

Keeping Top AI Talent in the United States

FINDINGS AND
POLICY OPTIONS
FOR INTERNATIONAL
GRADUATE STUDENT
RETENTION

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CENTER *for* SECURITY *and* EMERGING TECHNOLOGY

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Executive Summary

Talent is core to U.S. competitiveness in artificial intelligence, and international graduate students are a large source of AI talent for the United States. More than half of the AI workforce in the United States was born abroad, as were around two-thirds of current graduate students in AI-related fields. Tens of thousands of international students get AI-related degrees at U.S. universities every year. Retaining them, and ensuring a steady future talent inflow, is among the most important things the United States can do to address persistent domestic AI workforce shortages and to remain the global leader in AI.

This paper holds both good news and bad news for the United States. **The good news is that student retention has historically been a core U.S. strength**, with well over 80 percent of international U.S.-trained AI PhDs staying in the country, including those from AI competitors such as China. By contrast, other studies have found that the vast majority of China-trained AI talent currently lives outside China. Moreover, contrary to popular perception and anecdotal reports, there is no evidence of recent declines in U.S. retention rates.

The bad news is that two trends are placing this U.S. strength in student retention at risk. The immigration obstacles international graduates face have grown steadily in the past two decades and have worsened in recent years. At the same time, other countries are investing heavily in AI talent attraction and retention, pumping money into their domestic AI ecosystems and opening up their immigration systems to foreign AI talent. In the past, the United States could rely on its status as the world's sole science and technology superpower to compensate for the flaws of

its immigration system, but in today's more competitive world, complacency is likely to come at a higher cost. Without serious immigration policy changes, the United States stands to lose a vital asset in the international competition for AI leadership.

Results presented below are based on CSET-collected comprehensive career data on 2,000 recent AI PhD graduates from U.S. universities, as well as original analysis of 43,000 immigration records of AI professionals and multiple AI-related survey instruments. Key findings include the following:

- **International students are a key source for graduate-level U.S. talent in AI.**
 - Two-thirds of graduate students in AI-related programs are international students, and the number of domestic graduate students in these programs has not increased since 1990. Currently, U.S. universities graduate around 50,000 international graduate students (44,000 master's, 3,000 PhDs) in AI-related fields per year.
 - About 70 percent of immigrants sponsored by AI companies for permanent residency studied at U.S. universities, as did more than half of all international AI workers entering the U.S. labor market each year.
 - International graduates fill critical AI talent gaps in the U.S. labor market. Objective labor market indicators and expert assessments suggest demand for AI talent will far outstrip supply for the foreseeable future.
- **Stay rates among international graduates in AI are persistently high.**
 - Around 90 percent of international AI PhD students take a job in the United States after graduating, and more than 80 percent stay in the country for at least five years. Past studies strongly suggest stay rates are likely to be high beyond the five-year window for which there is hard AI-specific data.
 - Multiple data sources indicate retention rates have not fallen in recent years, contrary to popular perception and anecdotal reports.
 - Stay rates are highest—exceeding 90 percent—among students from Taiwan, India, Iran, and China, and lower—around 75 percent—among students from European countries.
 - Among the few graduates who leave the United States, the large majority go to U.S. allies and partners in Europe and Asia, such as the U.K., Canada, Singapore, and South Korea. Less than 20 percent of those leaving go to China.

- **Professional considerations are the main reasons for international talent to stay in the United States, while immigration difficulties and cultural factors are the most important issues pushing away talent.**

- The U.S. private sector is especially attractive to graduates; around 60 percent go on to work for companies after completing their degree, with most of the remainder going into academia.
- Graduates with ambitions to launch or work at startups are particularly hampered by immigration obstacles. Whereas more than 40 percent of domestic graduates who go into the private sector work at small companies, less than 20 percent of international graduates do so.

On the policy front, research highlights two important trends that, together, could erode the U.S. AI talent advantage:

- **Domestically, international graduates who want to stay are faced with significant obstacles in the U.S. immigration system, and these problems are getting worse.**
 - Green card wait times have increased significantly in recent years. One study estimates that an Indian AI PhD graduate sponsored for a green card today would face a wait time of around 50 years in the absence of immigration reforms.
 - Optional Practical Training, a program used by tens of thousands of international graduates from AI-related programs every year, is currently facing significant legal and policy challenges. Given the lack of available alternative visas for these graduates, many would likely be forced to leave the United States if OPT were eliminated.
 - There is no suitable U.S. entrepreneur visa for international graduates who want to start AI companies. Sponsoring employees for visas is often too costly for startups, in large part due to inflexible and long application timelines.
- **Internationally, the United States faces increasing competition for top AI talent.**
 - The United States has lost its historical near-monopoly on AI R&D and commercial activity. In 2013, the United States accounted for more than 70 percent of funding deals for AI startups. By 2018, this number had dropped to 40 percent.
 - Other countries are opening their immigration systems and aggressively recruiting U.S.-trained AI talent. Nearly two dozen countries

have recently launched startup visa programs marketed mainly to tech entrepreneurs.

- Other countries are also investing heavily in their education systems. The number of U.S. universities reporting international students declining admission offers because they preferred to study at home or in third countries increased three-fold between 2016 and 2018.

Based on these findings, the report lays out two priorities and several concrete options for U.S. policymakers.

- **First, policymakers need to reform high-skill immigration rules in order to maintain and improve U.S. international AI talent retention. Options for achieving this include:**
 - Reforming student visa regulations and procedures, for example by codifying OPT in statute and eliminating processing backlogs.
 - Streamlining post-graduation transitions into the U.S. labor force, as could be done through the creation of a statutory student-to-work pathway and a dedicated visa program for entrepreneurs.
 - Shortening the path to permanent residency and citizenship, for example by removing numerical caps for in-demand graduate talent or creating accelerated citizenship-through-service programs.
- **Second, policymakers should address legitimate security concerns around foreign AI talent while avoiding broad and potentially counterproductive restrictions. This can be done by:**
 - Improving policy coordination domestically and internationally by creating a new interagency task force and increasing engagement with allies, without whom counter-transfer efforts for diffuse technologies such as AI would almost certainly be ineffective.
 - Raising awareness of transfer practices through open-source collection and dissemination, for example by allocating more resources to open-source intelligence activities or adopting FARA-like legislation for foreign talent recruitment activities.
 - Collecting more and better data about student retention trends, including among master's students, for whom there is no government survey or other data source that tracks post-graduation career choices.

Introduction

The Importance of International Graduate Students to U.S. AI Competitiveness

There is widespread consensus among U.S. policymakers that AI is central to the future of U.S. security and economic competitiveness.¹ Improving the retention of international AI graduate students should be a key part of U.S. AI policy because talent is core to competitiveness in AI and because international graduate students are a key source of U.S. AI talent.

Talent is crucial for building and deploying the different parts of AI systems—algorithms, hardware, and data. Much of the knowledge for how to work with AI systems is tacit and acquired through experience, and continuous progress in the field means that today’s cutting-edge models could be outdated tomorrow. Countries and companies thus require adaptable skilled individuals who can continuously learn by doing and keep up with rapid changes. Xi Jinping has called talent “the first resource” in China’s push for “independent innovation.”² As analyst Elsa Kania has put it, in a sentiment echoed by many industry observers, “the real ‘arms race’ in [AI] is not military competition but the battle for talent.”³

Yet domestic AI talent in the United States is—and will for the foreseeable future remain—inadequate to fill rapidly rising demand. More than half of the AI workforce in both academia and the private sector was born abroad, and U.S. companies are increasingly setting up AI labs abroad because they cannot find enough talent at home. For example, on job site *Indeed*, the number of AI job postings in the United States more than doubled between 2015 and 2018, while the number of job searches increased only marginally.⁵ Expert consensus about workforce shortages in AI sets the field apart from other fields with many international students, including STEM fields, where labor shortages claims are heavily debated.⁶

“

Talent remains the most important driver of progress in all facets of AI.”

—U.S. National Security Commission for Artificial Intelligence (2019)⁴

International students are an especially valuable source of talent for the U.S. AI workforce. Most top AI programs in the world are at U.S. universities, and the students accepted into and trained in those programs represent the world's top talent.⁷ Employers also prefer students with a U.S. education because employers are better able to assess the reliability of prospective employees' qualifications and evaluate them through internships.⁸ Lastly, workers who come into a country as students tend to remain longer and integrate better than those who initially enter through a temporary employment visa.⁹ One study showed that international students co-founded 21 of the 87 "unicorns" the United States had in 2016, cumulatively worth \$60 billion and responsible for nearly 20,000 U.S. jobs.¹⁰

It should come as no surprise, then, that the majority of foreign-born workers hired today by American AI companies are former international students. In absolute terms, the number of international students graduating from U.S. universities with AI-related degrees stands at more than 50,000 per year, and nearly all of them are graduate students. By comparison, the annual number of domestic graduates with AI-related graduate degrees is around 23,000. In short, international graduate students are a main source of AI talent for the United States.

This paper asks what can be done to retain this source of AI talent, and its findings highlight the need for urgent action. The United States has historically excelled at international graduate recruitment and retention. But there are warning signs in the form of mounting domestic immigration difficulties and increased international competition. While it is conceivable that the strength of the U.S. AI ecosystem will continue to draw international talent despite these trends, complacency carries significant risks. It is much easier to maintain than to recover an advantage. And because talent attracts talent and ecosystems grow in self-reinforcing ways, any short-term increase in other states' relative attractiveness—even if counteracted after the fact—can have long-term and potentially irreversible consequences. U.S. policymakers have a window of opportunity for reform that they should not let pass.

To help policymakers bolster U.S. competitiveness in AI, this paper proceeds in three steps. First, it draws on evidence from a wide range of sources to show how the United States performs when it comes to graduate student retention in AI (**Chapter 1: "Understanding Student Retention"**). Second, it examines relevant policy trends, focusing on student-related U.S. immigration policies and recent measures adopted by other countries competing for U.S.-trained AI talent (**Chapter 2: "The Policy Context"**). Third, it lays out targeted policy options for improving graduate student retention and recruitment while also addressing security concerns around foreign talent (**Chapter 3: "Priorities and Options for U.S. Policymakers"**).

1 Understanding Student Retention

This chapter provides data and other evidence on the number of international AI students in the United States, how many and who among them stay in the country after graduating, why they decide to stay or leave, and what work they end up doing after graduating. Many of the findings and figures are based on original data collection and analysis that CSET conducted. Data sources and methodology are outlined in Box 1 and discussed in more detail in Appendix A.

BOX 1

Data sources analyzed in this report

- Data newly collected by CSET on the career and educational histories of 1,999 AI PhDs who graduated from top U.S. universities between 2014 and 2019.
- Data from the National Science Foundation's Survey of Earned Doctorates on CS PhD students' countries of origin and post-graduation professional plans.
- Data from the National Science Foundation and Department of Education on national enrollment trends in AI-related programs.
- Data from the Computing Research Association's Taulbee and Data Buddies surveys on computing students' fields of specialization and post-graduation professional plans.
- Data from the Department of Labor's PERM labor certification process on the educational and professional backgrounds of nearly 900,000 green card applicants (43,000 of whom we classify as AI-related).

WHAT DEGREES AND FIELDS ARE MOST IMPORTANT FOR AI?

Because AI is a new field, it is not clear which students should be counted as doing AI-relevant work or having AI-relevant skills, or what the most important degrees are. Yet answering those questions, even provisionally, is necessary for the analysis this paper sets out to do. Our research led us to focus on graduate students and look primarily at the fields of computer science and computer engineering.

We focus on graduate students because they represent around 85 percent of all U.S.-based international students in AI-relevant disciplines (see Table 1) and because most international workers hired by AI companies hold graduate degrees. For example, our analysis of data on AI companies' sponsorship of green cards shows that roughly 70 percent of individuals sponsored for technical jobs at these companies hold graduate degrees.¹¹

We focus primarily on computer science and computer engineering because those seem to be the main feeder fields into AI jobs and thus the most representative measure for AI talent pipelines.¹² Among workers sponsored for green cards for technical jobs at AI companies, about two thirds have computer science, computer engineering, or electrical engineering degrees.¹³ (This does not mean, of course, that everyone in CS, CE, or EE does AI-focused work; in fact, even in these fields AI appears to be the focus of only about a quarter of all students, though data on this question is sparse.¹⁴)

HOW MANY INTERNATIONAL STUDENTS ARE THERE?

International students first accounted for more than 50 percent of total CS/EE graduate students in the United States after 2000, with a rapid rise starting in 2013 bringing them to approximately 65 percent of the 150,000 total today (Figure 1).

TABLE 1

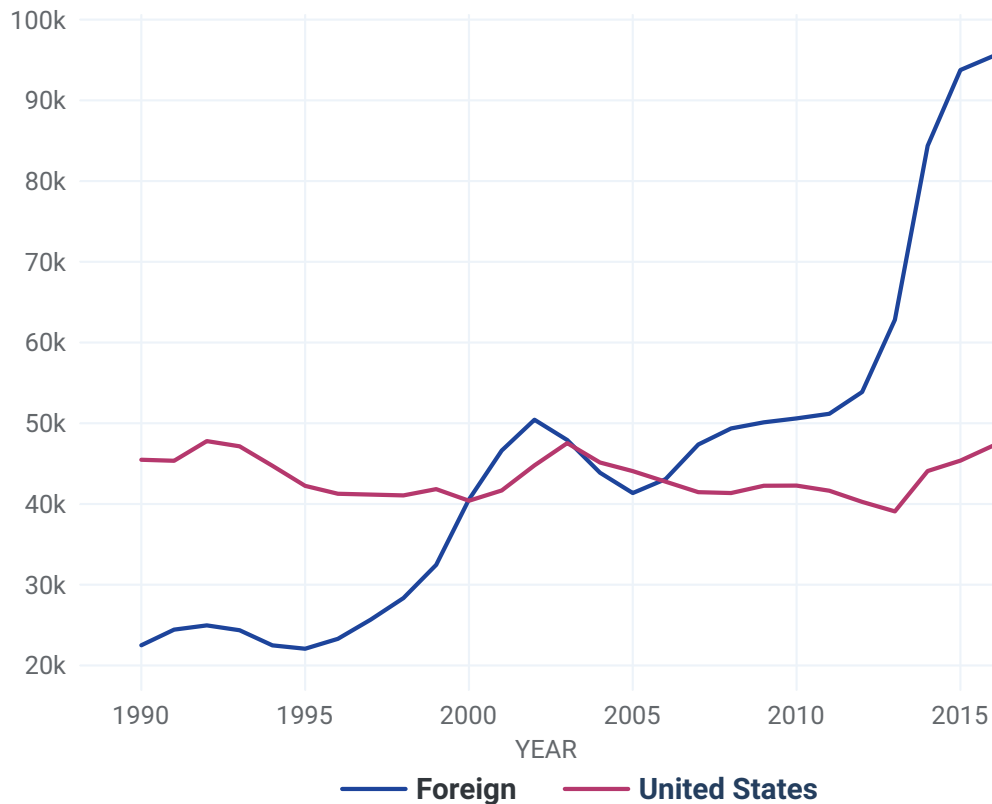
Number of domestic and international graduates in AI-relevant fields, AY2016-2017.

| | NUMBER OF CS/EE GRADUATES | PERCENT CS/EE GRADUATES INTERNATIONAL | NUMBER OF DOMESTIC CS/EE GRADUATES | NUMBER OF FOREIGN CS/EE GRADUATES |
|------------|---------------------------|---------------------------------------|------------------------------------|-----------------------------------|
| Bachelor's | 103,541 | 9% | 94,624 | 8,917 |
| Masters | 65,943 | 67% | 21,665 | 44,278 |
| PhD | 4,713 | 64% | 1,682 | 3,031 |

Source: Department of Education Integrated Postsecondary Education Data System (IPEDS).

FIGURE 1

Number of CS/EE graduate students enrolled at U.S. universities, 1990-2016.



Source: NSF Survey of Graduate Students and Postdoctorates in Science and Engineering (see Appendix A).¹⁵

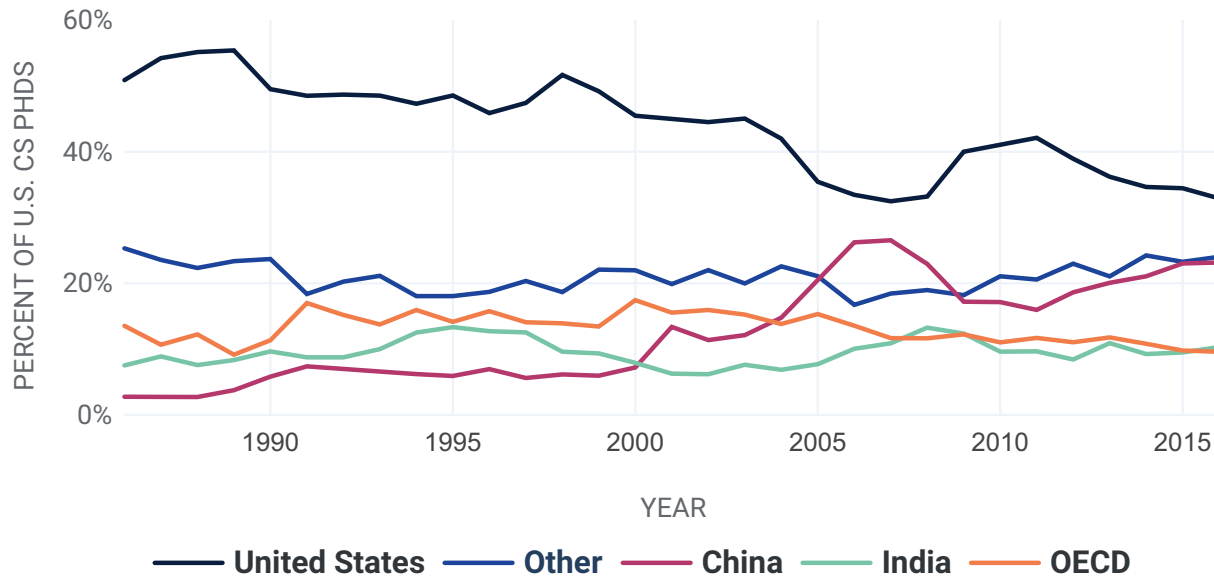
Looking at students' countries of origin (Figure 2), for which NSF PhD data is currently available to us only for CS students, Chinese and Indian nationals made up a majority of international CS PhD graduates in 2016. Together, they slightly outnumbered domestic U.S. graduates: 36 percent for China and India versus 35 percent for Americans. They are distantly followed by Iran (4 percent), South Korea (4 percent), Bangladesh (2 percent), Taiwan (2 percent), and Turkey (2 percent).¹⁶

What do these percentages translate into in terms of absolute numbers? Table 1 shows that U.S. universities graduate roughly 45,000 international master's students and 3,000 international PhD students in CS/EE per year (67 and 64 percent of total graduates respectively). At the bachelor's level, there is a much lower share of international students (9 percent) and about 9,000 international graduates per year. (Note that these numbers refer to annual graduates; the number of enrolled students is significantly higher at the undergraduate and doctoral levels since those degrees take multiple years to complete.)

