detail in *SI Appendix*.

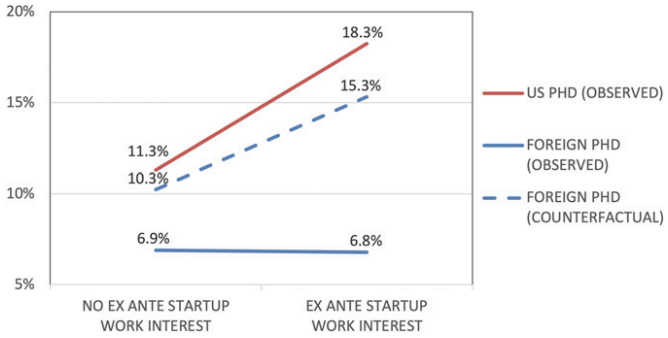

Fig. 5. Share of US and foreign PhDs working in a startup by ex ante stated startup work interest. Solid lines indicate the observed shares; the dotted line is the counterfactual predicted share based on observables for foreign PhDs.

To do this, we first estimated the likelihood of working in a startup for US PhDs given observable ex ante work interests, risk tolerance, demographic characteristics, job start year, and degree field (*SI Appendix*, Table S9). We then used these estimates to predict the out-of-sample probability of working in a startup for foreign PhDs based on the same observable variables. A critical assumption of this analysis is that, after accounting for observables, the remaining difference between US and foreign PhDs is attributable to visa policies that influence employment outcomes. In other words, we assume that temporary resident foreign PhDs are exogenously treated by work visa requirements that will differentially influence their job choice relative to US citizens who are untreated after controlling for other factors that influence job choice. A limitation of this approach is that it does not account for all possible factors that might constrain foreign PhDs from working in a startup, and the variance explained by our data is modest (*SI Appendix*, Table S9). Thus, it is conceivable that our estimates could partly reflect unobservable systematic differences between US and foreign PhDs other than visa sponsorship. Nevertheless, the primary objective of this analysis is to provide insights into whether foreign PhDs might be more likely to work in a startup under the counterfactual condition that visa constraints do not influence job choice.

Fig. 5 illustrates the observed share of US and foreign PhDs employed in startups by whether or not they were interested in working in a startup during graduate school. For US PhDs, there is an increase in the share who work in a startup: from 11.3% of US PhDs with no ex ante startup work interest to 18.3% of those with an ex ante interest. For foreign PhDs, however, there is no difference in the observed share working in startups between those who were not interested (6.9%) and those who were (6.8%). The counterfactual predicted share of foreign PhDs who work in a startup is illustrated as the dotted line in Fig. 5, which is quite comparable with the observed share of US PhDs. Notably, among foreign PhDs who were interested in working in a startup during graduate school, the counterfactual predicted share (15.3%) is more than double the observed share (6.8%). While one might expect the counterfactual share of foreign PhDs working in startups to be higher than US PhDs given the former's stronger interest in working in a startup, the relatively modest number of observable variables limits the precision of this analysis. Nevertheless, these results suggest that visa reforms could increase the overall size of the workforce available to startups.

Discussion

Overall, these findings illustrate a large gap in the startup employment outcomes of foreign and US STEM PhDs with degrees from US universities. Specifically, foreign STEM PhDs who require visa sponsorship are half as likely as their US peers to work in technology startups in their first industry job. This not only has implications for our understanding of science careers and the highly skilled immigrant workforce but also, reveals the burden that current US visa policies place on technology startups. Given the large and growing number of foreign STEM PhDs graduating from US universities, this is a significant issue for high-growth technology startups and the overall innovation economy.

These findings have implications for debates on visa reform relating to highly skilled STEM workers and entrepreneurship. For example, visa policies that facilitate permanent residency may make it easier for technology startups to hire foreign STEM PhDs as well as mitigate the visa concerns steering foreign PhDs away from startups. In addition, although based on a small number of observations, our finding that a large share of foreign PhD startup employees work on OPT suggests that rescinding the OPT STEM extension, which has been the subject of recent policy debate, could severely limit technology startups' ability to hire and retain foreign PhD graduates.

We understand, of course, that the opportunity to work in the United States is a great prize, and incentives are strong for ancillary actors to game the system, such as already occurs in other areas of temporary work visas. Visa reforms that level the playing field for startups will need regulatory structures and auditing systems to prevent fraudulent startup job offers or other workarounds that take advantage of any new or eased visa policies.

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Supporting Information Appendix

Why Foreign STEM PhDs are Unlikely to Work for U.S. Technology Startups

Michael Roach, Cornell University
John Skrentny, University of California-San Diego

Data

Our empirical analysis utilizes a national longitudinal survey of a cohort of science and engineering PhDs from 39 top-tier U.S. research universities. Respondents were first surveyed in 2010 or 2013 while in graduate school (*PhD survey*, 10,781 respondents, 30% response rate) and then again after graduation in 2013, 2016, and 2018 as they transitioned into post-graduation employment (*employment survey*). The surveys provide detailed micro data on individuals' stated preferences and characteristics, PhD experience, and research lab setting while in graduate school, as well as employer characteristics and work activities after graduation.