There is also a significant number of U.S.-based international post-doctoral researchers in CS/EE. There were a total of 2,100 CS/EE postdocs in 2016, for example, of which roughly 70 percent were international.¹⁷

FIGURE 2

Country of origin among CS PhD graduates in the United States, 1986-2016.



Source: NSF Survey of Earned Doctorates (see Appendix A).

HOW MANY GRADUATES STAY, AND FOR HOW LONG?

Calculating stay rates is complicated because of the different ways in which one can define and measure what it means to “stay” in the United States. One common approach is to ask students if they intend to stay or have plans to stay in the United States after completing their degree. Another is to track where graduates end up working and to see if they actually stay based on publicly available career data (e.g., from CVs).

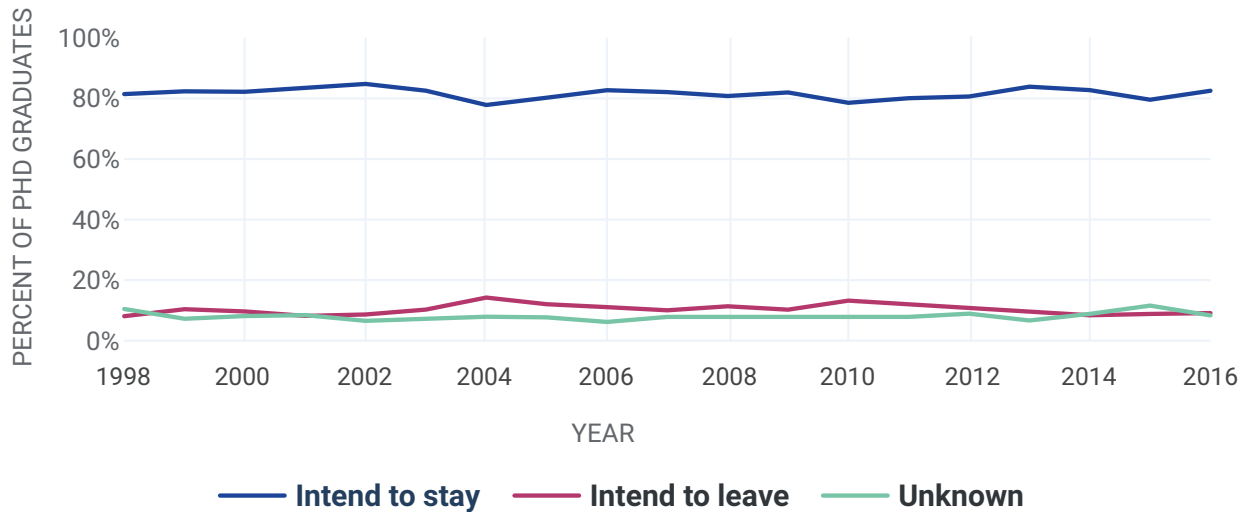
Both measures have advantages and disadvantages. One advantage of using CV data is that it provides reliable longitudinal data on the same individual. Intention-to-stay data, on the other hand, has the advantage of reflecting students’ underlying preferences more closely than their behavior does (which reflects legal restrictions as well as their preferences). Intentions are also prospective, while stay behavior is historical and thus a lagging indicator of changes in retention trends. This report therefore presents data on both measures.

Looking first at data on intentions, **the vast majority of international PhD students want to stay.*** This finding is consistent across different data sources. In a survey by the National Science Foundation (NSF) of CS PhD graduates, roughly 75 percent said they intend to stay (Figure 3a). A survey by the Computing Research

*No data source that we know of tracks stay rates among master’s students, so we report results specific to PhD students in this report. In Chapter 3, we recommend that the National Science Foundation fill this informational gap by launching a survey of graduating master’s students similar to the survey it runs of graduating PhD students.

FIGURE 3A

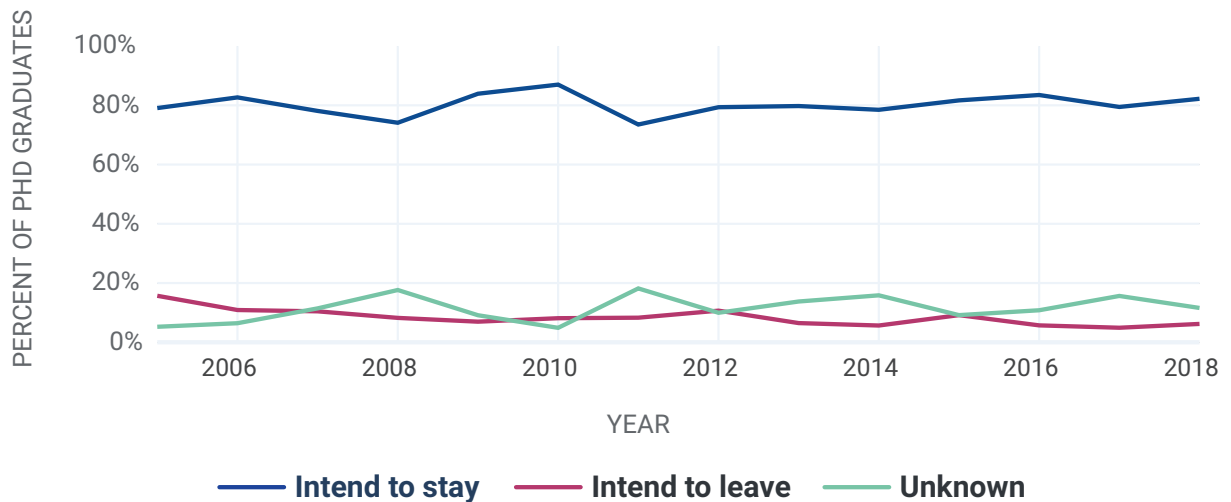
Percentage of international CS PhD students intending to stay in the United States after graduating, 1998-2016.



Source: NSF Survey of Earned Doctorates (see Appendix A).

FIGURE 3B

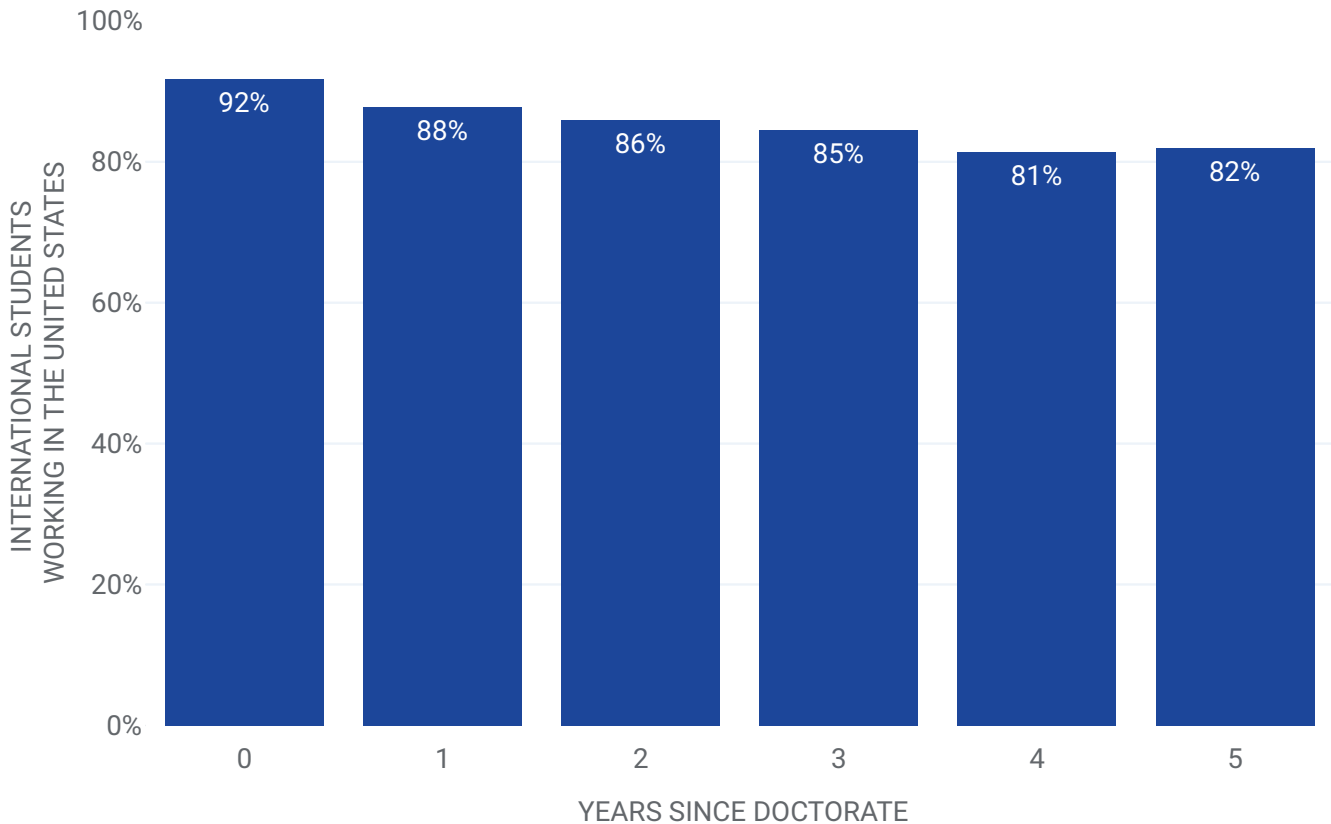
Percentage of international AI PhD students intending to stay in the United States after graduating, 2005-2018.



Source: CRA Taulbee Survey (see Appendix A).

FIGURE 4

Percentage of top international U.S. AI PhD graduates still in the United States, by years since graduation.



Source: CSET U.S. AI PhD Career Data (see Appendix A).

Association (CRA), which collects information on students' subfields and thus allows us to look specifically at doctoral graduates doing AI research, also finds intention-to-stay rates around 80 percent (Figure 3b). About half of the remaining students surveyed by NSF and CRA had not yet made up their mind about post-graduation plans when asked (around 10 percent of total), while the other half intended to leave the United States (also around 10 percent of total).

To study stay rates, CSET also undertook a months-long data collection effort on the pre- and post-PhD educational and professional histories of 1,999 PhDs who completed an AI-related dissertation at a U.S. university ranked in the top 20 nationally for AI between 2014 and 2019 (described in more detail in Appendix A). Looking at this group, there are also **very high stay rates when it comes to actual behavior**, with more than 90 percent staying in the United States initially and more than 80 percent remaining in the United States five years after graduating (Figure 4).

While CSET's AI-specific data cannot speak to retention beyond a five-year period, prior research on PhD stay rates more broadly suggests that if graduates stay for five years, they are also very likely to stay for a much longer period. For example, Michael Finn at the Department of Energy, who has studied retention for years, finds that a large majority of attrition has historically happened in the first few years after graduating; while 30 percent of all international PhD students leave within two years, in the subsequent ten years only another 10 percent leave.¹⁸ Other studies confirm this.¹⁹ For example, a survey by Nature finds that younger researchers are more open to moving "because their career paths were not settled and they were less likely to be tied down by relationships and families."²⁰

BOX 2

Have stay rates been declining recently?

Experts and media outlets have claimed that an increasing number of international AI graduates are leaving the United States, especially Chinese students due to recent tensions and a booming domestic tech sector and Indian students due to the incredibly long green card queues.²¹

However, the multiple datasets examined in this report show no evidence of downward retention trends in either the overall PhD graduate population or for these specific countries of origin. For example, neither NSF or CRA surveys on intention-to-stay data (Figure 3) nor CSET-collected career data broken down by graduation cohort (Figure 5) show any signs of recent decline. And NSF data shows that there aren't notable differences in retention trends across students from different countries (Figure 6).

Still, we do not interpret our findings as entirely disproving claims about declining stay rates. First, there is good retention data only on PhD students, and it could be that stay rate patterns among bachelor's or master's students are different. Second, most data sources lag by one or two years, while many of the events cited as decreasing students' desire or ability to stay—such as rising feelings of discrimination among Chinese students and perceived upticks in visa processing times, denials, and cancellations—have occurred recently.²²

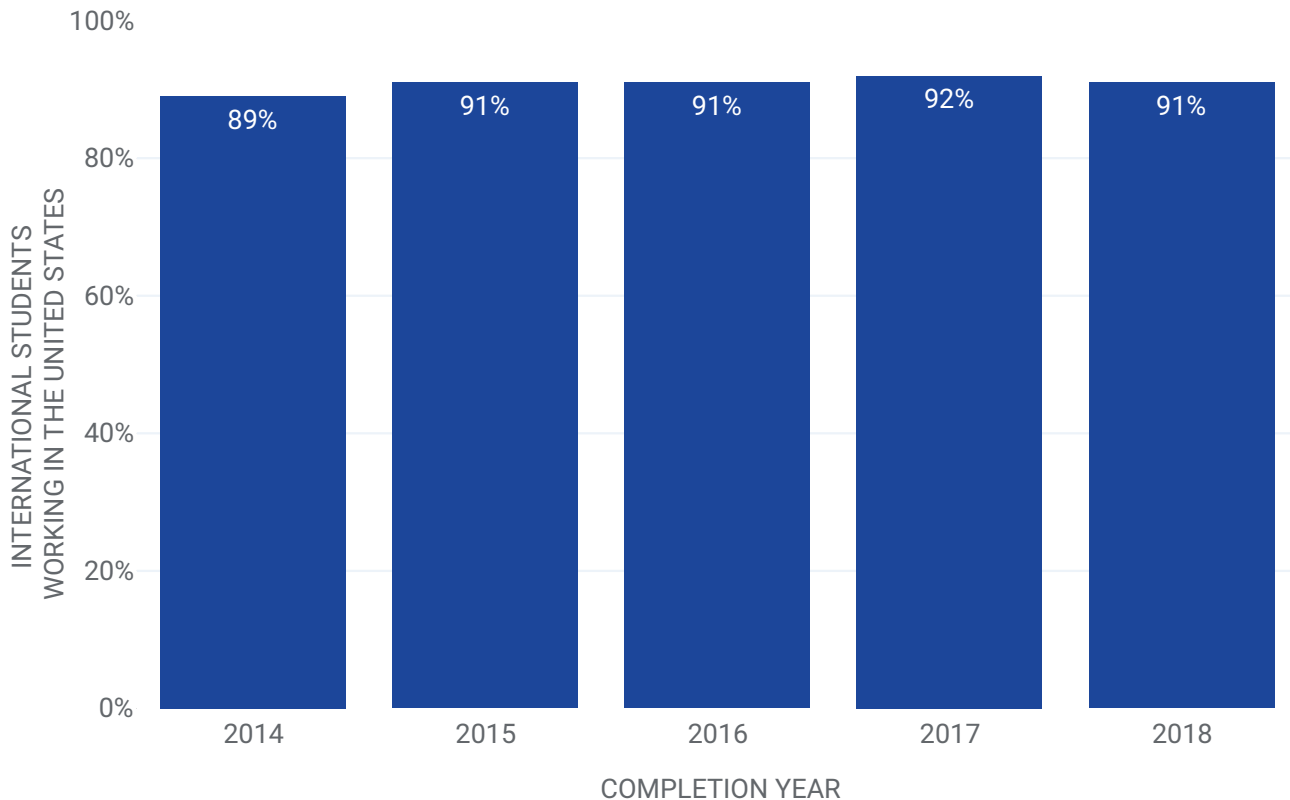
Third, it could be that the same percentage of graduates stay in the United States immediately after graduation but that the *duration* of (intended) stay is declining

BOX 2 CONTINUED

for recent cohorts, which would not show up in the data for a while.²³ For example, while it is possible to know what the five-year stay rate for the 2013 cohort is, we won't know that stay rate for the 2018 cohort is until 2023. Given how fast the field of AI is changing, it's important to be cautious about extrapolating past trends into the future.

FIGURE 5

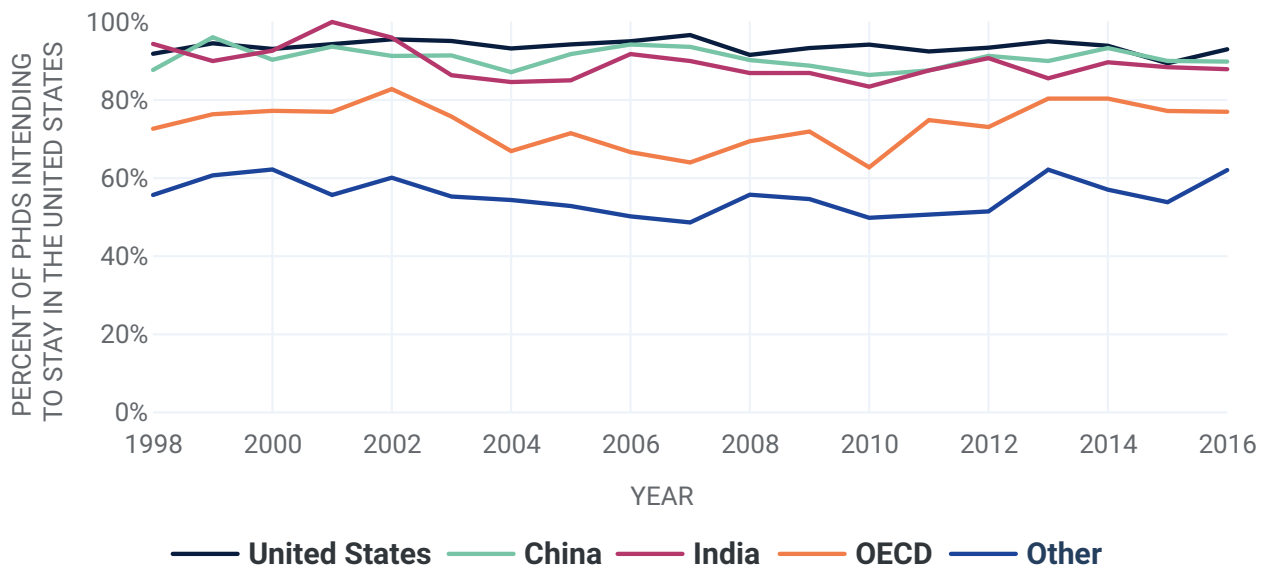
Percentage of international AI PhD students who remain in the United States directly after graduating, by year of graduation.



Source: CSET U.S. AI PhD Career Data (see Appendix A).

FIGURE 6

Percentage of CS PhD students intending to stay in the United States after graduating by nationality, 1998-2016.



Source: NSF Survey of Earned Doctorates (see Appendix A).

WHO STAYS AND WHO LEAVES?

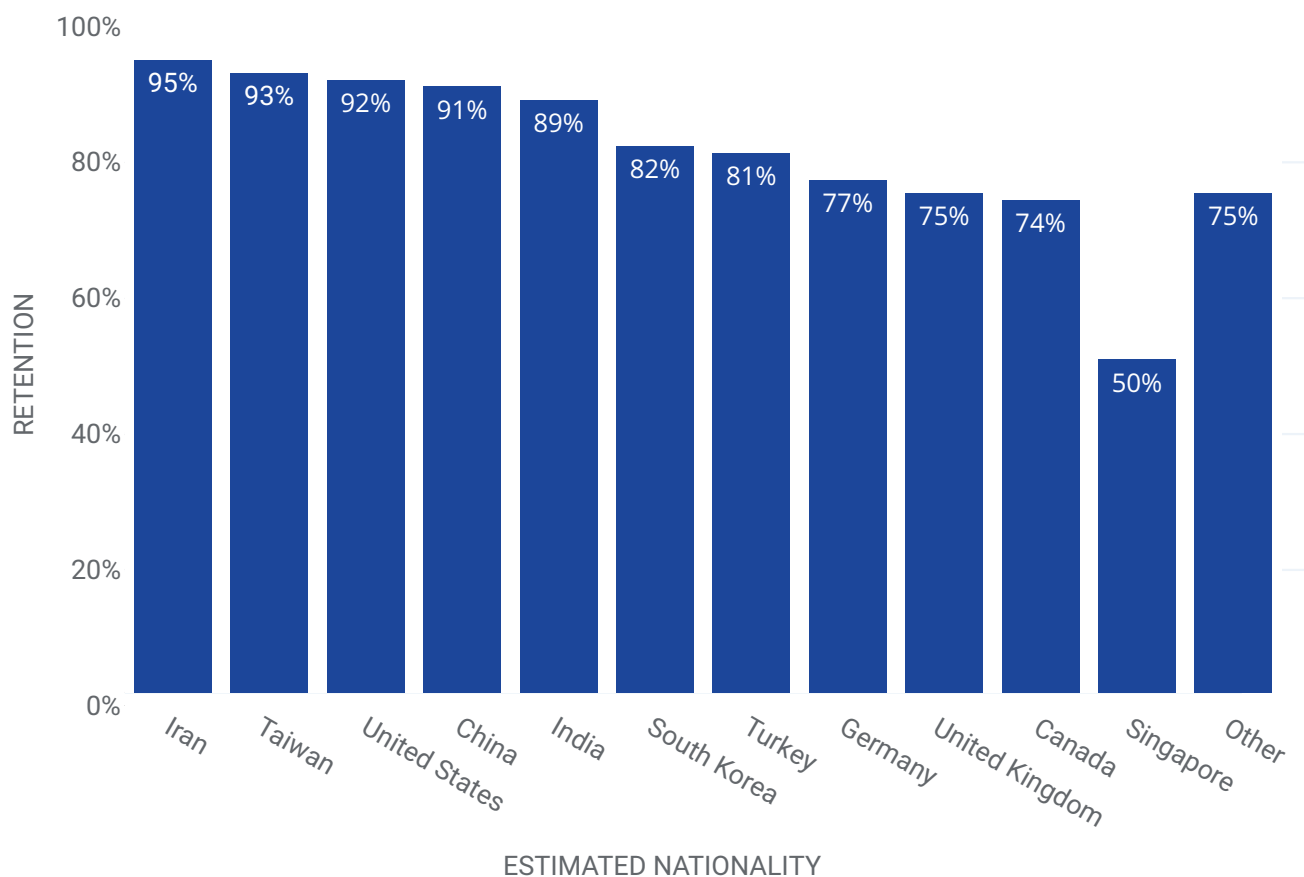
One of the most consistent predictors of a student's decision to stay or leave is their country of origin. As Figure 6 shows, there are a lot of differences across nationality in how many students want to stay. The highest intention-to-stay rates are among Chinese and Indian students, with lower rates among citizens of highly developed Organization for Economic Cooperation and Development (OECD) member countries. Unsurprisingly, U.S. citizens also tend to remain in the United States at very high rates, but there have been years when more Indians than Americans intended to stay in the country.

This same cross-country stay rate pattern is also reflected in CSET's top U.S.-trained AI PhD career history data, where we estimate a student's nationality by the county where they did their undergraduate studies (Figure 7).²⁴ For example, more than 90 percent of Indian and Iranian students are still in the United States five years after obtaining their PhD, compared to around 75 percent for many European countries.

Interestingly, there are lower stay rates among students from traditional U.S. allies than among students from countries with which the United States has less friendly relations. The most common explanation for this pattern is wealth: as countries become richer, they tend to have more professional opportunities and higher

FIGURE 7

Percentage of top AI PhD students still in the United States five years after graduating, by country of undergraduate degree.



Source: CSET U.S. AI PhD Career Data (see Appendix A).

quality of life, and so they will see more top talent returning home. From the perspective of the United States losing valuable talent, then, its allies have been a much more persistent challenge than potential adversaries (as is underscored in Figure 9).

Past research has also identified other factors that predict leaving. For example, older international students or those who receive home government funding tend to return at much greater rates.²⁵ Studies of other fields such as economics indicate that the highest-quality international students generally have the highest likelihood of remaining in the United States,²⁶ but there is no evidence available on whether this is also true for AI.

WHY STAY OR LEAVE?

Unfortunately, no systematic data addresses the “why” question for the AI-relevant graduate student population specifically.²⁷ However, research on other fields points to factors that affect whether international graduate students—among the

most mobile migrant populations in the world—decide to stay in their country of education. The most important factors are professional opportunities, immigration rules, and personal and cultural considerations.²⁸ (Appendix C contains a more in-depth review of evidence on return decisions among Chinese and Indian graduates.)

Professional opportunities. Several types of evidence point to professional considerations as being decisive for many graduate students. For example:

- Job opportunities and the ability to stay and work after graduation are often among the main reasons that students decide to study abroad in the first place.²⁹ When the U.K. closed its “post-study work route” immigration category in 2010, international student applications fell by an unprecedented 30 percent.³⁰
- Historically, return rates have increased when domestic labor markets improve.³¹ For example, return rates among Taiwanese and South Korean graduates rose sharply after their home countries underwent rapid industrialization in the 1980s³² but briefly fell again during the financial crises of the 1990s.³³
- In surveys, most graduating students cite career prospects as their main reason for staying.³⁴ This pattern also holds for more senior migrants; for example, a plurality of international scientists who initially stayed abroad after obtaining their PhD report “job opportunities” as the main determinant of whether they’ll eventually return to their home country.³⁵

Immigration rules. Immigration restrictions, including those that do not bar graduates from staying outright, have also been found to reduce stay rates³⁶:

- In interviews and surveys, one of the most common reasons graduates cite for not attempting to stay in the United States is “uncertainties about obtaining green cards following graduation.”³⁷ Even if graduates can find ways to stay in the short term, long-term uncertainty and unpredictability are strong deterrents.³⁸
- Due to numerical caps in the U.S. system, students from certain countries, especially India and China, face years- or even (for Indians) decades-long waitlists for permanent residency (see Chapter 2). One study estimates that the number of Indian and Chinese graduates staying in the United States drops by several percentage points for each year of extra delay due to green card waitlists.³⁹ Another study focused specifically on Indian high-skill immigrants found 94 percent concerned about green card wait times and 70 percent actively considering emigrating to a more visa-friendly country.⁴⁰

- Restrictions on the type of work international graduates are allowed to do also affects stay rates. For example, the lack of a U.S. visa category for those wishing to start their own business has driven away many graduates with entrepreneurial ambitions.⁴¹ Lack of work authorization for spouses can have similar effects.⁴²

Personal and cultural considerations. Personal and cultural considerations often both pull students back to their home country and push them away from their host country:

- Social ties are important pull factors; family is usually an especially important consideration.⁴³ Research finds that “professional factors were generally cited as encouraging students to stay in the United States, while societal and personal factors were more likely to draw them back to their home countries.”⁴⁴
- Social and cultural concerns can also serve as push factors. In one recent survey, roughly 60 percent of international STEM graduate students report experiencing cultural and/or social challenges.⁴⁵ Amid geopolitical tensions and security measures, many international students, especially from China and Iran, have felt less welcome in the United States due to a sense of discrimination.⁴⁶

In summary, an accommodating immigration system is a necessary but not a sufficient reason for students to remain in the United States, with professional reasons typically being decisive in motivating people to stay. Even when immigration barriers are absent, people may still leave for professional or personal reasons. For example, in one survey of 1,203 Indian and Chinese returnees, around 25 percent of Indian and 35 percent of Chinese respondents held either permanent residency or citizenship in the United States at the time of their departure.⁴⁷

WHAT DO GRADUATES DO IF THEY STAY?

Because professional considerations play such a large role in graduates’ decisions about whether to stay or leave, it is useful to understand their career choices in more detail. Looking at data on career trajectories can also uncover evidence of immigration rules’ labor-displacing effects and help assess the security risks that departing students pose to the United States, topics discussed in more detail in Chapters 2 and 3.

After graduating, doctorate holders could go on to work in the private sector, academia, nonprofits, or the public sector. Based on CSET-collected data, the private sector is the most popular sector among top AI PhD graduates who stay in

TABLE 2

Sector of first post-graduation job among U.S. AI PhD graduates staying in the United States, by year of graduation.

| | 2014 | 2015 | 2016 | 2017 | 2018 | TOTAL |
|--------------------------|-----------|-----------|-----------|-----------|-----------|-------------|
| Academic | 95 (41%) | 100 (36%) | 123 (35%) | 126 (30%) | 163 (33%) | 607 (34%) |
| Government/ Nonprofit | 16 (7%) | 11 (4%) | 24 (7%) | 28 (7%) | 23 (5%) | 102 (6%) |
| Private Sector | 123 (53%) | 168 (60%) | 204 (57%) | 260 (63%) | 305 (62%) | 1,060 (60%) |
| Total | 234 | 279 | 351 | 414 | 491 | 1,769 |

Source: CSET U.S. AI PhD Career Data (see Appendix A).

Note: Percentages may not add up to 100 due to rounding.

the United States (with 60 percent of graduates taking a job there), followed by academia (about 35 percent), with public sector and nonprofit roles far behind (5 percent combined). There do not appear to be any changes in the relative popularity of the different sectors in the past five years (Table 2).

Of course, not everyone stays in their first job, or even in the same sector. Looking at where graduates work four years after obtaining their degrees—data available only for the 2014 and 2015 graduating cohorts—nearly 20 percent have switched sectors. Of the graduates who start in government or nonprofit jobs, nearly 75 percent leave for either industry or academia within four years. Around 20 percent of the graduates who started off in academia moved to the private sector, and 10 percent of those who started off in private sector traveled the opposite path.⁴⁸

WHAT DO GRADUATES DO IF THEY LEAVE?

While a large majority of U.S.-trained AI PhDs stay in the United States, 205 students (out of the 1,881 for which CSET has complete career data) left the country after graduating. These graduates face two important choices. Like those who stay, they have to decide what kind of job to take. But since they are in demand across the world, they also have to decide on the place where they pursue that path.

Europe and Asia are the most popular destinations for those who leave, with the United Kingdom and China taking the top spots (Figure 9). In total, about 39 percent go to Europe (18 percent to the United Kingdom, 7 percent to Germany, 4 percent to Switzerland, and 10 percent to other European countries), and about

BOX 3

How does U.S. immigration policy affect career choices?

The choice of career path, like the choice of whether or not to stay in the United States, can also be affected by immigration rules.

In government, where technical workforce shortages are large, the fact that international students' path to citizenship often takes more than a decade means they cannot fill jobs with security clearance requirements. Since many interesting technical jobs have such requirements, international students are generally thought to be much more likely than domestic students to eschew government careers.

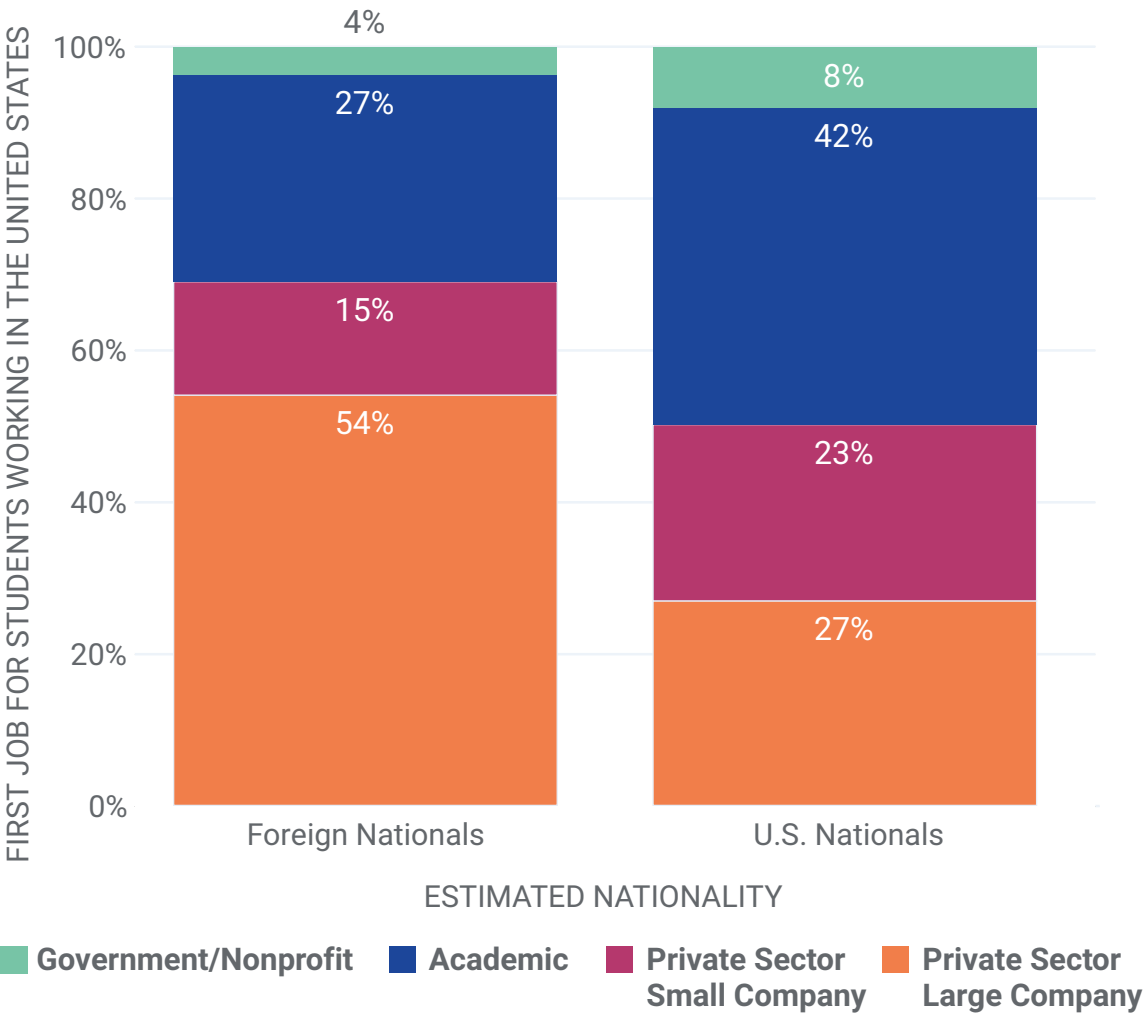
In academia, universities are exempt from numerical caps on H-1B visas and are therefore able to sponsor more international students for employment. Some studies suggest that this makes international students more likely to "settle" for academia, even if they might prefer to work in a different sector.⁴⁹

In the private sector, there are two ways in which immigration rules can steer international students toward large firms. First, the cost of sponsorship to employers—in both time and money—means that startups and small businesses are much less likely to sponsor work visas than large firms. Because smaller companies often have more urgent hiring needs, long and uncertain application timelines for visas also mean that sponsorship is generally off the table even for those willing to incur these costs.⁵⁰ Second, the lack of a dedicated visa category for entrepreneurs means it is much riskier for international students to start their own companies. A recent study of entrepreneurial intentions and outcomes among STEM PhDs finds that international students are twice as likely to want to start companies (21 percent, versus 10 percent for domestic students) but are less likely to actually do so (4.6 percent, versus 6.3 percent for domestic students).⁵¹

In CSET data on the career choices of AI PhD graduates who remain in the United States, the differences between domestic and international students are consistent with some of these arguments about immigration rules' effect on career choice and inconsistent with others. Most strikingly, far fewer foreign nationals work for or founded startups even though more foreign nationals go into the private sector. This suggests the U.S. immigration system is harming AI startups.⁵² However, there is no evidence that foreign graduates are more likely to "settle" for academia (Figure 8).