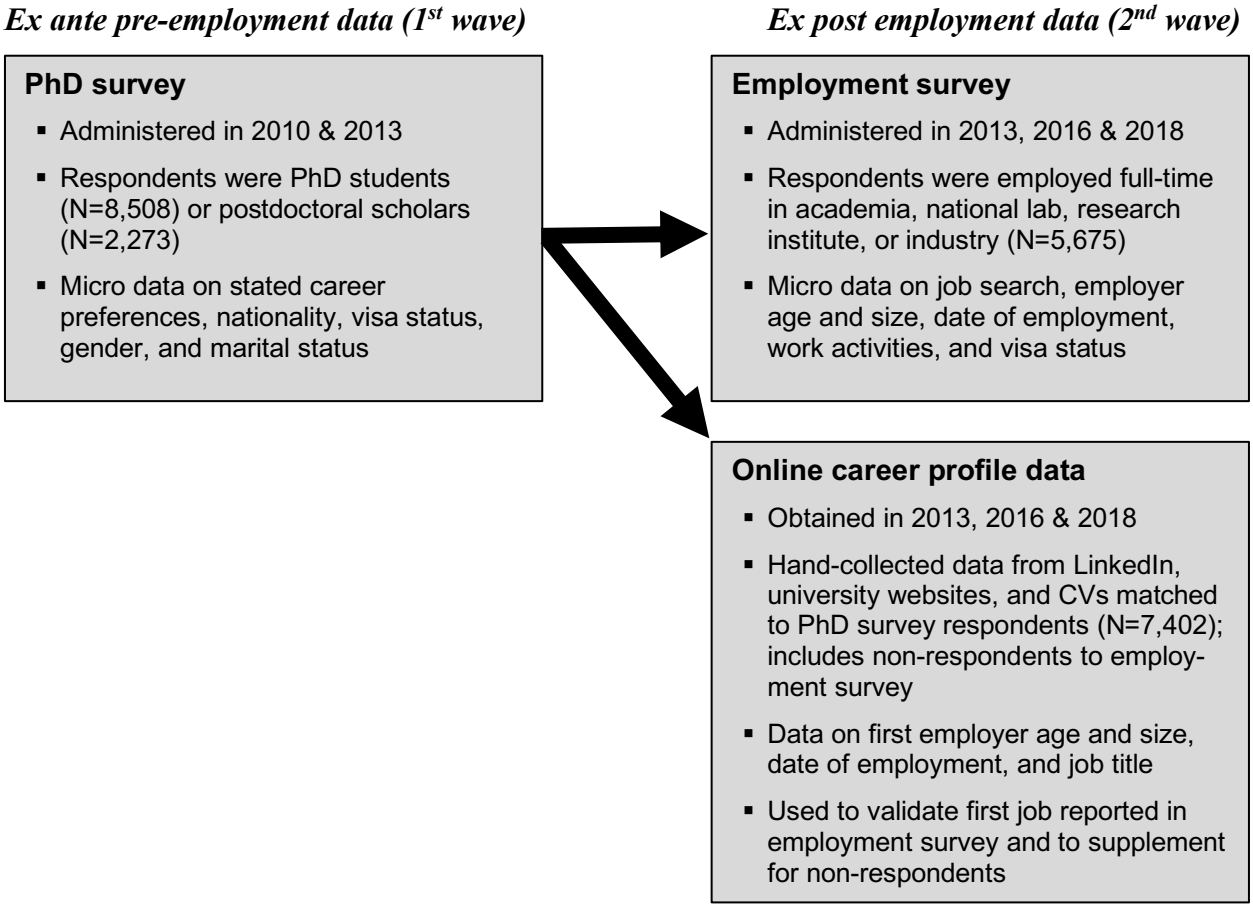
To obtain the initial survey sample, we identified top-tier U.S. research universities with doctoral programs in science and engineering using the National Science Foundation's Survey of Earned Doctorates.[1] Our selection of universities was based largely on program size while also ensuring variation in private/public status and geographic region (see Table S2 for the list of fields and Table S3 for the list of universities). 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%. 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 them with PhD students and include a control variable for respondents who completed a postdoc prior to full-time employment.[2]

Respondents were surveyed again in 2013, 2016, and 2018 as they progressed through the PhD program and transitioned to post-graduate employment with an average response rate of 73% of the initial 2010 sample. The employment surveys asked respondents to indicate their current employment type (university, national lab or research institute, established firm, startup, founder, or other), as well as whether this was their first full-time job (78% indicated it was their first full-time job). To ensure comprehensive data on employment outcomes, we supplemented the survey with hand-curated online career profile data from LinkedIn, university websites, and a Google search for all respondents in the baseline PhD survey (including non-respondents to subsequent employment surveys). The online career data include individuals' job title and employer

[1] National Science Foundation (2017) *Survey of Earned Doctorates* (Arlington, VA).

[2] The National Postdoctoral Association defines a postdoctoral scholar as "an individual holding a doctoral degree who is engaged in a temporary period of mentored research and/or scholarly training for the purpose of acquiring the professional skills needed to pursue a career path of his or her choosing." Among PhDs who are employed in industry, 22% of foreign PhDs and 30% of U.S. PhDs did a postdoc prior to transitioning to industry (average postdoc duration of 2.7 years for foreign PhDs and 2.0 years for U.S. PhDs).

characteristics such as founding year and number of employees. Together, these data provide employment outcomes for 8,446 respondents who were employed full-time (excluding those who were still a PhD student or a postdoc): 5,675 in the employment survey, 7,402 from online career profile data, and 4,631 with both survey and online sources. For the 4,631 observations where we have data from both sources the correspondence of employment type is 79%. Where jobs did not correspond or where respondents reported in the survey that their current job was not their first job, we manually examined the online career profile data to identify their first full-time employment. We obtained post-graduation outcomes for 86% of our respondents, of which 7.7% are still PhD students, 25.2% are postdocs, 22.1% are in a university position (tenure and nontenure track), 5.8% are in a national lab or research institutes, 33.5% are in industry occupations, and 5.7% are in other private sector occupations.



We restrict our sample to 2,324 respondents who entered full-time employment in the U.S. private sector in R&D occupations between 2010-2016. We first used survey responses on work activities (i.e., at least 40% of weekly work activities are basic research, applied research, and/or development) to identify PhDs employed in R&D-related occupations in U.S. firms. In cases where survey data were unavailable, we used LinkedIn data on job titles (e.g., research scientist, software engineer, etc.) to identify R&D-related occupations.[3] For PhDs where we have both survey-reported

[3] We code job titles as an R&D occupation if they include any of the following key words: research, scientist, engineer, science, technology, developer, development or R&D.

work activities and LinkedIn job titles, the correspondence for R&D occupations is 95.8%. To ensure that we compare individuals who are equally likely to work in startups or established firms in similar 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. We also exclude founders and startup executives (e.g., CTO) to retain our focus on R&D occupations.

For all analyses that follow, we also performed analyses using a more comprehensive sample that includes PhDs who remained in academia to explore for potential selection bias. Although we do not find any evidence of selection between academia and industry based on citizenship, we do find evidence of selection based on ex ante stated career preferences, with PhDs who prefer a faculty career more likely to remain in academia and less likely to work in a startup or established firm. These analyses are available from the authors.

Industry R&D employee sample

- Employed full-time in the U.S. and primary work activity is R&D (N=2,324); identified using survey responses on share of work time spent on research and/or development and whether their employment was in the U.S., as well as online career data on job title and employment in the U.S.
- Exclude non-R&D occupations such as consulting, law, and management
- Startup employee if firm age is five years or less and firm size is 100 employees or less (N=300); all other coded as established firm employee (N=2,024)
- Foreign PhD if entered full-time industry employment on F-1 student or J-1 researcher visa (N=713), permanent resident PhD if entered full-time industry employment with a permanent resident visa (N=90), U.S. PhD if entered full-time industry employment as a U.S. citizen (N=1,521)

We benchmark our sample to the NSF Survey of Doctorate Recipients, 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, and whose primary work activity is R&D. Table S1 compares the share of all PhDs by field (column percentages), which are highly comparable. The difference between surveys in the share of engineering and computer science PhDs is possibly due to differences in the grouping of fields between our survey and the SDR, and combined the shares are more comparable. Table S2 reports the STEM fields represented in our sample, Table S3 reports the universities.

Table S1. Share of PhDs by field for the PhD survey and the NSF Survey of Doctorate Recipients.