FIGURE 8

Sector of first job among AI PhD graduates who stay in the United States, across domestic and international students



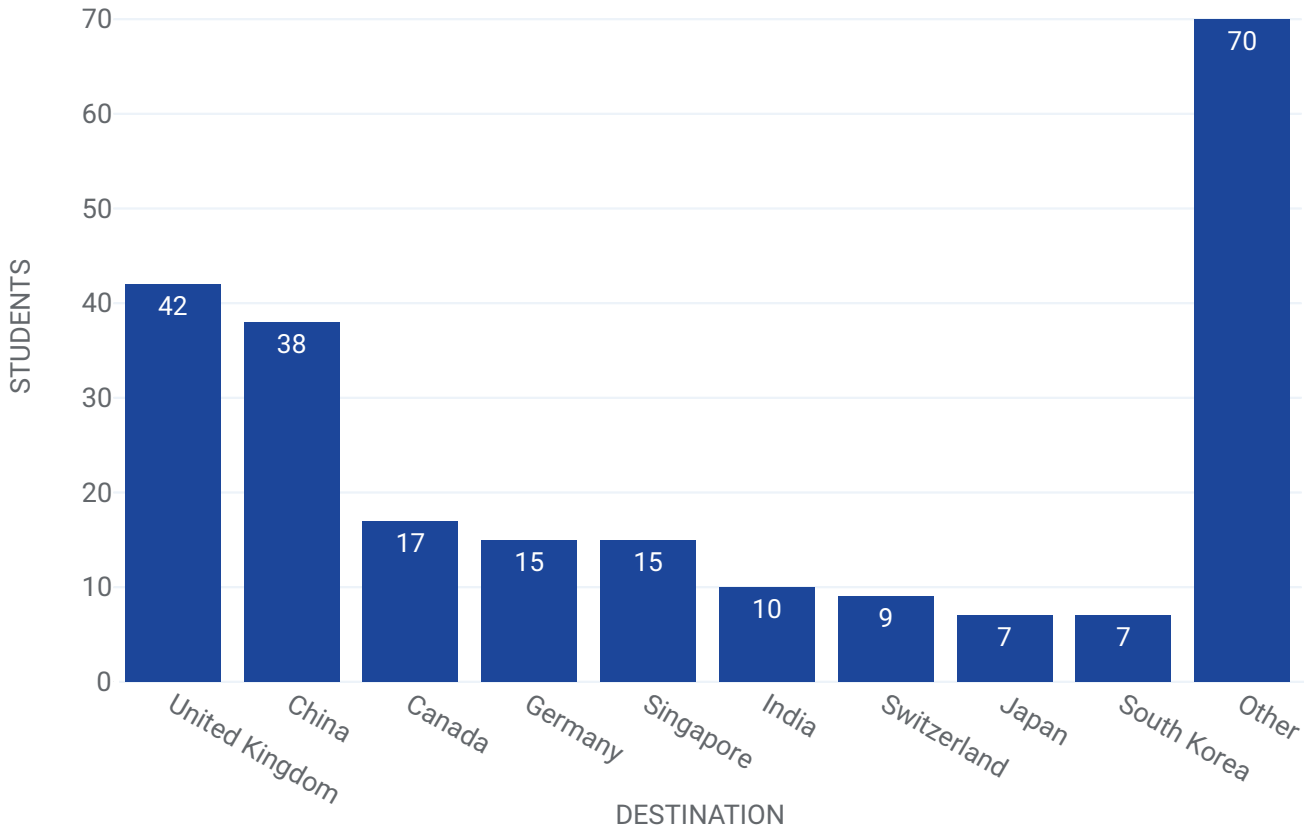
Source: CSET U.S. AI PhD Career Data (see Appendix A).

38 percent to Asia (17 percent to China, 7 percent to Singapore, 4 percent to India, 3 percent each to South Korea and Japan, and 4 percent to other Asian countries). Canada is another popular destination, attracting 7 percent of those who leave.

Past studies of international students who leave the United States generally find that most of them return to their home countries,⁵³ and this appears to be true in the field of AI as well. For example, in the CSET dataset, out of those who did their undergraduate education in China and left the United States after their PhD, 27 out of 38 return to China (with the others mainly going to the United Kingdom and Switzerland). Western countries attract more international talent than others. Only five of the 17 who left for Canada, for instance, got their undergraduate degree in Canada.

FIGURE 9

Destination countries among the 230 AI PhD students who leave the United States at any point after graduating (out of 1,999 total).



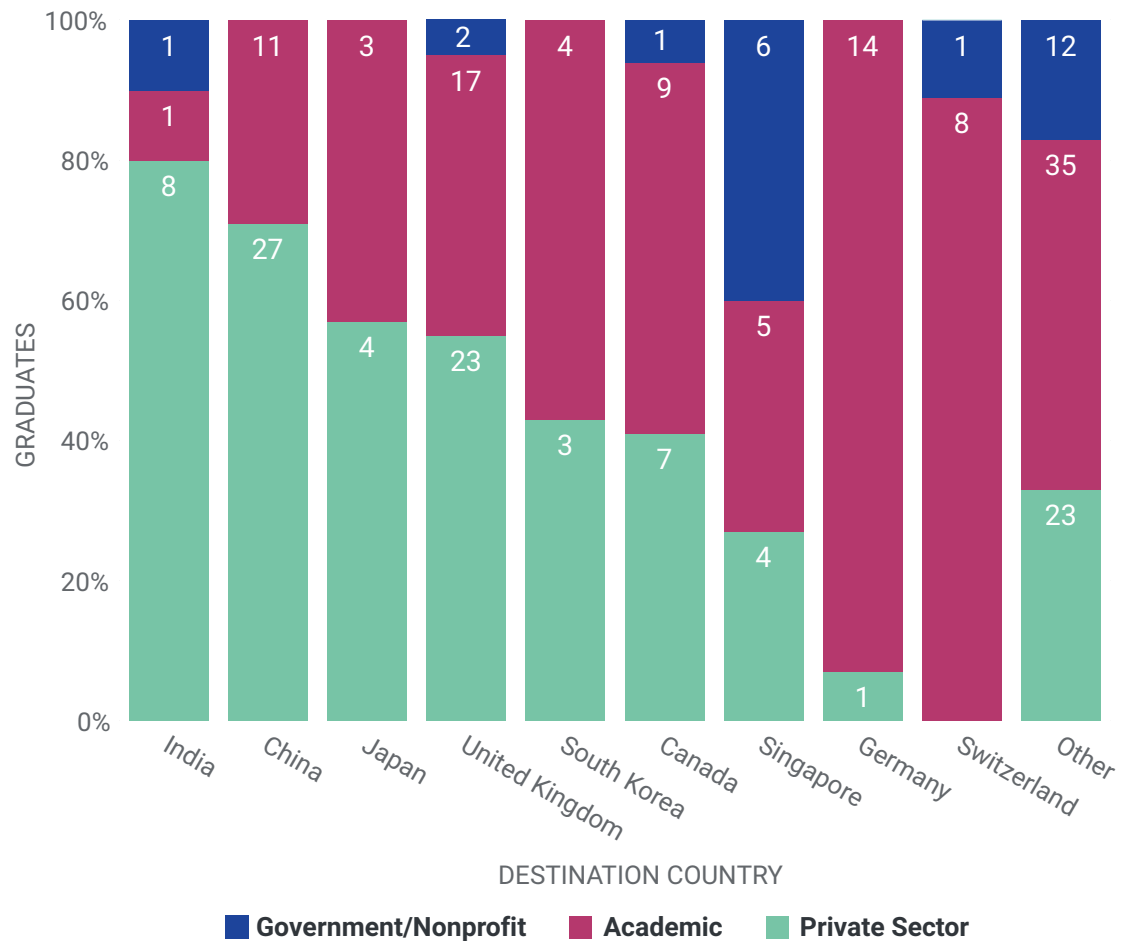
Source: CSET U.S. AI PhD Career Data (see Appendix A).

Departing graduates make somewhat different career choices than those who stay. Whereas 60 percent of those who stayed in the United States went into industry, only 43 percent of those who left did. Academic jobs are more common among those who leave, with 47 percent going to work at a university (compared to 35 percent of those who stay). Government and nonprofit jobs are slightly more common among those who leave, with 10 percent working in those sectors (compared to 5 percent of those who stay).

What sector graduates take jobs in varies depending on the country they move to. Graduates who leave for the India, for instance, tend to work in the private sector at much higher rates (8 out of 10) than graduates who leave for Germany (1 out of 15) (Figure 10). More research is needed to understand this variation.⁵⁴

FIGURE 10

Sector of first job among U.S. AI PhD graduates who left the United States, by destination country.



Source: CSET U.S. AI PhD Career Data (see Appendix A).

SUMMARY OF FINDINGS AND TAKEAWAYS

- International students make up a majority of students in AI-related graduate programs.** About two thirds of graduate students in computer science and electrical engineering are international students (Figure 1 and Table 1). At the PhD level, roughly 30 percent of international students come from China, 15 percent from India, 10 percent from OECD countries, and the remaining 45 percent from other countries (Figure 2).
- International graduates overwhelmingly want to stay in the United States, primarily for professional reasons.** More than 80 percent of students in AI-related fields want to and do stay after graduating (Figures 3-5).

This reflects the historical dominance of the United States in science and technology; survey evidence shows that job opportunities and other professional factors are the main reasons graduates want to stay, and retention rates are generally higher for graduates from developing countries such as India and China (Figures 6-7).

- **Immigration difficulties are an important reason for graduates to leave.** Students who want to stay face uncertainty and long waits in their immigration process, and surveys indicate that this makes many graduates less likely to stay. Immigration rules also affect the type of jobs open to students; data on graduates' career choices suggest that U.S. immigration rules prevent international students with entrepreneurial ambitions from working for startups or starting their own companies (Figure 8).
- **When graduates leave, they primarily go to U.S. allies and partners.** China is the second most common destination country among those who leave (17 percent), but a large majority go to countries whose relations with the United States are much more friendly, such as the United Kingdom, Canada, or South Korea (Figure 9). In some countries, such as the India, those who leave primarily go on to work in the private sector, whereas in others, such as Germany, they primarily work in academia (Figure 10).

Of the factors affecting graduates' choice of whether to stay or leave, immigration policy is the factor most directly under the control of U.S. policymakers, which is why Chapters 2 and 3 focus on immigration policy.

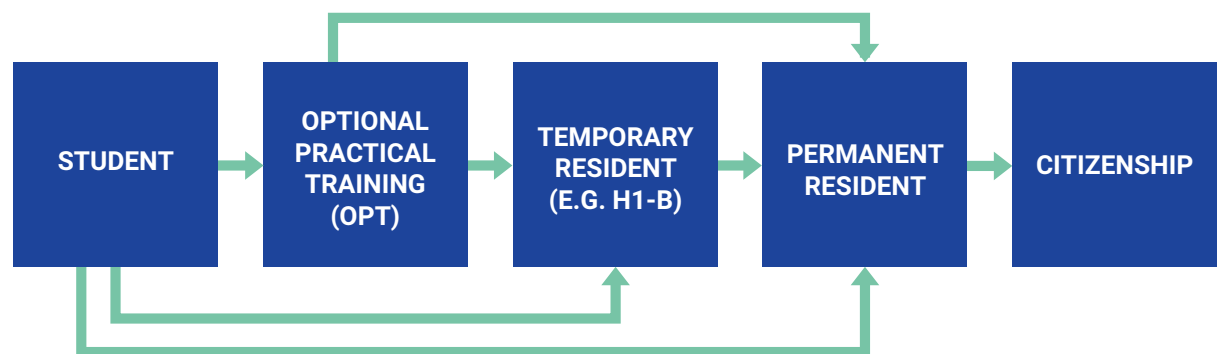
Other factors, even if they are not as easy for U.S. policymakers to control, serve as an important backdrop for policymaking—and this backdrop is largely bad news for the United States. As Chapter 2 discusses, the United States is losing its status as the world's sole science and technology superpower, with other countries making both large science and technology (S&T) investments and liberalizing their high-skill immigration systems to attract S&T talent. Given that professional considerations have been the main reason for most international graduates to stay, these reforms could draw talent away from the United States. This makes action in immigration and other areas U.S. policymakers can control all the more important.

2 The Policy Context

Chapter 1 showed that the vast majority of graduate students in AI want to—and do—stay in the United States, but that some are denied this opportunity due to problems with the U.S. immigration system. To set the stage for policy recommendations in Chapter 3, this chapter first outlines the immigration process graduate students have to go through to stay and provides numerical estimates for the size of the international student population in different parts of the U.S. immigration system. Second, it discusses recent policy reforms and trends in both allied and competitor countries that have been laying the foundations for increased AI talent competition with the United States.

FIGURE 11

Immigration pathways available to international students.



Arrows represent possible transitions between different immigration steps.

DOMESTIC POLICY CONTEXT: INTERNATIONAL GRADUATE STUDENTS' IMMIGRATION PROCESS

Students who stay in the United States will typically proceed through some or all of the following steps in their immigration process: post-graduation Optional Practical Training (OPT), temporary residency (e.g., an H-1B visa), permanent residency, and finally citizenship.

Students and OPT

Students in AI-relevant fields generally come into the U.S. on **F-1 visas**.^{*} The number of F-1 visas that can be issued each year is unlimited, and F-1 students can generally stay in the U.S. for the duration of their degrees.

Graduates who were on F-1s are also entitled to up to three additional years (one year for those studying non-STEM subjects) of **Optional Practical Training (OPT)**, during which they are authorized to work full-time while retaining their F-1 status. The program is widely used but also controversial. A court challenge to OPT's legality has been pending for years, and the Trump administration in fall 2017 declared its intention—though it took no action—to roll back the program, which is regulatory rather than legislative in nature and can therefore be changed or eliminated through executive action alone.⁵⁵ Changes to OPT were re-added to the administration's fall 2019 regulatory agenda.⁵⁶

After studying or OPT, graduates can try to get either temporary residency on a non-immigrant work visa or jump directly into permanent residency ("green card" status), depending on an employer's willingness to sponsor and the availability of green card slots (discussed below).

Temporary residency

Graduates can get temporary work authorization if an employer sponsors them for a "non-immigrant" employment visa (so-called because "immigrant" technically means someone who intends to reside in a new country permanently, not temporarily).

The most commonly used temporary work visa is the **H-1B visa**. H-1B visas are typically valid for three years and can be renewed for another three years once, with additional indefinite one-year extensions for individuals who are in the green card queue. The annual number of new H-1B issuances is capped at 85,000, though universities and many nonprofits are exempt from this cap. Because

^{*}This paper uses the term "visa" colloquially to describe a legal right to be physically present in the United States or a document conferring that right. Legally speaking, a visa is a document allowing a noncitizen to travel to a port of entry to seek admission to the United States. The separate right to be present in the United States is often referred to as "legal status" or just "status." See "Student Visa vs. Student Status: What is the Difference?," Department of Homeland Security, <https://studyinthestates.dhs.gov/2016/01/student-visa-vs-student-status-what-is-the-difference>.

the number of applications usually far exceeds the number of available slots, U.S. Citizenship and Immigration Services (USCIS) runs a once-yearly lottery to select awardees. Less than half of eligible applicants have been able to get an H-1B visa in recent years.⁵⁷

Many other non-immigrant employment visas exist. They are not widely used by international graduates specifically and are thus not discussed here, even though some of them, like L-1 and J-1 visas, are important to the AI workforce more generally.⁵⁸

Permanent residency

Employers can also sponsor graduates for permanent residency (also known as “green card” status), either while they are still students (on an F-1 visa) or while they have a dedicated work visa (most commonly on an H-1B visa).

Relevant employment-based permanent residency categories include **EB-1** (for those with “extraordinary ability” or “outstanding professors and researchers”), **EB-2** (for those with “exceptional ability,” most commonly used by those with graduate degrees), and **EB-3** (college graduates). Since this paper is mainly focused on graduate students, the EB-2 category is the most relevant of the three (though graduate students are generally also able to apply for EB-3 visas).

About 80,000 slots are available for EB-2 and EB-3 applicants each year, allocated on a first-come-first-served basis. Spouses and children of green card holders count toward this cap, so the annual number of slots for workers is significantly lower (typically less than half of the total number of available slots).⁵⁹ There are also caps on what proportion of green cards can go to people born in a given country in a single year.

People from India and China face significant backlogs and delays because there are so many employment-based applicants from those countries. For example, one study projects the time spent in the “green card queue” for new EB-2 applicants from China is six years; for Indians, that number is a staggering 54 years.⁶⁰ It is difficult for employees to get promoted or to switch companies while in this queue, which means these large backlogs can carry significant professional costs for prospective immigrants from these countries.⁶¹ (After getting a green card, changing jobs or employers no longer requires approval from immigration agencies.)

Citizenship

Permanent residents can generally apply for U.S. citizenship after five years on an employment-based green card. This step is, for practical purposes, optional; some permanent residents do not apply for citizenship and instead stay in the United States by renewing their green card every ten years. From an employment perspective, the main difference between permanent residency and citizenship is that citizenship is required for many government- or defense-related jobs.⁶²

BOX 4

Graduates' U.S. immigration pathways, by the numbers.

The public picture of the immigration pipeline is incomplete due to lack of accessible data. However, by piecing together information from different data sources, it is still possible to assess the approximate number of AI-relevant international graduates entering the U.S. immigration system each year and which status categories are most important to them (Table 3). When combined with estimates of how much AI talent there is in the U.S. immigration system as a whole, as outlined in the CSET report *Immigration Policy and the U.S. AI Sector*, these findings suggest that former international students make up well over half of all foreign-born workers entering the U.S. AI labor market each year.⁶³

TABLE 3

Annual number of AI-relevant international graduates from U.S. universities entering into OPT, H-1B status, or permanent residency.

| | TOTAL NUMBER OF ENTRANTS IN FY2017 | PERCENT WHO WERE INTERNATIONAL STUDENTS | PERCENT WHO HELD GRADUATE DEGREES | PERCENT WHO HELD AI-RELATED DEGREE |
|-------------------------|------------------------------------|---|-----------------------------------|------------------------------------|
| OPT ⁶⁴ | ~270,000 | 100% | ~70% | ~50% |
| H-1B | ~125,000 | 55% ⁶⁵ | 54% ⁶⁶ | >35% ⁶⁷ |
| EB(-2/-3) ⁶⁸ | ~80,000 | 42% | 90% | 49% |

OPT. The most notable recent visa-related trend among international students has been the very rapid rise in the use of OPT. For example, between 2014 and 2017 the number of students granted OPT per year increased from 133,000 to 276,500.⁶⁹ Data obtained by Pew Research Center through a Freedom of Information Act request indicates that among graduate students, who account for over two thirds of all OPT grantees, roughly half of those on OPT hold AI-relevant degrees (CS or engineering).⁷⁰

H-1B. Little is known about how many and what kinds of international graduates are on H-1B visas due to a lack of publicly available data. However, it is clear that international graduates are an increasingly important source of H-1B entrants. Roughly 50,000 students transitioned from F-1 to H-1B status in 2018, and between 2012 and 2018 international students went from accounting for less than a quarter of H-1B entrants to accounting for more than half.⁷¹ It seems likely that a majority of students granted H-1B status hold AI-relevant degrees given that nearly three quarters of H-1B holders work

BOX 4 CONTINUED

in computing-related jobs,⁷² though we have not been able to find data on degree fields among H-1B applicants.

Permanent residency. Labor certification (PERM) data released by the Department of Labor provides a somewhat detailed picture of permanent residency applicants.⁷³ Based on this data, from 2015 to 2018, roughly 42 percent of workers sponsored for permanent residency had studied at U.S. universities, among whom 90 percent held graduate degrees and 49 percent had studied in AI-relevant fields (CS or EE). Because PERM data contains professional information, it is possible to zoom in on green card applicants whose job title and employer indicate that they could do specifically AI-related work (see Appendix A). From 2015 to 2018, there were about 26,000 green card applicants who met these criteria, of whom a large majority (71 percent) had previously studied at U.S. universities. Their most common countries of origin were India (47 percent), China (24 percent), and Canada (6 percent).

We do not have data on post-permanent-residency naturalization rates among AI-relevant graduates. One study finds that roughly 30 percent of all international doctoral graduates in the United States naturalize within 12 years of graduating.⁷⁴ However, many PhD fields have stay rates considerably lower than those in computer science and engineering, so we expect AI-relevant naturalization rates to be higher than this overall naturalization rate.

The policies and data reviewed point to several immigration challenges for international graduates. First, **large and growing bottlenecks in the immigration pipeline harm international AI graduates' prospects.** Bottlenecks have grown because the number of international students—and the number of other immigrants competing for the same spots—has steadily risen while the numerical caps on the number of available H-1Bs and green cards have not changed for decades. The result is that AI graduates face significant uncertainty about whether short-term or long-term immigration is possible at all, and even those who do manage to get through the system face long and costly wait periods. Large queues, processing backlogs, and uncertainty have been a problem for a while, but all have notably increased in recent years.⁷⁵

Second, **rollbacks to OPT would be catastrophic for international AI graduates.** While H-1B visas often dominate many immigration conversations, OPT—largely due to bottlenecks further down the immigration pipeline—has be-

come perhaps even more essential for (initial) graduate retention, with tens of thousands of AI graduates utilizing the program each year. If current legal and policy challenges to OPT were to succeed and no compensating reforms enacted, these graduates would likely have to leave the United States.

Third, **the employer-driven and inflexible nature of the U.S. immigration system places serious constraints on international AI graduates.** For example, none of the immigration programs open to graduates are designed for entrepreneurs, and time- and funding-constrained startups often cannot bear the costs of visa sponsorship. Moreover, because graduates are generally bound to the employers that sponsor them, they can face significant difficulties switching jobs or getting promoted. These features of the system make the United States significantly less attractive as a place for ambitious AI graduates.

INTERNATIONAL POLICY CONTEXT: INCREASED COMPETITION FOR TALENT

When international U.S. graduates decide where to work after graduation, they think not only about whether they are able to stay in the United States but also about how attractive their alternatives are. It is therefore useful to briefly examine other countries' policies and reforms aimed at attracting AI talent.

First, "receiving countries" that take in a large number of international students are important talent competitors for the United States. These countries can also provide lessons learned and models for policy change, for example in immigration policy. Second, a small number of "sending countries" produce most international students. These countries' policies, such as whether and how they incentivize post-graduation return, affect the United States' ability to recruit and retain students.

Receiving countries. After the United States, which had 1,094,792 international students in 2018, the top receiving countries are the United Kingdom (506,480), China (489,200), Australia (371,885), and Canada (370,710).⁷⁶ Most of these countries have a dedicated pathway for top students to become permanent residents that they are actively strengthening and promoting. Many countries have also launched programs to attract tech talent more generally, programs for which U.S. graduates are eligible and a prominent recruitment target. These receiving country efforts are discussed in more detail in Appendix B.

Sending countries. The top sending countries for international students, both in general and in AI-relevant fields, are China and India. Two trends contribute to an increase in the attractiveness of returning home after studying abroad. First, many sending countries are becoming more professionally and personally attractive due to their economic development (e.g., more robust domestic tech ecosystems, high-

“

The view from China: “Talent is an important factor for the future development of AI. Currently, the US remains the world’s gathering place for research talent, but the strength of Chinese people in the fields of AI research and applications, together with the Trump administration’s immigration policies, have provided China opportunities to bolster its ranks of high-end talent.”

—CCID, state-run Chinese consulting firm, CSET translation of “White Paper on Chinese Cities’ Development of Artificial Intelligence” (2018)⁷⁷

er quality of life). Second, sending-country governments are increasingly offering incentives to attract returnees (e.g., start-up subsidies, tax breaks, and scientific funding),⁷⁸ although experts have questioned the effectiveness of these programs, for example China’s Thousand Talents program. Appendix C discusses these points and the relevant evidence in more detail.

The broader lens through which to look at policy developments in these other countries is the globalization of science, R&D, and innovation. As noted in Chapter 1, career considerations tend to be the most important factor shaping the migration choices of high-skilled STEM talent. This means that welcoming immigration policies will not work without attractive professional ecosystems, and that attractive professional ecosystems can to some extent compensate for bad immigration policies.

For top technical talent, the United States’ status as the sole global S&T superpower was historically attractive enough to compensate for the flaws of the U.S. immigration system. Today, however, the United States is losing its S&T superpower status and facing competitors with increasingly robust private sector and academic ecosystems of their own.⁷⁹ For example, between 2013 and 2018, the United States went from accounting for more than 70 percent of funding deals for AI startups to 40 percent.⁸⁰ A recent analysis of 18 national AI strategies found that “AI talent policies” were included in every strategy.⁸¹

“

The view from Canada: “Talent is a key factor of success in the era of the Fourth Industrial Revolution. Canada’s world-class research universities already attract international STEM talent and organizations. ... As the U.S. continues to build a wall to exclude researchers from countries that it deems hostile, Canada should not only keep its doors open, but also actively attract and retain international talent seeking opportunities outside the U.S.”

— Asia Pacific Foundation of Canada (2019)⁸²

In summary, as surveys of prospective and current STEM students confirm, “the U.S. is no longer an automatic choice for obtaining the best PhD education in science and engineering,”⁸³ nor can one assume it will remain the automatic choice for top careers. The effects of these trends, if not yet apparent in retention statistics, are seen clearly in enrollment figures.⁸⁴ For example, in 2016, 14 percent of colleges had students decline admission offers because they decided to study at home, and 19 percent because they went to a third country. Two years later, in 2018, these proportions had risen to 39 percent and 59 percent.⁸⁵

3 Priorities and Options for U.S. Policymakers

Preserving the United States' leadership position in science and technology generally and AI specifically is essential for the country's economic and national security. Talent has been and will continue to be a crucial factor in that effort. From an economic perspective, more AI talent means more growth and innovation—labor market indicators point to a large talent shortage in AI, and experts are concerned that this shortage will persist and “slow the rate of diffusion of [AI] and any productivity gains that accompany it.”⁸⁶ From a security perspective, more AI talent means more people who can work toward ensuring that AI systems are effective, safe, and secure.

As explained in Chapter 1, international graduate students are a large source of AI talent for the United States, accounting for two thirds of graduates in AI-related fields. And more than 80 percent of these international graduates have historically stayed in the United States. However, Chapter 2 highlighted two trends that could erode this U.S. strengths in AI graduate student attraction and retention: increasing immigration obstacles for graduates who want to stay in the United States and increasing international competition for AI talent.

This chapter builds on these findings to offer concrete actions for policymakers to work toward two overarching priorities: first, attracting and retaining international graduate students, and second, addressing security concerns about foreign talent.

ATTRACTING AND RETAINING INTERNATIONAL GRADUATE STUDENTS

Attracting and retaining top AI graduate students can be broken down into three steps. First, students should want to come to the United States

to study. Second, they should want to remain and work in the country after graduating. Third, they should be able to obtain permanent residency so that they can stay indefinitely and have a pathway to citizenship. Policies targeting these steps will be mutually reinforcing. If long-term job prospects are good, more students will want to come study in the United States. Similarly, if students feel welcomed when they first arrive and are helped with their initial transition into the labor market, they are also more likely to want to stay long-term.

Today, U.S. immigration policies hamper both the attraction and retention of top AI talent. In a 2018 survey, more than 80 percent of universities said visa delays and denials contributed to declines in the number of international students accepting offers, up from 36 percent in 2016.⁸⁷ Moreover, students who do come face several constraints and limitations that can reduce their desire to stay and—if they decide to stay—their ability to contribute to innovation and growth.

The following policy options address these and other problems with the current U.S. system. Together, they would improve both attraction and retention and substantially increase U.S. competitiveness in the international battle for AI talent.

Reform student visa regulations and procedures

Codify the Optional Practical Training program. Available data suggest tens of thousands of graduate students with AI-relevant degrees use the F-1 visa's OPT program every year and depend on it for initial entry into the U.S. labor force (Table 3). However, OPT was created via regulation and faces serious legal and policy challenges.⁸⁸ To safeguard the status of this important part of the AI talent pipeline, Congress should codify the existence of OPT in legislation. (The codification of OPT would be unnecessary if, as discussed below, Congress were to create a statutory student-to-work pathway separate from the F-1 student visa.)

Address backlogs in F-1 and OPT processing. Significant increases in processing times of F-1 and OPT applications have forced many students to delay or entirely forego education and employment.⁸⁹ For example, in the summer of 2019, processing times for OPT employment authorization regularly exceeded the 90-day window in which students were allowed to apply for OPT, meaning they were not allowed to show up to work on their jobs' purported start date. To address these issues, USCIS could reinstate a recently rolled back internal rule mandating processing of employment authorization requests within 90 days,⁹⁰ and similar time constraints could be introduced, where feasible, for the interagency security review (SAO) process that some F-1 applicants must go through. Congress, for its part, could conduct further oversight over backlogs and allocate additional resources to agencies where necessary.⁹¹

Retain and improve flexibility in student visa conditions. Experts predict that pre-existing administrative backlogs—and the costs they impose on students—

would grow even larger if certain pending F-1 regulatory proposals were implemented. Several policies, such as changing the duration of status from a flexible to a fixed term, could also directly and negatively impact students. To avoid this, the administration should amend or withdraw the relevant F-1 regulations and guidance.⁹² Given the desire expressed by policymakers across the political spectrum to have students stay in the United States after graduating, Congress could also amend the Immigration Nationality Act (INA) to allow students to express intent to stay in the United States long-term without putting their visa at risk.⁹³

Streamline post-graduation transition into U.S. labor market

The policy options outlined in this section mostly concern temporary (“non-immigrant”) employment programs. However, if Congress adopts legislation allowing graduate students to receive permanent residency (“immigrant” status) immediately after graduation, reform to non-immigrant programs could be partially or entirely redundant. Policy options for permanent residency reform are discussed in the next section.

Create a statutory student-to-work pathway. In contrast to Canada and some other countries, the United States has no dedicated post-graduation employment visa for international students, and there are many more graduates than there are available visa slots in current non-student-specific programs. To alleviate this bottleneck and to help U.S. universities compete for top international talent, Congress could create a student-specific temporary employment visa program akin to successful programs in other countries with many international students (see Appendix B). Such a program could include especially favorable conditions (e.g., duration of visa, increased processing speed, more flexible certification requirement) for students with job offers in labor-constrained fields like AI.

Allow entrepreneurial graduate students to start companies. There is currently no visa program tailored to entrepreneurs in the U.S. immigration system, as most visas require a formal employer-employee relationship. To fill this gap, Congress could create a visa category that allows international graduate—or foreign-born workers more generally—to obtain either temporary or (conditional) permanent residency status if they start their own company. Barring legislative changes, the White House could reverse its process of rolling back the International Entrepreneur Rule, an Obama-era regulatory program intended to facilitate entrepreneurship among immigrants.⁹⁴

Improve the flexibility of employment visas. Graduates and employers in fast-changing emerging technology fields such as AI face additional barriers due to certain inflexibilities in the immigration system. For example, there are reports of

people with physics degrees having trouble getting H-1Bs for data science roles on the grounds that their degrees are insufficiently related to their jobs.⁹⁵ Other flexibility issues such as difficulties transferring H-1Bs between jobs or employers also affect AI talent, as does spousal employment authorization. Because statutory language on such matters is typically broad, many of these problems could be addressed by USCIS through guidance or regulations.⁹⁶

Reduce the burdens of visa allocation processes. To facilitate more efficient and timely hiring, the relevant agencies should work to increase the frequency of visa allocations and decrease processing times. For example, USCIS could hold an H-1B lottery quarterly as opposed to just once a year,⁹⁷ and the Department of Labor could reduce labor certification requirements in labor-constrained fields such as AI.⁹⁸ These measures would be especially beneficial to smaller employers, like start-ups, who work on tighter timelines and face more resource constraints than large firms. (AI employers have likely already benefited from certain recent USCIS-led changes that favor higher-paying and higher-degree H-1B applicants.⁹⁹)

Shorten the path to permanent residency and citizenship

Remove country-based caps on the number of available green cards.

Country-based caps have led to prohibitively long green card backlogs among Chinese and especially Indian nationals. As noted in Chapter 2, an Indian PhD entering the green card queue today is projected to face a wait time of around 50 years. This harms U.S. competitiveness in AI because approximately half of international graduate students in AI-relevant fields are from India and China (Figure 1). To reduce backlogs for AI talent source countries such as India and China, Congress could eliminate country-based caps from the INA (or raise caps more generally). *

Automatically grant green cards to postgraduate degree holders. Another approach to the green card backlog problem for AI students is to guarantee international graduate (or only PhD) students conditional permanent residency upon graduation from U.S. universities, either in general or for a smaller set of labor-constrained and strategically relevant fields such as AI.[†] To alleviate critics' concerns about automatic green cards incentivizing "diploma mills," labor market pressures,

* A bill to this effect, the "Fairness for High-Skilled Immigrants Act," passed the House and is currently stalled in the Senate. The consequences of removing country-based caps are complex, and before taking this step Congress should carefully assess its potential negative side-effects. Increasing the overall number of available green cards could achieve many of the same benefits to the AI sector as removing country-based caps without the latter's potential negative side-effects, but such a measure is likely politically infeasible today.

† Guaranteed green cards can also take the form of cap-exemptions, meaning that graduate students from U.S. universities who meet certain requirements could obtain permanent residency without entering lengthy green card queues. This was the approach taken in the Border Security, Economic Opportunity, and Immigration Modernization Act, S. 744, 114th Cong. (2013).

and dual residency,¹⁰⁰ the program could be made specific to students graduating from highly-ranked universities and include strict domestic residency requirements.

Create and utilize accelerated paths to citizenship in exchange for government service. Congress and agencies should work together to create programs whereby in-demand international talent can receive green cards and citizenship on accelerated timelines in exchange for a number of years of government service. To inform program design, studies should be commissioned to inventory and derive lessons learned from related past programs such as the Military Accessions Vital to National Security (MAVNI) program.¹⁰¹ (While a secure statutory program is preferable, MAVNI was created by executive order, suggesting similar AI-specific programs could be as well.)