	PhD Survey (n=2,324)	NSF-SDR (n=1,866)
Life science	21%	18%
Chemistry	14%	13%
Physics	13%	7%
Engineering	33%	50%
Computer science	18%	11%

We identify *foreign PhDs* as survey respondents who reported that they were international students on a temporary visa (e.g., F-1, J-1) during graduate school or their postdoc, and thus would require a visa to work in the U.S. after graduation. We compare foreign PhDs to *U.S. PhDs* who reported that they were U.S. citizens during graduate school. We also separately identified international

students who reported that they had a permanent resident visa (i.e., green card) prior to entering the workforce, typically by marriage as reported in open-ended responses. Since permanent residents possess a visa and have the same employment freedom as U.S. citizens, we include *permanent resident PhDs* as a comparison group to both foreign and U.S. PhDs. Approximately 30.8% of our sample are foreign temporary resident PhDs, 3.8% are permanent resident PhDs, and 65.4% are U.S. citizens. These number are similar to numbers from the NSF Survey of Doctorate Recipients for early-career PhDs in the private sector, which are 51.4% foreign temporary residents, 4.7% permanent residents, and 43.9% U.S. citizens.[4]

Among foreign temporary resident PhDs, 31.5% are from China, 23.7% are from India, 5.2% are from South Korea, and 4.3% are from Taiwan. The share of foreign PhDs in our sample is highest in computer science (49.8%) and engineering (37.8%), and lowest in the life sciences (16.4%). The share of life science PhDs in our sample is slightly lower than the overall population found in the SDR, which is likely the result of many recent life science doctorates in our sample who are doing a postdoc and have yet to transition to full-time employment. We control for 18 detailed fields of study to account for variation in career paths, salary, and other factors, as well as whether an individual did a postdoc before entering private sector employment.

To identify whether PhDs were employed in a startup or an established firm, we rely upon both survey and LinkedIn data on employer age and number of employees at the time an individual started working at the company. We code startups (i.e., young and small) as any employer that is five years or younger and has 100 or fewer employees at the time the employee joined the company. All other employers are coded as "established" firms, including fast growing entrepreneurial ventures that had over 100 employees at the time the PhD joined the company (e.g., Uber) and corporate spinoffs that are typically young and large (e.g., Google Life Sciences spinoff Verily).

For survey respondents who indicated that they worked in a startup, we verified their employer size and age with LinkedIn data. For 28% of survey respondents who reported that they worked in a startup, LinkedIn data indicated that their employer was either over five years of age (average 7.6 year) or had more than 100 employees (average of 203 employees). These cases typically reflect growth-stage companies or corporate spinoffs and not startups, and as such were coded as established firms.[5] In addition, 2.5% of survey respondents who reported that they worked in an established firm were identified in LinkedIn data as working in a startup (average firm age of 4 years and 48.6 employees). Since LinkedIn data allow us to precisely identify the first employer, these cases were coded as startup employees. Based on this classification, 6.8% of foreign PhDs are employed in startups compared to 15.8% of U.S. PhDs and 11.1% of permanent resident PhDs, illustrating a large disparity in startup employment. Fig. S1 illustrates the shares of U.S. and foreign PhDs by field who work in an established firm or startup, respectively. For example, among computer science PhDs employed in industrial R&D, 3.2% are foreign PhDs in startups while 46.4% are foreign PhDs in established firms.

[4] Authors' calculations based on the public use SESTAT Data Tool: https://ncsesdata.nsf.gov/sestat/sestat.html
[5] The share of U.S. PhDs who reported that they work in a startup is 20.4% compared to 9.3% of foreign PhDs.

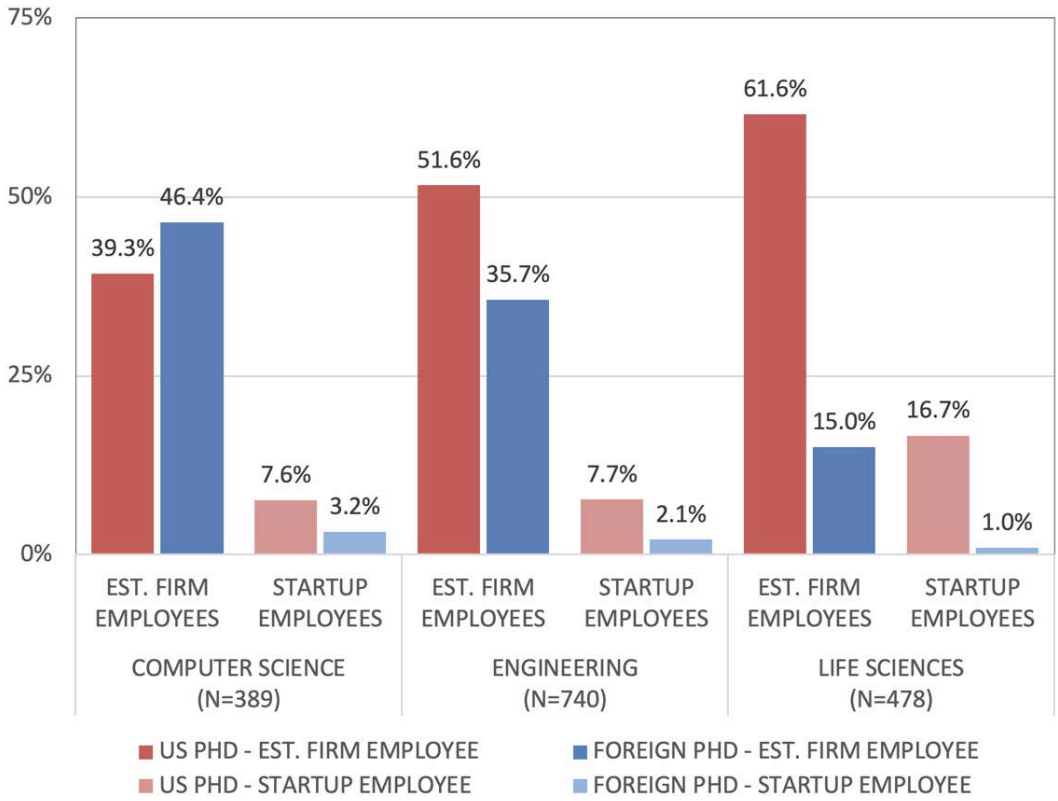


Fig. S1. Percentages of U.S. and foreign PhDs employed in established firms or startups by degree field. The denominator is the number of PhDs employed in industrial R&D by field. Permanent resident PhDs included in calculations but not presented in the graph.