Policy priorities besides immigration

It is not enough for a country to be welcoming. Graduates, in order to come and stay, also need to see a country as professionally attractive. The United States is already strong on this front, but it is facing increased competition from China, Canada, the U.K., and other countries. Policies that bolster the U.S. academic and commercial AI ecosystems—for example by addressing AI faculty shortages at universities—would therefore also aid graduate retention. Future CSET reports will provide more specific policy options on this front.

ADDRESSING SECURITY CONCERNS ABOUT FOREIGN TALENT

Policymakers should also act to address security concerns around the training and presence of foreign talent in dual-use fields such as AI.

Other countries, most notably China, are actively engaged in trying to extract and absorb AI-relevant technology and knowledge from the United States to strengthen their economies and militaries.¹⁰² Students are one vector through which these countries hope to achieve such technology transfer. U.S. law enforcement agencies are now focusing on “non-traditional collectors” and calling out graduate students as a population of concern,¹⁰³ and commentators outside of government have echoed their concerns.¹⁰⁴ Recent FBI enforcement actions and policy changes at federal funding agencies have, in turn, sparked pushback from affected communities.¹⁰⁵

Given the dual-use nature and strategic value of AI, there are legitimate reasons for U.S. policymakers to worry about technology transfer. Some specific concerns, however, seem to be based at least partially on misperceptions. A prominent 2018 report by the Defense Innovation Unit notes that 25 percent of graduate students in STEM fields are Chinese and that “nearly all [of them] will take their knowledge and skills back to China” because they “do not have visas to remain in the U.S.,” the implication being that U.S. universities are educating the country’s competitors without

much benefit to the United States.¹⁰⁶ As this report shows, that is not the case—with the vast majority of Chinese graduate students in fact staying in the United States—despite longstanding efforts by the Chinese government to draw them back.

Other disagreements stem from real uncertainty about the nature and extent of risk. For example, CSET data collection found that out of the small number of students who return to China after completing their PhD in the United States, most go to work for the private sector and none directly for the Chinese government or military (Figure 10). To what extent this assuages concerns about “educating our competitors” depends on whether one believes China’s military-civil fusion plans, whereby the government intends to convert civilian technological successes into a long-term military advantage, will actually bear fruit. This is a question that China experts continue to debate.¹⁰⁷ Other areas of potential disagreement include how easy it is to militarize AI, or how difficult it will be to distinguish between civilian and military lines of AI R&D as the technology advances.¹⁰⁸ A lack of systematic data and analysis on these and related questions makes it hard for governments and other stakeholders to conduct risk assessments and develop countermeasures.¹⁰⁹

However, even if technology transfer risks are potentially substantial, policies must also account for the serious security risks from not attracting and retaining foreign students in the same way the United States does today. Given that there are large talent shortages in AI, any decrease in international talent inflow and retention would hurt U.S. industry and, by extension, the defense industrial base. Talent shortages also increase the risk of technology transfer by incentivizing U.S. companies to set up labs in countries where protections against transfer are worse than in the United States, as has already started happening in the AI sector.¹¹⁰

Conversely, competitors would benefit from decreased U.S. openness. One study of top Chinese-trained AI researchers finds that 75 percent currently live outside of China, nearly all of them in the United States.¹¹¹ China’s aggressive talent recruitment efforts (discussed in more detail in Appendix C) show that its leadership is unhappy with this situation and thinks its competitiveness in AI would increase if more of this talent returned from abroad. Lastly, because the United States does not have a monopoly on AI, it is likely that any unilateral counter-transfer measures would simply displace, not decrease, transfer activities.

For these reasons, **we do not recommend adopting policies targeting broad student populations**, such as the recent shortening of visa durations for Chinese graduate students in certain technology fields.¹¹² Such measures put a core U.S. advantage in technology competition at risk. Many are also likely to be ineffective. For example, Nicholas Eftimiades, a former senior U.S. counterintelligence official and author of a book on Chinese intelligence practices, said of proposals

to broadly enhance screening of Chinese students and scholars, “Not a good idea. The process will almost certainly fail at determining an individual’s future course of action.”¹¹³

Instead, **the United States should adopt a more targeted approach to countering the risks of technology transfer via talent flow.** First, it is important to acknowledge that there is a clear need to encourage more domestic students to pursue graduate degrees in AI-related fields,^{*} and that most large-scale transfers of data and intellectual property involve not individual researchers but cyber breaches or private investment and acquisitions. Much can still be done on those fronts without running the risk of harming U.S. talent competitiveness.¹¹⁴ Even when it comes to addressing transfer occurring through individual students and scientists, however, there are relatively low-risk measures U.S. policymakers can take today that would help lay the groundwork for better and more targeted policy decisions down the line. The remainder of this section outlines some of these measures.

Enhance domestic and international policy coordination

Create an interagency task force charged with improving both screening and retention. A wide range of organizations, including the Departments of State, Defense, Homeland Security, Commerce, and Education; the intelligence community (IC); and various science funding agencies, are involved in creating and implementing U.S. policies relevant to foreign S&T talent screening and retention. There is no U.S. government entity with a policy focus and a mission that includes both the screening and retention of foreign S&T talent, two goals essential to U.S. security and affected by many of the same policy decisions.[†] This can lead to a disproportionate focus on some policy goals at the expense of others. In designing a new entity to fill this gap, policymakers could take inspiration from the membership structure and certain other aspects of the Committee on Foreign Investment in the United States (CFIUS). The tradeoffs CFIUS navigates—between the national security benefits and risks of foreign investment—are similar to those that crop up with foreign S&T talent and similarly require cross-agency input and

^{*} How to encourage more domestic students to do graduate studies—and understanding domestic students’ educational and career decisions more broadly—will be the focus of future CSET research.

[†] There are entities that bring together different agencies to execute specific functions, such as making individual student and scholar visa vetting decisions, or adjudicating deemed export control licenses. However, these groups are typically not focused on policy-level activities and have narrow remits. Recently, a subcommittee within the Office of Science and Technology Policy, JCORE, took on a coordinating function for certain research security policies. This is a step in the right direction, but JCORE’s mission does not explicitly include talent retention, and it is unclear whether the committee will have sufficient resources or institutional clout. See “Letter to the Research Community,” Office of Science and Technology Policy, September 16, 2019, <https://www.whitehouse.gov/wp-content/uploads/2019/09/OSTP-letter-to-the-US-research-community-september-2019.pdf>

expertise. At minimum, a new interagency task force or other entity should get an advisory and coordinating role.

Engage international allies about knowledge transfer concerns. To avoid having to act unilaterally, the White House should engage allies with robust emerging technology ecosystems to discuss how harmful knowledge transfer can be avoided in an internationally coordinated fashion. Absent coordination, U.S. countermeasures are likely to steer international talent toward other AI hubs such as the U.K. and Canada without achieving any of the desired outcomes. Recent multilateral initiatives organized by the State Department are a good first step and should be expanded.

Raise awareness and improve screening through open-source collection and dissemination

Allocate more resources to open-source intelligence collection. Many indicators of transfer activity and evidence of potentially illegal behavior are available in the public domain, as recent indictments and agency enforcement actions demonstrate.¹¹⁵ For example, one recently indicted Chinese researcher accused of hiding his employment at a Chinese university had his dual affiliation listed on multiple public scientific papers. Unfortunately, open-source intelligence (OSINT) collection and analysis currently get short shrift in the intelligence community, leading one former deputy CIA director to argue “open-source intelligence deserves its own agency.”¹¹⁶ One advantage of such OSINT reforms would be to improve vetting and monitoring capability when it comes to foreign researchers in sensitive fields. Another is that open-source analysis can—to some extent—be shared with professors and university administrators, some of whom are currently mistrustful of transfer-related warnings from the intelligence community because they are not able to scrutinize the evidence for themselves.

Consider expanding the scope of the Foreign Agents Registration Act (FARA) to cover foreign talent recruitment efforts. FARA is a law aimed at increasing public disclosure of foreign propaganda activity, with the intent not of banning such activity but of educating the American public and relevant stakeholders.¹¹⁷ Analysts have suggested this same framework might be appropriate for technology transfer activity.¹¹⁸ Congress should study whether and how it should adapt or expand FARA to increase the visibility of foreign recruitment efforts of U.S.-based talent and other transfer activities.

Collect more and better data about student retention trends

Expand agency surveys of U.S. student populations to include master’s students and more retention-related questions. The National Science Foundation and other agencies administer many useful surveys of student populations in the United States, some of which this report draws on. However, these surveys

can be expanded in both who and what they cover. For example, there are currently no regular government agency surveys of master's students—even though there are now many times more master's students than there are PhD students in important fields like computer science (see Table 1). Existing surveys also often do not ask how long students intend to stay after graduating or what factors drive those decisions. To fill these informational gaps, Congress should ask—and allocate the necessary resources to—the National Science Foundation to expand its existing portfolio of student surveys. Congress could also require periodic reports on retention trends and their causes from the relevant agencies.

Conclusion

Talent is a crucial competitive advantage for the United States in AI, in large part because of the country's ability to attract and retain the best technical minds in the world. Many of these minds first come to the United States as students and subsequently stay to become some of the country's best AI scientists, engineers, and leaders. In doing so, they help fill critical talent gaps in the U.S. AI sector.

Despite its historical strength in student attraction and retention, the United States needs to act if it wants to maintain the country's AI talent advantages. These advantages are being challenged by two trends. First, the U.S. immigration system is becoming increasingly difficult to navigate even for the most highly skilled. And whereas U.S. primacy in science and technology used to be such that the United States was virtually the only place where AI talent could do cutting-edge work, today other countries are rapidly building up their domestic tech and AI ecosystems and becoming attractive professional destinations.

While there is little that U.S. policymakers can do to halt the rise of competition, they can control whether the United States remains an attractive and welcoming destination for international talent. The primary tool they have for this is immigration policy. Immigration reforms must go hand in hand with policies aimed at expanding the domestic talent pipeline. But domestic talent policies will take years to pay dividends, and domestic talent will never be able to fully substitute for international talent.

Overview of immigration policy options

REFORM STUDENT VISA REGULATIONS AND PROCEDURES

Potential legislative actions

- Codify the Optional Practical Training program in statute.
- Increase oversight of processing backlogs in F-1 applications and OPT employment authorizations.
- Allow students to express a desire to remain in the U.S. upon graduation ("dual intent").

Potential executive actions

- Avoid restrictions on the OPT program that hurt AI employers.
- Adopt and implement rules that limit F-1 and OPT processing times to reasonable timeframe

STREAMLINE POST-GRADUATION TRANSITION INTO U.S. LABOR MARKET

Potential legislative actions

- Create a new student-to-work pathway with a dedicated employment visa for former international students.
- Create a visa category for entrepreneurs that allows international students to start their own companies upon graduation.

Potential executive actions

- Hold H-1B lotteries quarterly in order to increase time-constrained AI startups' ability to utilize the H-1B visa.
- Reduce labor certification requirements for labor-constrained fields such as AI.
- Reverse the rollback process for the International Entrepreneur Rule.

SHORTEN THE PATH TO PERMANENT RESIDENCY AND CITIZENSHIP

Potential legislative actions

- Eliminate country-based caps on the annual number of green cards that can be issued.
- Automatically grant green cards to (or exempt from green card caps) international graduate students from select universities.
- Create accelerated paths to citizenship for international graduates in exchange for government service.

Potential executive actions

- Create accelerated paths to citizenship for international graduates in exchange for government service.

Several of these actions could be implemented in ways that either apply to international graduate students broadly or to AI graduates specifically, as discussed above.

At the same time, the United States must balance the security and economic benefits it derives from being the global hub for AI talent with security concerns around training foreign talent that might later work for U.S. competitors. This balancing act is a delicate one. The easiest way for the United States to hurt itself in competing with China is to help the Chinese government recruit U.S.-based AI talent by becoming less welcoming. To avoid such outcomes, U.S. policymakers should first focus on implementing necessary counter-transfer reforms that pose fewer risks to talent competitiveness, such as strengthening investment and cyber protections, improving domestic and international policy coordination, and shoring up the country's open-source intelligence apparatus.

Future Work

In the future, CSET aims to build on the research presented in this paper in several ways:

- **Conduct career choice surveys.** In its future surveys of AI students and faculty, CSET will fill informational gaps in existing surveys and learn more about career choices, the factors that influence moving decisions, and the destination countries students consider attractive.
- **Further analyze administrative immigration data.** Available data from immigration agencies is helpful but incomplete. Pending responses to agency requests, CSET will conduct further analyses of administrative immigration data to form a better picture of the pathways students travel through the immigration system and where they most frequently encounter problems.
- **Continuously track retention rates.** Existing survey-based approaches to measuring stay rates often provide incomplete coverage and suffer from delays in data availability. In the future, CSET aims to continuously track retention rates via publicly available resume data in order to provide timely information about changing patterns and trends in post-graduation choices.
- **Mapping graduate flows internationally.** This report focused on graduate students in the United States, but the career and destination choices of graduate students in other countries also provide valuable information about the attractiveness of different AI ecosystems and global talent flows. CSET aims to expand data collection efforts to other countries as well, including Canada, the United Kingdom, and China.
- **Track enrollment trends.** From a workforce perspective, it matters not only where students go after graduating but also where they decide to enroll in the first place. In future work, CSET hopes to get a better picture of enrollment trends both in the United States and other countries across different degree levels and AI-relevant fields.
- **Better understand AI source fields.** Since AI is a rapidly growing and changing field, the picture of the educational and employment routes into the AI workforce is imperfect. Examining the career histories of those currently employed in AI jobs can offer a better sense of the backgrounds and skills AI employers look for. This information could inform, for example, immigration officers' decisions about whether an applicant's skills and education meet the legal criteria for employment-based visas, or Department of Labor assessments of labor supply and shortages.

- **Further assess security concerns.** Student retention rates are only one part of the discussion about the potential security risks of foreign talent in dual-use fields such as AI. CSET will also study other questions that are part of this discussion, including further data collection and assessments of potential countermeasures.

We welcome questions, feedback, and collaboration proposals on these topics; please feel free to contact remco.zwetsloot@georgetown.edu.

Appendix

A. DATA SOURCES

We drew on several data sources in Chapters 1 and 2 of this report. This Appendix briefly discusses each of them, describing the information available in the sources and the analytical choices we made in working with the data.

Original CSET data collection: top U.S. AI PhD graduates

For data on the education and career histories of AI PhD graduates from U.S. universities, CSET launched a large-scale collection effort in early 2019. We started by creating a population list of recent PhD graduates on the basis of a ProQuest dissertation search using AI-ML keywords. For this initial effort, we looked at students who graduated between 2014-2019 from one of the 20 universities with the highest-ranked AI departments in the U.S.¹¹⁹ A team of research assistants took this list and manually collected data on their pre- and post-PhD educational history, their professional activities, and their scientific publications from sources such as LinkedIn and Google Scholar. This paper reports results on 1,999 graduates for whom we have collected complete histories so far. This data forms the basis for Figures 4, 5, 7, 8, 9, and 10, and Table 2.

Data collection for the United States is ongoing, and collection is also expanding into other countries (initially Canada, the United Kingdom, and China). In future publications we will expand on the data collection methodology and highlight further findings. Readers interested in discussing the data in more detail in the meantime are welcome to contact us.

Administrative immigration data

Several U.S. departments charged with administering and enforcing immigration regulations regularly release data on the number and characteristics of immigrants. The most detailed of these is the Department of Labor's "PERM" data, which includes information on foreign workers for whom employers initiated a labor certification process since 2010. This process is a prerequisite for green card sponsorship. Data on these workers includes their country of citizenship, their educational and professional backgrounds, and characteristics of their prospective jobs. Approximately 888,000 individuals are included in the 2010-2019 data.* We used the PERM dataset to study the main feeder fields into AI jobs (Chapter 1) and the backgrounds of foreign workers sponsored for green cards (Box 4). To do this analysis, we needed working definitions of "AI employers" and "AI jobs." We outline these definitions briefly and will elaborate on them in future work.

There is no widely agreed-upon definition or list of "AI employers." For the purposes of this paper and the PERM dataset, where we were primarily interested in identifying individuals with AI skills, our goal was to find employers who have hired significant amounts of AI talent, even if AI represents a minority of what the employer does. We ultimately compiled a list of several hundred AI companies from several sources: (1) companies that had been identified in Crunchbase as specializing in AI and that (a) are publicly listed, (b) have 50 or more employees, or (c) have raised at least \$10 million in funding;¹²⁰ (2) leading AI startups, as identified by market research firm CB Insights; and (3) companies that are especially active in hiring personnel with AI skills, as identified by market research firm Paysa.¹²¹ There were 50,391 entries (sponsored individuals) at these AI employers in our database.

It is similarly difficult to define what counts as an "AI job," especially with access to only a job title. A "software engineer" at Google, for example, could work on an AI team or could be doing something else entirely. For this paper we took a broad approach, reporting statistics for people who worked in broadly "technical" roles.¹²² This approach prioritizes minimizing the number of "false negatives" over minimizing the number of "false positives,"

*Data for 2019 were downloaded in spring and are thus not comprehensive for that year.

leaving in some non-AI-related technical jobs but at least excluding management, sales, accounting, and similar “non-technical” jobs. Roughly 15 percent of jobs at AI employers in the PERM database were non-technical or difficult to classify and thus dropped, leaving us with a total of 43,070 *potentially* AI-related jobs at AI employers.

Other publicly available immigration datasets and statistics (e.g. on OPT or H-1B entrants) contained too little information to do similarly detailed analysis, but they were used in Table 2 for aggregate statistics. To address these data gaps and allow us to conduct further analysis, we have several FOIA requests pending with the relevant agencies.