While there is no widely accepted threshold in the entrepreneurship literature regarding age and size cutoffs for startups, we chose the size threshold of 100 employees to focus on smaller companies that are unlikely to have the scale to justify internal HR departments, are unlikely to have much experience obtaining work visas, and have limited resources to fund visa sponsorship. Nevertheless, one might be concerned that our results are sensitive to the construction of our startup measure. To examine this, Fig. S2 reports the share of foreign and US PhDs who are employees for different types of companies: (1) early-stage startups that are 1-2 years of age and 100 or fewer employees, (2) mid-stage startups that are 3-5 years of age and 100 or fewer employees, (3) late-stage startups that are 6-10 years of age and 1,000 or fewer employees, (4) established firm spinouts that are 1-10 years of age and any size (although typically more than 1,000 employees), and (5) all other established firms over 10 years of age. For all startup types, the share of PhD employees who are foreign temporary residents is lower than the share in established firm spinouts or established firms. The share of foreign PhDs is lowest in mid-stage startups that were 3-5 years of age when the employee joined the company and slightly higher for late-stage startups that are more mature, less risky, likely well-financed, and typically growing.

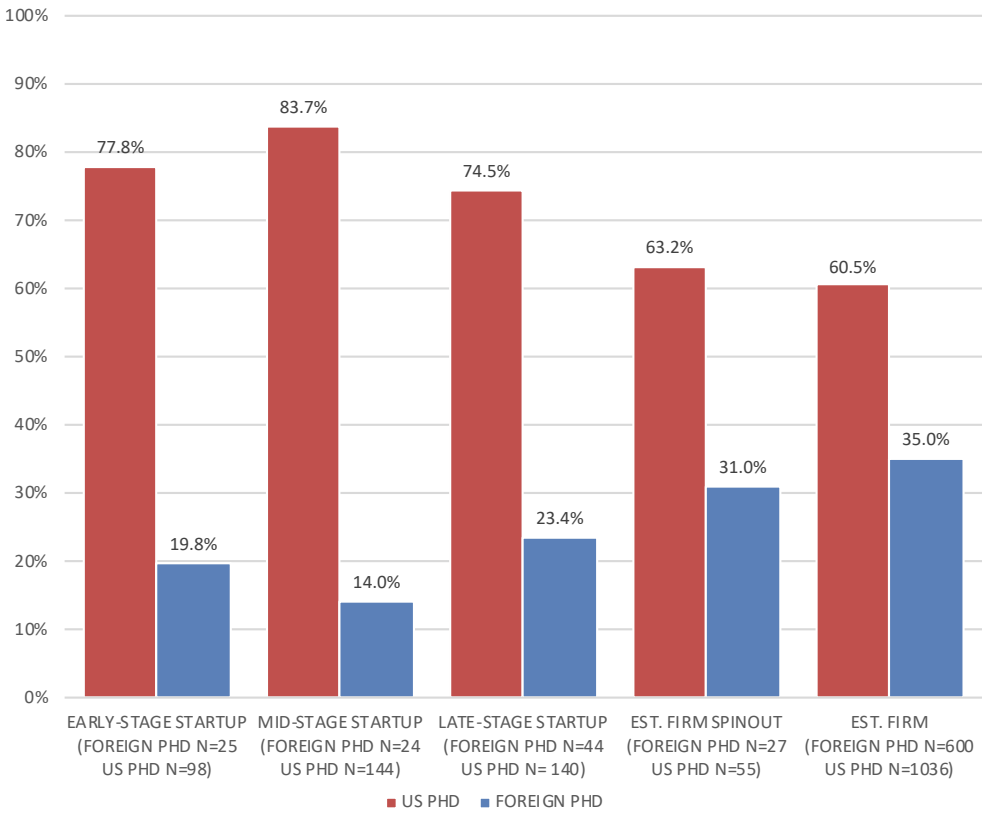


Fig. S2. Share of U.S. and foreign PhD R&D employees, respectively, employed in a startup for different company stages.

A follow-up employment survey was sent in 2013 and 2016 to the same PhD students who responded to the PhD survey in 2010 or 2013. The employment survey asked questions about PhDs' postdoc experience, job search, year of first industry employment, first employer age and size, starting salary and, for foreign PhDs, their visa progression throughout employment. In addition, in 2018 we surveyed PhDs who did not respond to the 2013 or 2016 employment surveys but were identified in the LinkedIn data as working in industry to obtain additional data on first-time employment and visa sponsorship. We received 1,321 responses to the employment survey for PhDs employed in industrial R&D, for an unadjusted response rate of 56%. For many of our respondents we only had a university email address that was no longer active, and thus we were unable to reach these respondents to participate in the employment survey. Table S4 reports the variables and their measure for all analyses.

Table S2. Number of observations and share of startup employees by degree field

Degree field	Obs.	%Startup empl.
Cellular & molecular biology	94	21.3%
Microbiology	48	12.5%
Developmental biology & genetics	61	21.3%
Immunology	38	18.4%
Neuroscience	65	16.9%
Biochemistry	148	19.6%
Biology, other	41	17.1%
Chemistry	325	11.7%
Physics	302	14.2%
Biomedical engineering	148	20.3%
Chemical engineering	177	7.9%
Electrical/computer engineering	220	10.0%
Mechanical engineering	91	4.4%
Materials science	96	7.3%
Computer science	409	11.0%
Other field	77	1.9%
Total	2,340	12.9%

Table S3. Number of observations and share of startup employees by university

University name	Obs.	%Startup empl.
California Institute of Technology	26	15.4%
Columbia University	58	10.3%
Cornell University	60	15.0%
Duke University	59	6.8%
Emory University	21	19.1%
Georgia Institute of Technology	31	6.5%
Harvard University	20	10.0%
Iowa State University	34	8.8%
Johns Hopkins	69	14.5%
Massachusetts Institute of Technology	132	20.5%
Michigan State University	55	1.8%
North Carolina State University	135	5.9%
Northwestern University	36	16.7%
Pennsylvania State University	42	4.8%
Princeton University	57	7.0%
Purdue University	141	2.8%
Rensselaer Polytechnic Institute	6	0.0%
Stanford University	29	31.0%
Texas A&M University	44	0.0%
The Ohio State University	25	16.0%
University of California-Berkeley	166	20.5%
University of California-Davis	76	7.9%
University of California-Irvine	9	11.1%
University of California-Los Angeles	50	18.0%
University of California-San Diego	114	19.3%
University of California-San Francisco	19	26.3%
University of Chicago	44	22.7%
University of Florida	62	21.0%
University of Illinois Urbana-Champaign	104	5.8%
University of Maryland	16	6.3%
University of Michigan	64	10.9%
University of Minnesota	57	1.8%
University of North Carolina	67	13.4%
University of Southern California	13	15.4%
University of Texas	83	10.8%
University of Washington	116	24.1%
University of Wisconsin	111	9.9%
Washington University-St. Louis	59	23.7%
Yale University	30	13.3%
Total	2340	12.9%