Existing surveys

We also analyzed data from existing surveys of AI-relevant student populations and university departments. Our primary sources of survey data were:

The **Survey of Earned Doctorates** (used in Figures 2, 3a, and 6), an annual census of PhD graduates conducted by the National Science Foundation (NSF).¹²³ The survey collects individual-level data on graduates’ academic field, country of origin, and career plans, generally achieving response rates exceeding 90 percent. Researchers must request a license in order to access the data.

The **Survey of Graduate Students and Postdoctorates in Science and Engineering** (used in Figure 1 and note 15), an annual census of research university science and engineering departments conducted by the NSF.¹²⁴ It asks departments for the number of enrolled students and postdocs and their demographic profiles, among other information. It does not contain questions on students’ specific countries of origin, only whether they are domestic or international. Its 2017 survey, the latest for which data is publicly available, was the first that asked departments to report statistics for master’s and PhD students separately (see note 15).

The **Taulbee Survey** (used in Figure 3b and note 14), an annual survey of PhD-granting computer science, computer engineering, and informatics departments in the United States and Canada run by the Computing Research Association (CRA).¹²⁵ It asks departments to provide information about PhD, master’s, and bachelor’s students’ demographic background, and about PhD graduates’ fields of specialization and post-graduation plans. CRA surveys nearly 300 departments, with response rates of 60-70 percent. Notes 14 and 52 also draw on data from CRA’s separate **Data Buddies** survey.¹²⁶

We thank these organizations for sharing their data and insights with us, which we will continue to draw on in future publications. CSET will also field its own surveys; readers interested in providing input on such surveys are welcome to reach out.

B. “RECEIVING” COUNTRIES: COMPARING STUDENT RETENTION POLICIES

The United States leads the world in international student enrollment, followed by the United Kingdom, Canada, and Australia. Comparing student retention policies across these countries, however, the United States does substantially worse.

Student-to-work pathways. Most countries with significant international student populations have created specific “student-to-work” pathway. These are generally similar to Optional Practical Training (OPT) in the United States. Unlike in the United States, however, these countries’ student-to-work routes are generally more securely codified in law and more widely supported among policymakers. Indeed, many countries have recently reformed and expanded the immigration options available to international students.

- In **Australia**, students can obtain a post-study work visa that is valid for two to four years (depending on education level) and participate in a year-long professional program that prepares students for a career in Australia.¹²⁷ These two professional activities yield graduates extra points in Australia’s points-based immigration system, thereby increasing a graduate’s chances of obtaining permanent residency.¹²⁸

- In **Canada**, the Post-Graduation Work Permit (PGWP) allows students to work up to three years without restrictions after getting their degree. As in Australia, a major benefit of the PGWP is that graduates can use Canadian work experience to boost their rank in the recently launched points-based Express Entry system to secure permanent residency.¹²⁹ In early 2019, Canada liberalized PGWP regulations by extending the deadline to apply from 90 days after graduation to six months.¹³⁰
- The **United Kingdom** terminated its two-year post-study work visa in 2012, and since then students have had to compete with other immigrants for a general work visa capped at 20,700 spots per year. In a recent effort to carve out a new student-to-work pathway, the government has proposed extending the time graduates can seek a job, reinstating the post-study work visa, and eliminating the cap on the general work visa by 2021.¹³¹ In October 2019, the government already exempted PhD level occupations from the general work visa cap.¹³²

Other countries with straightforward student-to-work pathways include France, Germany, and New Zealand.¹³³

Besides having codified student-to-work pathways, other countries' immigration systems also differ from the U.S. system in other ways relevant for the AI workforce.

Entrepreneurial visas. Nearly 20 other countries—including Canada, France, the United Kingdom, and Israel—have recently introduced specific visa programs for entrepreneurs (especially in tech), which make it possible for domestically- and internationally-trained students to start businesses after graduating.¹³⁴ As previously noted, the United States currently has no operational visa category for entrepreneurs.

Permanent residency. Many other countries provide easier paths to permanent residence than the United States, which—since most student-to-worker pathways are initially temporary in nature—is important for graduates' ability to stay in the long term. In the United States,¹³⁵ as noted in Chapter 2, the number of eligible graduates and workers far exceeds the number of available green card slots, especially among Indian and Chinese nationals. The United States is not unique in this—prior to its recent reforms, caps on the number of skilled workers that can get permanent residency in the United Kingdom led to similar bottlenecks in their system.¹³⁶

C. “SENDING” COUNTRIES: COMPARING CHINESE AND INDIAN STUDENTS AND RETURNEES

The majority of foreign-born AI-relevant graduate students come from just two countries: China and India. While some generalizations can be made about why students decide to stay in or leave the United States, in many cases the relative importance and salience of different factors depends on country-specific details. Because of the outsized importance of China and India, and to see stay-departure decision-making play out at a more granular level, this section describes returnee dynamics among these two countries' students specifically.

To summarize, there are both similarities and differences between the two communities. The main similarity is that professional opportunities resulting from economic development are the prime reason that students and workers return home. A salient difference is that Indian students face a much tougher immigration environment due to green card queues. Many more Indian returnees report going home for immigration-related reasons. On the policy front, the Indian government has been much less aggressive than the Chinese government in trying to recruit full-time returnees, instead focusing on attracting diaspora financial investment and remittances.

Indian students and policy

- **Professional opportunities.** Around half of Indian returnees cite professional opportunities as their main reason for returning across a range of surveys.¹³⁷ Many private sector returnees cite budding startup ecosystems in places like Bangalore and Hyderabad as particularly attractive.¹³⁸
- **Immigration rules.** As noted in Chapter 2, green card queues for Indian in the U.S. are very long; current PhD graduates can expect to wait around 50 years for permanent residency.¹³⁹ Some high-tech immigrants stuck on temporary status or in the queue now consider their decision to move to the United States the “worst

decision of my life.”¹⁴⁰ In a survey of academics who returned to India, 26 percent of respondents said that immigration problems were an important factor in their decision. For many academics, though, the main problem was their inability to get work authorization for their spouse, as opposed to their own status.¹⁴¹ In another survey of mostly private sector returnees, 30 percent said visa issues were significant.¹⁴²

- **Personal and cultural considerations.** In one survey of returnees, over 30 percent state they had family-related reasons for returning.¹⁴³ In another, about 25 percent report either family reunification or “Indian cultural identity” as their primary reason.¹⁴⁴ A study of Indian medical doctors based abroad found that 40 percent were “ready to return,” “mainly for personal reasons.”¹⁴⁵

Interestingly, there have not been many Indian policy efforts to attract returnees, in contrast to China. One study concludes that “the government in New Delhi has done little or nothing” to encourage high-skilled in-migration because it is more concerned about increasing investment and remittances from abroad.¹⁴⁶ Another similarly concludes that “there has not been any concerted effort to induce return migration in India, except in some indirect and limited ways,” hypothesizing that an excess of domestic labor reduces the need for returnees and that bureaucratic problems hampered the few nascent programs that did get launched.¹⁴⁷

Chinese students and policy

- **Professional opportunities.** One survey of Chinese returnees found that professional opportunities were a “very” or “extremely” important factor for 70 percent of respondents.¹⁴⁸ Another study that focused specifically on returned STEM faculty in China found that “job opportunities” was the most common reason for return (cited by 46 percent of respondents).¹⁴⁹ Experimental research with U.S.-educated Chinese STEM students has found that salary is an important determinant of returnee preferences;¹⁵⁰ the fact that economic growth and investment in high-tech fields have driven up salaries and created more interesting jobs in China is a big factor for many returnees.¹⁵¹ Many returnees also feel they have better professional networks in China than in the United States.¹⁵²
- **Immigration rules.** Visa problems do not seem to be a very important reason for return among academics¹⁵³ or prospective entrepreneurs (20 percent of whom rated expiring visas as an extremely to moderately important reason for return),¹⁵⁴ though in some surveys Chinese graduate students do report difficulties finding employment as non-citizens,¹⁵⁵ which is likely at least partially visa-related.
- **Personal and cultural considerations.** In the same study of STEM faculty who returned to China previously cited, “family” was the second most important reason for returning, cited by 45 percent of respondents.¹⁵⁶ Other commonly cited reasons were “wanting children to receive a Chinese education” (18 percent) and “did not adjust well to foreign culture” (10 percent). Another survey finds that 84 percent of Chinese graduate students in the United States who intended to return home after their studies considered “missing family/friends” an important reason for returning, with the second most important factor being “cultural comfort” in China (79 percent).¹⁵⁷

There are many factors that disincentivize U.S.-educated students from returning to China. Salary gaps between the United States and China are still large, even though Chinese salaries have been rising,¹⁵⁸ and roughly 80 percent of returnees report lower-than-expected salaries.¹⁵⁹ Returnees also often experience challenges integrating into the Chinese labor market, with 70 percent saying that their position did not match their experience and skills.¹⁶⁰ Many in academia consider the research environment in China to be less merit-based, leading to frequent complaints about plagiarism and the political nature of promotions.¹⁶¹ Governments and university administrators also try to dictate much of the content and output of research. One survey of academics finds that “the goal of research in China is no longer seen as about the pursuit of knowledge; rather, it has become a pursuit designed to meet quantitative indicators for one’s evaluation.”¹⁶² Potential returnees who are thinking about going into the private sector have felt deterred by the political environment as well.¹⁶³

The Chinese government has been very active in trying to encourage return, for example by offering financial incentives to both returnees and Chinese institutions, using a combination of embassy and other official networks to

create linkages, and providing job search and other administrative support. The most well-known returnee program is the "Thousand Talents Program," but there are many more.

Many analysts, however, doubt that government policies have been central in shaping returnee patterns to China, and they may even unintentionally increase emigration. As a literature review on this topic states, "Most studies argue that governments have limited impact on the return tide. Preferential policies for returnees can, in fact, increase the numbers going abroad, since preferred benefits are available only to returnees."¹⁶⁴ Tensions between returnees and "domestic" workers and scientists are currently commonplace, with those who have never gone abroad alleging discrimination and those who have finding it hard to break into longer-standing domestic networks.¹⁶⁵ Moreover, returnees are often thought to be of lower quality on average than those who remain abroad.¹⁶⁶

Endnotes

1. "Artificial Intelligence for the American People," White House, <https://www.whitehouse.gov/ai/>.
2. CCTV, "Why Is Xi Jinping's 'First Resource' So Important? ("习近平眼里的“第一资源” 为何如此重要"), July 18, 2018, <http://politics.people.com.cn/n1/2018/0718/c1001-30155931.html>.
3. Elsa Kania, "China's AI Talent 'Arms Race,'" *The Strategist*, April 23, 2018, <https://www.aspistrategist.org.au/chinas-ai-talent-arms-race/>. People in industry, such as David Wipf, a Principal Researcher at Microsoft Research, similarly talk about a "battle for talent" and its importance to AI leadership; see e.g. David Cyranoski, "China Enters the Battle for AI Talent," *Nature*, January 15, 2018, <https://www.nature.com/articles/d41586-018-00604-6>.
4. "Interim Report to Congress," National Security Commission for Artificial Intelligence (November 2019), 16, <https://drive.google.com/file/d/153OrxnuGEjsUvLxWsFYauslwNeCEkvUb/view>.
5. Daniel Culbertson, "Demand for AI Talent on the Rise," *Indeed Hiring Lab* (blog), March 1, 2018, <https://www.hiringlab.org/2018/03/01/demand-ai-talent-rise/>.
6. For a more extensive discussion of talent shortages in AI and the proportion of foreign-born workers in the U.S. AI workforce, see Remco Zwetsloot, Roxanne Heston, and Zachary Arnold, *Strengthening the U.S. AI Workforce: A Policy and Research Agenda* (Center for Security and Emerging Technology: September 2019), https://cset.georgetown.edu/wp-content/uploads/CSET_U.S._AI_Workforce.pdf.
7. "CSRankings: Computer Science Rankings," CSRankings, accessed August 12, 2019, <http://csrankings.org>.
8. Lesleyanne Hawthorne, "Attracting and Retaining International Students as Skilled Migrants," in *High-Skilled Migration: Drivers and Policies*, Mathias Czaika (Oxford University Press, 2018), <http://www.oxfordscholarship.com/view/10.1093/oso/9780198815273.001.0001/oso-9780198815273-chapter-10>. This is also better for the employees, who tend to find better employment matches more easily and receive higher starting wages; see John Bound, Murat Demirci, Gaurav Khanna, and Sarah Turner, "Finishing Degrees and Finding Jobs: US Higher Education and the Flow of Foreign IT Workers," *National Bureau of Economic Research* (University of Chicago Press, 2015): 64-65, <https://www.journals.uchicago.edu/doi/pdfplus/10.1086/680059>.
9. Bound et al., "Finishing Degrees and Finding Jobs"; Christiane Kuptsch, "Students and Talent Flow - the Case of Europe: From Castle to Harbour?," in *Competing for Global Talent*, ed. Christiane Kuptsch and Pang Eng Fong (International Institute for Labour Studies, 2006): 41, http://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/@publ/documents/publication/wcms_publ_9290147768_en.pdf#page=44.
10. Stuart Anderson, "Immigrants and Billion Dollar Startups," *National Foundation for American Policy*, March 2016, <https://nfap.com/wp-content/uploads/2016/03/Immigrants-and-Billion-Dollar-Startups.NFAP-Policy-Brief.March-2016.pdf>. Between 1995 and 2005, roughly 50 percent of U.S. technology and engineering companies founded by immigrants were founded by former international students; see Vivek Wadhwa, Ben A. Rissing, AnnaLee Saxenian, and G. Gereffi, "Education, Entrepreneurship and

Immigration: America's New Immigrant Entrepreneurs, Part II," SSRN, June 2007, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=991327.

11. CSET analysis of Department of Labor PERM data, 2015-2019 (see Appendix A). Only 60 percent of applications describe workers' education history, so this is an estimate with some uncertainty. Among applicants who reported their highest degree, 60 percent reported a master's degree and 9 percent reported a PhD degree. This compares to 41 percent and 5 percent at non-AI employers. No comparably detailed data is available for domestic workers or for foreign-born workers on other visa categories.

12. Jean-Francois Gagne, "Global AI Talent Report 2019," <https://jfgagne.ai/talent-2019/>.

13. CSET analysis of Department of Labor PERM data, 2015-2019 (see Appendix A). Other fields all accounted for less than two percent of workers in the dataset. Note that computer engineering (CE) is a subfield of electrical engineering (EE), and often not reported by students or universities as a separate field. Universities also often do their CS and EE training within a single department; Berkeley, for example, teaches AI in its "Department of Electrical Engineering and Computer Science." For these reasons, we report statistics on CS/EE student populations below when CE-specific data is unavailable.

14. CSET analysis of Computing Research Association data (see Appendix A). In the Fall 2017 CRA Data Buddies survey of graduate students in computing programs, 1,437 out of 4,550 respondents (32 percent) report "Artificial Intelligence" as one of their specialties. In the 2018 CRA Taulbee survey of PhD students in computing programs, roughly 20 percent selected "Artificial Intelligence / Machine Learning" as their specialty, up from 14 percent in 2016 and 2017 and 10 percent in prior years.

15. The 2017 version of this survey was the first to publish separate statistics for master's and PhD students. At that time there were, at the master's level, 75,618 CS students (of which 58 percent were temporary visa holders) and 29,816 EE students (of which 68 percent were temporary visa holders). At the PhD level, there were 14,291 CS students (of which 63 percent were temporary visa holders) and 17,936 EE students (of which 71 percent were temporary visa holders). Master's students thus make up roughly 75 percent of all graduate students. See "Table 4-4b. Citizenship, Ethnicity, and Race of Master's Students, By Detailed Field: 2017," National Science Foundation, last accessed August 12, 2019, <https://ncesdata.nsf.gov/gradpostdoc/2017/html/gss17-dt-tab004-4b.html> and "Table 4-4c. Citizenship, Ethnicity, and Race of Doctoral Students, By Detailed Field: 2017," National Science Foundation, last accessed August 12, 2019, <https://ncesdata.nsf.gov/gradpostdoc/2017/html/gss17-dt-tab004-4c.html>.

16. Students from Russia, a geopolitically relevant country with significant ambitions in AI, accounted for only 0.4 percent of U.S. CS PhD graduates in 2016.

17. CSET calculations based on data from NSF's Survey of Graduate Students and Postdoctorates in Science and Engineering.

18. Michael G. Finn and Leigh Ann Pennington, *Stay Rates of Foreign Doctorate Recipients from U.S. Universities*, 2013 (Oak Ridge Institute for Science and Engineering Education: January 2018), Figure 2, <https://orise.orau.gov/stem/reports/stay-rates-foreign-doctorate-recipients-2013.pdf>.

19. Patrick Gaule, "Who Comes Back and When? Return Migration Decisions of Academic Scientists," *Economics Letters* 124, no. 3 (September 2014), <https://www.sciencedirect.com/science/article/abs/pii/S0165176514002699>.

20. Richard van Noorden, "Global Mobility: Science on the Move," *Nature* 490 (October 2012), <https://www.nature.com/articles/490326a>.