Table S4. Variables and measures

Employment		
Startup employee	1 if employer age was five years or less and employer size was 100 or fewer employees	12.9%
Citizenship		
Foreign PhDs	PhDs who entered the workforce on a temporary visa (e.g., F-1 or J-1)	30.8%
Permanent resident PhDs	PhDs who had a permanent resident visa prior to entering the workforce.	3.8%
US PhDs	PhDs who entered the workforce as US citizens	65.4%
Individual characteristics measured during graduate school		
Startup work interest	Stated attractiveness of working in a startup during graduate school and prior to entering the workforce. Respondents were asked "Putting job availability aside, how attractive do you personally find each of the following careers?", where careers included "startup firm job with an emphasis on research or development". Each job was rated independently on a 5-point Likert scale that ranged from "extremely unattractive" (1) to "extremely attractive" (5). Responses of "attractive" (4) or "extremely attractive" (5) were coded as 1 and all others to 0 to reflect whether a PhD was interested in working in a startup or not.	67.6%
Established firm work interest	Stated attractiveness of working in an established firm during graduate school and prior to entering the workforce. Respondents were asked "Putting job availability aside, how attractive do you personally find each of the following careers?", where careers included "established firm job with an emphasis on research or development". Each job was rated independently on a 5-point Likert scale that ranged from "extremely unattractive" (1) to "extremely attractive" (5). Responses of "attractive" (4) or "extremely attractive" (5) were coded as 1 and all others to 0 to reflect whether a PhD was interested in working in an established firm or not.	83.9%
Risk tolerance	Respondents were asked to choose between one of two gambles on a 10-point scale that ranged from "strongly prefer a 100% chance to win $1,000" to "strongly prefer a 50% chance to win $2,000." Respondents used a slider-scale to state their preference. Higher values reflect a greater willingness to choose a riskier outcome with a higher potential payoff, which we interpret as a greater risk tolerance.	2.26
Importance of financial pay	Respondents were asked "When thinking about an ideal job, how important is each of the following factors to you?", where the specific job attribute was "financial income (e.g., salary, bonus)". Responses were reported on a 5-point Likert scale that ranged from "not at all important" (1) to "extremely important" (5).	4.10
University dept. reputation	National Research Council ranking of a PhD's university department, which is a proxy for a PhD's perceived ability by prospective employers. The rankings were reverse-coded so that higher rankings would correspond to higher ability.	19.1
Male	1 if male, 0 if female	69.7%
Married	1 if married or in marriage-like relationship during graduate school	41.4%
Children	1 if had at least one child during graduate school	12.3%
Prior postdoc	1 if the PhD did a postdoc prior to entering the workforce	26.4%
Control variables		
Job start year fixed effects	Dummy variables for the year of observed first job (2010-2016)	
Degree field fixed effects	Dummy variables for 18 science and engineering fields	

To test for potential response bias, we performed a logistic regression of the likelihood of a respondent to the PhD survey also responding to the employment survey (1 if yes). We include as independent variables basic demographic, degree field, and university fixed effects (please see variable descriptions in the main analyses that follow). The results in Table S5 show that foreign PhDs are less likely to respond to the employment survey, indicating that they are less represented in the employment survey. Although we are unable to determine why foreign temporary residents are less likely to respond to the employment survey than U.S. citizens, given that permanent residents are no different from U.S. citizens it is conceivable that temporary residents may be more reluctant to participate in career surveys given their less secure employment status in the U.S. To

account for this potential response bias, we constructed non-response sample weights using two different data sources. First, we constructed proportional weights for the employment survey for specific nationalities by dividing the proportion who respond to the employment survey (i.e., the "sample proportion") by the proportion observed in the PhD survey used in our sample (i.e. the "population proportion"). Second, we constructed proportional 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 models for both types of sample weights for all the analyses that follow using nearly identical results to the unweighted results reported below (results available from the authors).

Table S5. Logistic regression estimates of the likelihood of responding to the employment survey.

Dependent variable	Employment survey respondent
Foreign PhD	-1.18***
	(0.11)
Permanent resident PhD	-0.44
	(0.24)
Startup work interest	-0.09
	(0.07)
Established firm work interest	0.03
	(0.13)
Univ. dept. reputation (NRC ranking)	0.08
	(0.11)
Male	0.02
	(0.12)
Married	-0.75***
	(0.09)
Children	-0.33*
	(0.14)
Prior postdoc	0.50***
	(0.10)
Constant	0.16
	(0.30)
Degree field FE	Incl.
University FE	Incl.
Job start year FE	Incl.
Obs.	2328
Log-likelihood	-1404.20

NOTES: Robust SEs clustered on university reported in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Job applications and job offers

To obtain measures on job applications and offers we asked respondents in the employment survey "Other than your first employer, when you were searching for your first industry job did you apply for and/or receive job offers from other startups?" Responses were recorded separately for yes or no for "applied for job" and "received at least one offer," respectively. Table S6 reports the full results for logistic regressions that examine job application, job offers, and work outcomes. The dependent variable for Models 1a and 1b is applying to a startup job, for Models 2a and 2b the dependent variable is receiving a startup job offer conditional upon applying for a startup job, and for Models 3a and 3b the dependent variable is working in a startup conditional upon receiving a startup job offer. Models 1b, 2b, and 3b focus specifically on the interactions for foreign and U.S. PhDs, and thus exclude permanent resident PhDs from the sample. All models report robust standard errors clustered on PhD university. We also estimated logistic regressions for an expanded sample that included PhDs who remained in academia rather than transitioned to industry with substantively identical results (available from the authors). Thus, our results are not sensitive to restricting the sample to PhDs who transitioned to industry R&D employment.

Table S6. Logistic regressions of the likelihood of applying to, receiving an offer from, and working in a startup.

Dependent variable	Applied for startup job		Received startup job offer		Work in startup	
Model	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Foreign PhD	-0.15		0.12		-0.97**	
	(0.10)		(0.29)		(0.32)	
Permanent resident PhD	-0.54		-0.48		0.04	
	(0.33)		(0.47)		(0.50)	
Startup work interest	0.53***		0.09		0.56*	
	(0.12)		(0.19)		(0.25)	
Foreign PhD X Startup work interest		0.46*		0.27		-0.31
		(0.19)		(0.40)		(0.46)
Foreign PhD X No startup work interest		-0.36		-0.08		-1.92
		(0.21)		(0.57)		(1.19)
U.S. PhD X Startup work interest		0.51***		0.06		0.52*
		(0.15)		(0.17)		(0.26)
Established firm work interest	-0.32	-0.33	-0.16	-0.20	-0.22	-0.24
	(0.20)	(0.20)	(0.24)	(0.25)	(0.27)	(0.26)
Univ. dept. reputation (NRC ranking)	-0.02	-0.03	0.21*	0.24*	0.18	0.20
	(0.07)	(0.07)	(0.09)	(0.10)	(0.10)	(0.10)
Male	0.14	0.12	-0.01	-0.01	-0.17	-0.14
	(0.16)	(0.17)	(0.26)	(0.25)	(0.24)	(0.23)
Married	-0.01	-0.07	-0.05	-0.01	0.01	0.06
	(0.12)	(0.12)	(0.18)	(0.19)	(0.21)	(0.22)
Children	-0.17	-0.23	0.01	0.01	-0.44	-0.51
	(0.23)	(0.23)	(0.29)	(0.30)	(0.47)	(0.46)
Prior postdoc	0.08	0.03	0.06	0.10	0.51	0.52
	(0.14)	(0.14)	(0.20)	(0.20)	(0.31)	(0.30)
Constant	-1.00***	-1.06**	0.78	0.79	0.28	0.20
	(0.29)	(0.39)	(0.69)	(0.71)	(0.84)	(0.88)
Degree field FE	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Job start year FE	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Observations	1327	1276	587	567	364	350
Log-likelihood	-865.03	-824.76	-375.33	-362.49	-229.69	-219.74

NOTES: Sample for Models 2a and 2b is conditioned on applying for a startup job; sample for Models 3a and 3b is conditioned on receiving a startup job offer; samples in Models 1b, 2b and 3b exclude permanent residents to focus on interactions for foreign and US PhDs. Robust SEs clustered on university reported in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

In addition to the results presented in the main paper, we find that university department reputation is significantly associated with the likelihood of receiving a startup job offer, suggesting that startups try to hire PhDs from more prominent departments. We see no difference based on gender, marital status, having children, or having done a postdoc prior to entering the workforce.

Determinants of working in a startup

To examine alternative reasons why foreign PhDs might be less likely to work in a startup, we estimate a series of logistic regressions predicting startup employment. Table S7 reports the full results and the dependent variable in all models is startup employment. Model 1 includes the full sample of PhDs, Models 2 and 3 split the sample between PhDs who reported during graduate

school that they were either interested in working in a startup (Model 2) or not (Model 3), and Models 4 and 5 split the sample between U.S. (Model 4) and foreign PhDs (Model 5), respectively. All models report robust standard errors clustered on PhD university.

Table S7. Logistic regressions of the likelihood of working in a startup.

Sample	Full	Startup work interest	No startup work interest	U.S. PhD	Foreign PhD
Model	(1)	(2)	(3)	(4)	(5)
Foreign PhD	-0.79***	-0.91***	-0.42		
	(0.18)	(0.21)	(0.45)		
Permanent residents PhD	-0.44	-0.52	-0.20		
	(0.33)	(0.42)	(0.75)		
Startup work interest	0.61***			0.66***	0.38
	(0.16)			(0.18)	(0.42)
Established firm work interest	-0.61***	-0.55*	-0.62*	-0.58**	-0.83
	(0.19)	(0.27)	(0.30)	(0.21)	(0.48)
Risk tolerance	0.04*	0.06**	-0.03	0.07*	-0.00
	(0.02)	(0.02)	(0.07)	(0.03)	(0.05)
Importance of financial pay	-0.05	-0.02	-0.10	-0.05	-0.09
	(0.09)	(0.10)	(0.16)	(0.10)	(0.33)
Univ. dept. reputation (NRC ranking)	0.24**	0.23*	0.28	0.21*	0.48**
	(0.09)	(0.09)	(0.16)	(0.10)	(0.18)
Male	-0.06	-0.06	-0.06	-0.04	0.02
	(0.14)	(0.20)	(0.24)	(0.14)	(0.50)
Married	0.10	-0.06	0.53	-0.02	0.54
	(0.14)	(0.15)	(0.29)	(0.17)	(0.34)
Children	-0.03	-0.09	0.40	-0.17	0.54
	(0.25)	(0.25)	(0.39)	(0.26)	(0.62)
Prior postdoc	0.26	0.21	0.31	0.34*	-0.35
	(0.15)	(0.18)	(0.25)	(0.16)	(0.40)
Constant	-1.78***	-1.19*	-2.10	-1.69***	-4.57**
	(0.52)	(0.59)	(1.26)	(0.50)	(1.71)
Degree field FE	Incl.	Incl.	Incl.	Incl.	Incl.
Job start year FE	Incl.	Incl.	Incl.	Incl.	Incl.
Obs.	2328	1576	740	1525	677
Log-likelihood	-821.49	-583.82	-222.82	-620.46	-147.78

NOTES: Sample for Model 2 is restricted to PhDs with startup work interest during graduate school and Model 3 to PhDs with no startup work interest during graduate school. Sample for Model 4 is restricted to U.S. PhDs and Model 5 is restricted to foreign temporary visa PhDs. Robust SEs clustered on university reported in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

In addition to the results presented in the main paper, we also examined the robustness of our results to an alternative measure of startups that included late-stage companies that were less than 10 years of age and under 1,000 employees at the time the PhD joined as an employee. We find that the disparity between foreign and U.S. PhDs diminishes for larger and older startups. Foreign PhDs are 41% less likely to work in a startup compared to US PhDs, and the difference is highly significant. This is likely due to companies having more funding, being more established and less risky, and having more experience sponsoring visas foreign workers. Full results with different startup cutoffs are available from the authors.

We also examined for potential selection bias by including PhDs who remained in academia and estimating a multinomial logistic regression of the likelihood of remaining in academia or working in a startup relative to working in an established firm (the reference group; results available from the authors). We find that foreign PhDs do not differ significantly from U.S. PhDs in their likelihood of remaining in academia relative to working in an established firm. We also find that foreign PhDs are significantly less likely to work in a startup relative to working in an established firm. In addition, consistent with the results presented above, we find that ex ante career preferences are a strong predictor of employment outcomes, with PhDs who ex ante prefer faculty careers more likely to remain in academia rather than move to industry. Thus, we do not find systematic evidence of potential citizenship-based selection bias between US and foreign PhDs in their likelihood of remaining in academia. Moreover, restricting our sample to PhDs who work in industrial R&D does not alter our key findings that foreign PhDs are less likely than U.S. PhDs to work in startups.

Entrepreneurial region effects

An important concern with the employment of recent PhD graduates in startups is the concentration of startups in entrepreneurial regions like Silicon Valley and Boston, while universities are geographically dispersed across the U.S. For example, a PhD student from a university not embedded in an entrepreneurial region, such as Cornell, might face labor market constraints that make it more difficult to obtain a startup job relative to PhD students from Stanford or Berkeley. These constraints might be exacerbated for foreign PhDs from more remote universities who may not possess as much institutional knowledge about entrepreneurial regions or may face other language or cultural challenges that prevent them for finding startup jobs. On the other hand, as illustrated in the employment heat map in Fig. S3, many PhDs in our sample are employed in established firms and startups in Silicon Valley and Boston, suggesting that employment in the entrepreneurial regions is high.

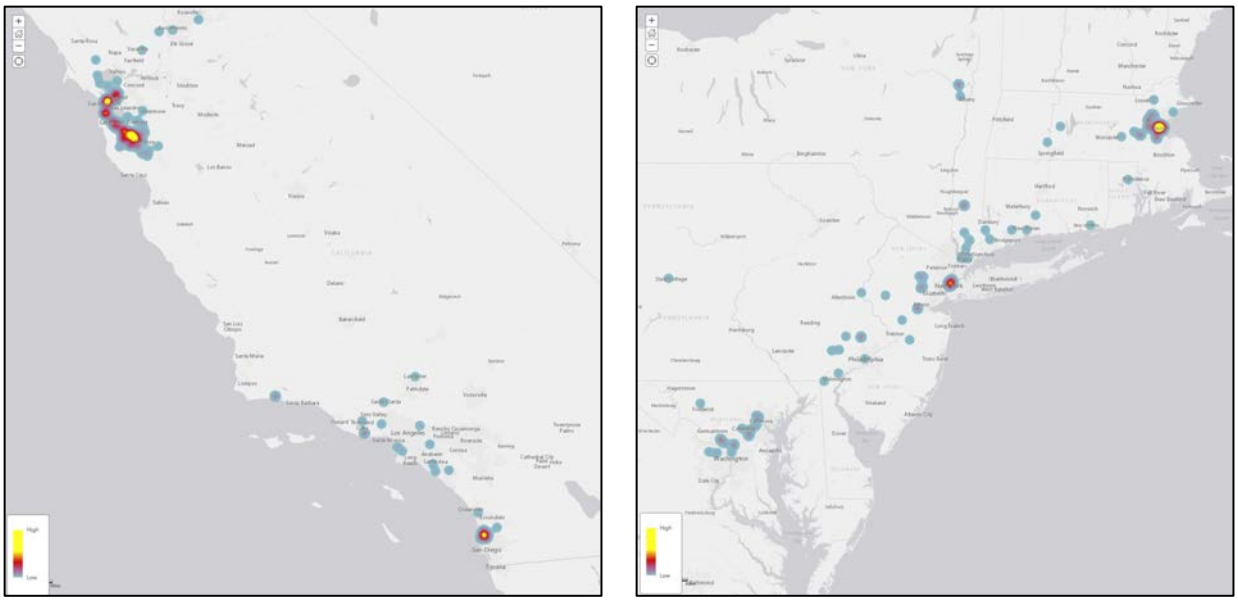


Fig. S3. Heat maps of the concentration of STEM PhDs employed in industrial R&D in California (left) and the Northeast (right). The regions with the highest concentrations are San Francisco and Boston.

To explore the possibility that foreign PhDs from universities outside of entrepreneurial regions might be more constrained in their ability to work in startups, we constructed a variable that is 1 if an individual received their PhD from a university in either the San Francisco Bay Area (i.e., Berkeley, Stanford or UCSF) or the Boston Area (i.e., Harvard or MIT).[6] To the extent that doing their PhD at a university within an entrepreneurial region facilities a PhD's ability to find startup jobs, then we expect this variable to significantly predict startup employment, and this effect will be greater for foreign PhDs relative to U.S. PhDs. In addition to geographic proximity, universities in entrepreneurial regions may also be more likely to encourage PhD students to work in startups. However, prior research has shown that the encouragement of entrepreneurship varies across universities even within an entrepreneurial region, where, for example, MIT more strongly encourages PhDs to work in startups while Harvard does not.[7]

Table S8 presents a series of logistic regressions to explore this relationship. The baseline results in Model 1 illustrate that individuals who did their PhD at a university in an entrepreneurial region are significantly more likely

Table S8. Logistic regressions of the likelihood of working in a startup with entrepreneurial region effects

Model	(1)	(2)
PhD univ. in entrepreneurial region	0.51*	
	(0.22)	
Foreign PhD	-0.76***	
	(0.19)	
Permanent residents PhD	-0.43	
	(0.33)	
Entr. region X U.S. PhD		1.26***
		(0.27)
Not entr. region X U.S. PhD		0.82***
		(0.22)
Entr. region X foreign PhD		0.74
		(0.43)
Startup work interest	0.62***	0.62***
	(0.16)	(0.17)
Established firm work interest	-0.61**	-0.60**
	(0.19)	(0.20)
Risk tolerance	0.04*	0.05*
	(0.02)	(0.02)
Importance of financial pay	-0.05	-0.05
	(0.09)	(0.09)
Univ. dept. reputation (NRC ranking)	0.10	0.12
	(0.10)	(0.10)
Male	-0.05	-0.04
	(0.15)	(0.15)
Married	0.11	0.08
	(0.13)	(0.13)
Children	-0.02	-0.08
	(0.24)	(0.23)
Prior postdoc	0.28	0.28
	(0.16)	(0.15)
Constant	-2.24***	-3.08***
	(0.58)	(0.57)
Degree field FE	Incl.	Incl.
Job start year FE	Incl.	Incl.
Obs.	2,328	2,238

NOTES: PhD university in entrepreneurial region is 1 if respondent did their PhD at Stanford, Berkeley, UCSF, MIT or Harvard. Robust SEs clustered on university reported in parentheses; Column 2 excludes permanent resident PhDs to focus on interaction between region and US vs. foreign PhDs;
* p < 0.05, ** p < 0.01, *** p < 0.001.

[6] One might be concerned that by including these particular universities our results reflect an "elite university" effect rather than an entrepreneurial region effect. In results available from the authors, we include an "elite university" variable that includes the following universities in our data: Berkeley, Caltech, Chicago, Columbia, Cornell, Duke, Harvard, MIT, Princeton, Stanford and Yale. Our results reported in Table S5 are robust to the inclusion of this variable.

[7] Roach M (2017) Encouraging Entrepreneurship in University Labs: Research Activities, Research Outputs, and Early Doctorate Careers. *PLoS ONE* 12(2):e0170444.

to work in a startup. The coefficient estimate for foreign PhDs is slightly lower than in Table S7, but the main effect that foreign PhDs are significantly less likely than U.S. PhDs to work in startups remains. Model 2 reports interactions between entrepreneurial region and foreign and U.S. PhDs. We see that U.S. PhDs are still more likely to work in a startup compared to foreign temporary residents who did their PhD in a university outside these entrepreneurial regions (the omitted group), and this effect is greater for U.S. citizens who did their PhDs in entrepreneurial regions. The coefficient for foreign temporary residents who did their PhDs in entrepreneurial regions is positive and significant at the 0.10 level. Thus, although there are clear positive effects of working in a startup for PhDs from universities in entrepreneurial regions, foreign PhDs, whether they are from universities in entrepreneurial regions or not, are still considerably less likely to work in startups than their U.S. counterparts.

Visa progression

To examine whether foreign PhDs might be more likely to move to startups after receiving permanent residency, we asked respondents in 2013, 2016, and 2018 to report their current visa status including OPT without employer sponsorship for another visa, H-1B, and permanent resident. In addition, for permanent residents we also asked about the preference category of their visa (e.g., EB-1, EB-2 etc.) and whether their visa was employer-sponsored, self-sponsored, or family-sponsored. We also asked whether they have changed employers and, if so, about their current employer's size and age, as well as coded employment transitions based on LinkedIn career histories.

We include in this analysis a variable that indicates whether a foreign PhD has received a green card from their employer, thereby enabling them to freely move to other employers including a startup. To isolate the effect of receiving a green card, which typically takes several years, from being in the workforce long enough to transition to another job, we also include a variable that indicates whether the PhD has been in the workforce for at least three years.

Table S9 presents results from a multinomial logistic regression predicting job changes to another established firm or to a startup relative to staying at the first established firm employer. Model 1 reports results for the sample of foreign PhDs and Model 2 shows the results for U.S. PhDs for comparison. Column 1a shows that foreign PhDs who have received a permanent resident visa are more likely to move to another established firm employer relative to staying with their first employer (relative risk ratio of 1.90), as are foreign PhDs who have been working at least three years (relative risk ratio of 2.07). Column 1b shows that foreign PhDs who have received a permanent resident visa are much more likely to move to a startup (relative risk ratio of 13.16), and the difference from the estimate from Model 1a is significant ($\chi 2 = 7.68$, p-value=0.006). Column 2a shows that U.S. PhDs who have been working for at least three years are more likely to move to another established firm, but not to a startup. The results indicate that foreign PhDs who receive a green card are more likely to move to a startup.

Table S9. Employee mobility from established firms to other established firm or startups.

Sample	Foreign PhD est. firm employees		U.S. PhD est. firm employees	
Dependent variable	Move to other est.	Move to startup	Move to other est.	Move to startup
Model	(1a)	(1b)	(2a)	(2b)
Perm. visa after first job	0.64*	2.58***		
	(0.26)	(0.64)		
Working at least three years	0.73**	1.09	0.96***	0.28
	(0.27)	(0.76)	(0.15)	(0.23)
Startup work interest	0.23	1.19	0.27	0.92***
	(0.23)	(0.62)	(0.16)	(0.27)
Established firm work interest	-0.25	0.18	0.03	-0.16
	(0.35)	(1.02)	(0.20)	(0.30)
Univ. dept. reputation (NRC ranking)	-0.09	0.26	-0.04	0.21**
	(0.11)	(0.22)	(0.05)	(0.08)
Male	-0.20	0.83	-0.03	0.18
	(0.22)	(0.75)	(0.18)	(0.28)
Married	-0.14	0.15	0.06	0.34
	(0.24)	(0.47)	(0.15)	(0.24)
Children	-0.63	-1.21	0.21	0.43
	(0.50)	(1.07)	(0.22)	(0.31)
Prior postdoc	-0.21	-0.09	0.05	0.69*
	(0.24)	(0.59)	(0.22)	(0.31)
Constant	-2.56***	-6.25***	-2.67***	-2.94***
	(0.57)	(1.87)	(0.45)	(0.42)
Degree field FE	Incl.		Incl.	
Observations	664		1,281	
Log-likelihood	-330.87		-805.62	

NOTES: Sample for Model 1 is foreign PhDs whose first job was in an established firm; sample in Model 2 is U.S. PhDs whose first job was in an established firm. Both models report multinomial logistic regression coefficients for the likelihood of employment transitions from first established firm (reference group) to employment in another established firm (Model 1a and Model 2a) or a startup (Model 1b and Model 2b). Robust SEs clustered on university reported in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Policy Analysis

The objective of this analysis is to gain insights into whether foreign PhDs might be more likely to work in startups if visa policy constraints were relaxed. The critical assumption of this analysis is that after accounting for observable characteristics such as ex ante stated work interests and risk tolerance, the remaining difference between US and foreign PhDs is attributable to visa requirements that influence employment outcomes. This is admittedly a strong assumption, and we recognize that there are other unobservable differences between US and foreign PhDs, as well as within foreign PhDs themselves. Nevertheless, we believe this analysis provides suggestive insights into whether foreign PhDs would be more likely to work in startups if they had the same freedom of job choice as US citizens.

Table S10 reports results of the regression model used to estimate the predictors of working in a startup for U.S. citizens along (Model 1) and U.S. citizens and permanent residents combined (Model 2). In both models, ex ante career interests are strong predictors of working in a startup or established firm, as well as university department rank and for U.S. citizens risk tolerance. We then predicted the likelihood of working in a startup for foreign PhDs based on the same set of nine individual observable variables, in addition to degree field and job start year fixed effects. If visa concerns deter foreign PhDs from working in startups, then we would expect that in these out-of-sample predicted values, foreign PhDs with stronger preferences for working in a startup, higher risk tolerance, and from higher ranked university departments would be more likely to work in a startup. As illustrated in Fig. 5 in the manuscript, the counterfactual predictions show that foreign PhDs are indeed more likely to work in startups.

Table S10. Logistic regressions of the likelihood of working in a startup

Sample	U.S.	U.S. + PERM
Model	(1)	(2)
Permanent residents PhD		-0.49
		(0.32)
Startup work interest	0.66***	0.67***
	(0.18)	(0.17)
Established firm work interest	-0.58**	-0.59**
	(0.21)	(0.20)
Risk tolerance	0.07*	0.05
	(0.03)	(0.03)
Importance of financial pay	-0.05	-0.05
	(0.10)	(0.10)
Univ. dept. reputation (NRC ranking)	0.21*	0.19*
	(0.10)	(0.10)
Male	-0.04	-0.06
	(0.14)	(0.14)
Married	-0.02	0.01
	(0.17)	(0.17)
Children	-0.17	-0.09
	(0.26)	(0.28)
Prior postdoc	0.34*	0.33*
	(0.16)	(0.17)
Constant	-1.69***	-1.63***
	(0.50)	(0.50)
Degree field FE	Incl.	Incl.
Job start year FE	Incl.	Incl.
Obs.	1,525	1,615
Pseudo R^2	0.070	0.069
Log-likelihood	-620.46	-650.79

NOTES: Sample for Model 1 is restricted to U.S. PhDs and Model 2 is restricted to U.S. and permanent resident PhDs. Robust SEs clustered on university reported in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001.

One implication of this analysis is that if immigration policies were enacted that enabled STEM PhDs from U.S. universities – particularly those who were funded by federal grants during graduate school – to receive a green card upon graduation, such as the long-proposed STAPLE (Stopping Trained in America PhDs from Leaving the Economy) Act, then a greater share of foreign PhDs may choose to work in startups rather than established firms. In light of prior research that suggests that hiring high-skilled immigrants does not displace native workers and actually leads to greater firm innovative output (Kerr & Lincoln 2010; Hunt & Gauthier-Loiselle 2010; Hunt 2011), we might expect such visa reforms could increase the overall size of the entrepreneurial workforce. Assuming that the share of U.S. PhDs working in startups does not change, then preliminary calculations suggest that reducing visa barriers to foreign PhDs working in startups could increase the total entrepreneurial workforce from 12.9% of all STEM PhDs employed in industrial R&D as observed in this study to an estimated 16.0%, which is an increase of approximately 24%. Although speculative, this increase could result in greater startup innovative performance, survival, and growth.