21. For example, Yolanda Gil, writing on behalf of the Association for the Advancement of Artificial Intelligence (AAAI), states that "International PhD graduates are leaving the US in larger numbers than

before, in part due to immigration constraints but also due to the availability of attractive opportunities for AI overseas." See "AAAI Response to NITRD RFI: National Artificial Intelligence Research and Development Strategic Plan," Association for the Advancement of Artificial Intelligence, October 26, 2018: 8, <https://www.nitrd.gov/rfi/ai/2018/AI-RFI-Response-2018-Yolanda-Gil-AAAI.pdf>. Some, such as Vivek Wadhwa and co-authors, already stated that "it appears likely that the trend of skilled workers to return has accelerated [since 2000]" roughly a decade ago; see Vivek Wadhwa, AnnaLee Saxenian, Richard B. Freeman, and G. Gereffi, "America's Loss is the World's Gain: America's New Immigrant Entrepreneurs, Part 4," SSRN, March 2, 2009, 6 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1348616. For China-specific examples of claims about increased returnee rates, see Meng Jing, "Why Trump's Clampdown on Academia is Forcing Many Chinese Researchers into a Difficult Corner," *South China Morning Post*, June 13, 2019, <https://www.scmp.com/tech/policy/article/3014185/why-trumps-clampdown-academia-forcing-many-chinese-researchers>, Bloomberg Businessweek, "Chinese Workers Abandon Silicon Valley for Riches Back Home," January 10, 2018, <https://www.bloomberg.com/news/articles/2018-01-10/chinese-workers-abandon-silicon-valley-for-riches-back-home>, and Richard Engel and Kennett Werner, "China's Rising Tech Scene Threatens U.S. Brain Drain as 'Sea Turtles' Return Home," NBC News, July 14, 2019, <https://www.nbcnews.com/tech/tech-news/china-s-rising-tech-scene-threatens-u-s-brain-drain-n1029256>.

22. Emily Feng, "Chinese Students are Under Suspicion in China and the U.S.," *NPR*, June 4, 2019, <https://www.npr.org/2019/06/04/729510902/a-foot-in-both-worlds-students-under-suspicion-in-china-and-the-u-s>; Elizabeth Redden, "Science vs. Security," *Inside Higher Ed*, April 16, 2019, <https://www.insidehighered.com/news/2019/04/16/federal-granting-agencies-and-lawmakers-step-scrutiny-foreign-research>.

23. Some research indicates that there have been increases in the number of Chinese students who say they eventually want to return home, even if they initially stay; see Ryan P. Kellogg, "China's Brain Gain? Attitudes and Future Plans of Overseas Chinese Students in the US," *Journal of Chinese Overseas* 8, no. 1 (September 2010), https://www.researchgate.net/publication/228120877_China's_Brain_Gain_Attitudes_and_Future_Plans_of_Overseas_Chinese_Students_in_the_US. In a recent survey, 54 percent of Chinese STEM PhD students in the U.S. said they intended to work in the U.S. first before eventually returning home; see Michael Roach, Henry Sauermann, and John Skrentny, "Are Foreign STEM PhDs More Entrepreneurial? Entrepreneurial Characteristics, Preferences and Employment Outcomes of Native and Foreign Science & Engineering PhD Students," NBER Working Paper, September 2019, <https://www.nber.org/papers/w26225>. However, in the past many such surveys have seen higher intention to depart rates than were later found in actual departure rate statistics, so it's hard to know how much faith to put in such numbers.

24. Country of undergraduate education is commonly used as a proxy for nationality in academic studies when researchers do not have access to underlying citizenship data. The proxy has clear shortcomings, however, the main one of which is that many non-Western international students do their undergraduate education in the United States or Europe and that this proxy would misclassify their nationality. The undergraduate proxy in our data would imply that about 47 percent of AI PhDs in our data are American and 15 percent from OECD countries. From NSF survey data it is known that these figures are lower for CS PhDs more broadly (35 and 5 percent, respectively; see Figure 1). This suggests our proxy could misclassify the nationality of about 20 percent of our sample; a large number, but at the same time not so large that it could qualitatively change the results of the paper.

25. Grant C. Black and Paula E. Stephan, "The Importance of Foreign PhD Students to U.S. Science," in *Science and the University*, ed. Paula E. Stephan and Ronald G. Ehrenberg (Madison: The University of Wisconsin Press, 2007): 113-130.

26. Jeffrey Grogger and Gordon H. Hanson, "Attracting Talent: Location Choices of Foreign-Born PhDs in the United States," *Journal of Labor Economics* 33, no. 3 (2015); Linda Van Bouwel and Reinhilde Veugelers, "An 'Elite Brain Drain': Are Foreign Top PhDs More Likely to Stay in the U.S.?", SSRN, January 15, 2012, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2109278. Other studies find no correlation between measures of students' or scientists' ability (e.g. publications, degree-granting institution, awards) and their decision to return to their home country. See for example Gaule, "Who Comes Back and When?"
27. CSET plans to collect this data in future research.
28. Other factors that have been found to matter that are not in this list include domestic political stability, the level of democracy, and general quality of life (e.g. environmental) factors. See for example Dongbin Kim, Charles A. S. Bankart, and Laura Isdell, "International Doctorates: Trends Analysis on Their Decision to Stay in US," *Higher Education* 62, no. 2 (August 2011): 145-146 and Grogger and Hanson, "Attracting Talent."
29. Drawing on survey evidence, Xueying Han and Richard P. Appelbaum, "Will They Stay or Will They Go? International STEM Students Are Up for Grabs," Ewing Marion Kauffman Foundation, July 2016, found 74 percent of international graduate students in STEM fields reported future career opportunities as a reason to come, though only 22 percent came specifically because they wanted to stay in the United States. See also Paula Stephan, Giuseppe Scellato, and Chiara Franzoni, "International Competition for PhDs and Postdoctoral Scholars: What Does (and Does Not) Matter," *Innovation Policy and the Economy* 15, ed. William R. Kerr, Josh Lerner, and Scott Stern (Chicago: The University of Chicago Press, 2015): 73-133. Researchers have also found evidence of international students' educational choices changing depending on post-graduation job prospects; see Takao Kato and Chad Sparber, "Quotas and Quality: The Effect of H-1B Visa Restrictions on the Pool of Prospective Undergraduate Students from Abroad," *The Review of Economics and Statistics* 95, no. 1 (March 2013), https://doi.org/10.1162/REST_a_00245; Bound et al., "Finishing Degrees," and Catalina Amuedo-Dorantes, Delia Furtado, and Huanan Xu, "Did OPT Policy Chances Help Steer and Retain Foreign Talent into STEM?", IZA Discussion Papers No. 11548, Institute of Labor Economics (IZA), 2018. <https://www.econstor.eu/bitstream/10419/180566/1/dp11548.pdf>.
30. Hawthorne, "Attracting and Retaining," 202.
31. Shulamit Kahn and Megan MacGarvie, "The Impact of Permanent Residency Delays for STEM PhDs: Who Leaves and Why," National Bureau of Economic Research, October 2018, <http://www.nber.org/papers/w25175>. See also Gaule, "Who Comes Back and When," and Grogger and Hanson, "Attracting Talent." Except in Kahn and MacGarvie, "Impact of Permanent Residency," who use measures of a country's domestic S&T environment, most studies use GDP per capita in home country as proxies for professional opportunities. It is hard to parse out how much of GDP's effect comes from job opportunities specifically versus general quality of life improvements.
32. Philip G. Altbach, "Impact and Adjustment: Foreign Students in Comparative Perspective," *Higher Education* 21, no. 3 (April 1991), <https://www.jstor.org/stable/3447137>.
33. Richard Freeman, Paula Stephan, and John Trumbour, "Career Patterns of Foreign Born Scientists and Engineers Trained and or Working in the U.S.," National Bureau of Economic Research Workshop Report (January 2008): 3, <https://users.nber.org/~sewp/Workshop.Report.November.2007.pdf>.
34. In Han and Appelbaum, "Will They Stay," 80 percent of those who wish to remain in the United States cite "job opportunities" as their main reason, and over 50 percent also mention professional networks and salary as important reasons. See also Mark Musumba, Yanhong H. Jin, and James W. Mjelde, "Factors Influencing Career Location Preferences of International Graduate Students in the United States," *Education*

Economics 19, no. 5 (September 2009): 501-517, <https://doi.org/10.1080/09645290903102902>.

35. Chiara Franzoni, Giuseppe Scellato, Paula Stephan, "Foreign Born Scientists: Mobility Patterns for 16 Countries," *Nature Biotechnology* 30, no. 12 (December 2012), Figure 2, <https://www.nature.com/articles/nbt.2449.pdf>; Reinilde Veugelers and Linda Van Bouwel, "Destinations of Mobile European Researchers: Europe versus the United States," in *Global Mobility of Research Scientists: The Economics of Who Goes Where and Why*, ed. Aldo Geuna (London: Academic Press, 2015), 215-237, also find that, among European-born researchers who got their PhDs in Europe, "career motivations are more strongly related to mobility to the United States." See also Susan Guthrie, Catherine Lichten, Jennie Corbett, and Steven Wooding, *International Mobility of Researchers: A Review of the Literature* (Santa Monica, CA: RAND Corporation, 2017), <https://royalsociety.org/~media/policy/projects/international-mobility/researcher-mobility-report-review-literature.pdf>.

36. While immigration difficulties are universally agreed to be important, some consider them secondary to professional considerations. For example, William Kerr argues: "Restrictive US immigration policy plays a role [in encouraging return migration], but this role is likely secondary to the attractive opportunities for many in returning home." William R. Kerr, "US High-Skilled Immigration, Innovation, and Entrepreneurship: Empirical Approaches and Evidence," in *The International Mobility of Talent and Innovation: New Evidence and Policy Implications*, ed. Carsten Fink and Ernest Miguelez (Cambridge: Cambridge University Press, 2017).

37. Han and Appelbaum, "Will They Stay," 15.

38. Hawthorne, "Attracting and Retaining," 201-202.

39. Kahn and McGarvie, "Impact of Permanent Residency." Some of the effects found in this paper are complex and non-linear (i.e. the effects of an extra year of delay likely depend on how much delay students already faced).

40. Pooja B. Vijayakumar and Christopher J. L. Cunningham, "An Indentured Servant: The Impact of Green Card Waiting Time on the Life of Highly Skilled Indian Immigrants in the United States," *Industrial and Organizational Psychology Translational Research and Working Papers*, <https://scholar.utc.edu/iopsy/2/>.

41. Vivek Wadhwa, *The Immigrant Exodus: Why America is Losing the Global Race to Capture Entrepreneurial Talent* (Philadelphia: Wharton Digital Press, 2012).

42. Sonia Paul, "In Limbo, Some Families in the US with H-1B Visas Begin to Make Other Plans," PRI, September 18, 2018, <https://www.pri.org/stories/2018-09-18/limbo-some-families-us-h-1b-visas-begin-make-other-plans>.

43. Han and Appelbaum, "Will They Stay," finds that 80 percent of international STEM graduate students who intend to leave the U.S. cited family as an influential factor in their decision. The next most common factors are "cultural reasons" (37 percent), "friends" (35 percent), and "social reasons" (32 percent).

44. Heike C. Alberts and Helen D. Hazen, "'There Are Always Two Voices...': International Students' Intentions to Stay in the United States or Return to Their Home Countries," *International Migration* 43, no. 3 (November 2005); see also Guthrie et al., *International Mobility of Researchers*.

45. Han and Appelbaum, "Will They Stay." These challenges are typically greater for students from countries whose first language is not English, such as China.

46. Jing, "Why Trump's Clampdown."

47. Wadhwa et al., "America's Loss," Figure 6.

48. There are not many instances of dual affiliations in our dataset, i.e. of people who hold simultaneous

positions in two sectors. Out of a sample of 1,000 individuals for whom we looked into this question, 48 have simultaneous affiliations with academia and the private sector, 12 with academia and government or nonprofit institutions, and 12 with the private sector and government or nonprofit institutions.

49. Catalina Amuedo-Dorantes and Delia Furtado, "Settling for Academia? H-1B Visas and the Career Choices of International Students in the United States," *The Journal of Human Resources* 54, no. 2 (Spring 2019): 401-429. Different studies come to different conclusions about how much of this "settling for academia" effect can be explained by immigration restrictions versus students' preferences (see Xiaohuan Lan, "Permanent Visas and Temporary Jobs: Evidence from Postdoctoral Participation of Foreign PhDs in the United States," *Journal of Policy Analysis and Management* 31, no. 3 (2012): 623-640; Ina Ganguli and Patrick Gaulé, "Will the U.S. Keep the Best and the Brightest (As Post-Docs)? Career and Location Preferences of Foreign STEM PhDs," NBER Working Paper Series 24838, National Bureau of Economic Research, Cambridge, MA, July 2018).

50. Michael Roach and John Skrentny, "Why Foreign STEM PhDs are Unlikely to Work for US Technology Startups," *Proceedings of the National Academy of Sciences* 116, no. 34 (August 2019), <https://doi.org/10.1073/pnas.1820079116>.

51. Roach et al., "Are Foreign STEM PhDs More Entrepreneurial?", Figure 1.

52. An alternative explanation for this finding is that foreign nationals could simply have different career preferences. However, research has consistently shown *greater*, not *lesser*, entrepreneurial ambitions among international than among domestic students, which favors the immigration regulation-focused explanation of our findings; see Roach et al., "Are Foreign STEM PhDs More Entrepreneurial?". CSET analysis of CRA Data Buddies data, available upon request, confirms that this finding also holds for graduate students in AI specifically.

53. Kahn and McGarvie, "Impact of Permanent Residency"; Roach et al., "Are Foreign STEM PhDs More Entrepreneurial?"

54. Possible explanatory factors include differences in the relative attractiveness of countries' universities and private sectors in AI, differences in general career preferences among nationals from these countries, differences in the availability of domestically trained talent, and differences in the openness of countries' universities to those trained abroad. Some of the variation may also be due to random chance, since many countries have relatively few data points.

55. Office of Information and Regulatory Affairs, "Practical Training Reform," Fall 2017, available at <https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=201710&RIN=1653-AA76>. On subsequent inaction, see Laura D. Francis, "Foreign Student Training Program Gets Little Notice From Trump (2)," *Bloomberg Law*, March 26, 2019, <https://news.bloomberglaw.com/daily-labor-report/foreign-student-training-program-gets-little-notice-from-trump-2>.

56. Office of Information and Regulatory Affairs, "Practical Training Reform," Fall 2019, available at <https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=201910&RIN=1653-AA76>. The Fall 2019 rule description is more generic than the Fall 2017: "ICE will amend existing regulations and revise the practical training options available to nonimmigrant students on F and M visas" (2019), compared to "ICE will propose this rule to improve protections of U.S. workers who may be negatively impacted by employment of nonimmigrant students on F and M visas. The rule is a comprehensive reform of practical training options intended to reduce fraud and abuse" (2017).

57. Laura D. Francis, "H-1B Program 'Alive and Well,' Latest Visa Lottery Results Show," *Bloomberg Law*, April 17, 2019, <https://news.bloomberglaw.com/daily-labor-report/h-1b-program-alive-and-well-latest-visa-lottery-results-show>.

58. The L-1 visa is used by multinational U.S. AI companies to transfer employees from foreign offices to U.S. offices; since students are already based in the country this visa category is at best indirectly relevant (e.g. if students first go abroad before coming back to the United States). The J-1 visa is used by interns, post-docs, and scholars. The O-1 visa is for individuals with “extraordinary ability,” a qualification that most recent PhD graduates do not meet (according to the current legal interpretation of the term).

59. U.S. Citizenship and Immigration Services, “Estimated Dependent Multiplier for Employment Based Visa Categories, FY2016,” 2018, https://www.uscis.gov/sites/default/files/files/nativedocuments/Count_of_Approved_I-140_I-360_and_I-526_Petitions_as_of_April_20_2018_with_a_Priority_Date_On_or_After_May_2018.PDF.

60. David Bier, “Immigration Wait Times from Quotas Have Doubled: Green Card Backlogs Are Long, Growing, and Inequitable,” *CATO Institute*, June 18, 2019, Table 4, <https://www.cato.org/publications/policy-analysis/immigration-wait-times-quotas-have-doubled-green-card-backlogs-are-long>.

61. Jennifer Hunt and Bin Xie, “How Restricted is the Job Mobility of Skilled Temporary Work Visa Holders?,” *Journal of Policy Analysis and Management* 38, no. 1 (Winter 2019), <https://onlinelibrary.wiley.com/doi/full/10.1002/pam.22110>.

62. Other benefits of citizenship (compared to permanent residency) include the eligibility to vote and the ability to apply for a green card for relatives. One common explanation for why permanent residents choose not to naturalize is that such benefits are not worth the cost and effort of the required application process. Another is that certain countries do not allow dual citizenship, meaning naturalization in the United States would require someone to give up their citizenship in their country of birth.

63. Foreign-born workers who had not previously studied in the United States would most commonly enter the U.S. labor force on H-1B, L-1, J-1, or O-1 visas. Out of those, the H-1B is by far the most numerous, but as Table 3 notes, more than half of new H-1B entrants are now former international students. We have been unable to find good data on the background of J-1, L-1, or O-1 holders, but even if none of them were previously international students—which we consider highly unlikely—they would be outnumbered by OPT and H-1B holders. For more details, see Zachary Arnold, Roxanne Heston, Remco Zwetsloot, and Tina Huang, *Immigration Policy and the U.S. AI Sector: A Preliminary Assessment* (Center for Security and Emerging Technology: September 2019), Table 1, https://cset.georgetown.edu/wp-content/uploads/CSET_Immigration_Policy_and_AI.pdf#page=14.

64. Neil G. Ruiz and Abby Budiman, “Number of Foreign College Students Staying and Working in U.S. After Graduation Surges,” *Pew Research Center*, May 10, 2018, <https://www.pewresearch.org/global/2018/05/10/number-of-foreign-college-students-staying-and-working-in-u-s-after-graduation-surges/>.

65. “F-1 Students Obtaining Another Non-Immigrant Classification: Fiscal Year 2008-2018 Approvals,” U.S. Citizenship and Immigration Services, https://www.uscis.gov/sites/default/files/USCIS/Resources/Reports/Report_-_F-1_Students_Obtaining_Another_Nonimmigrant_Classification.pdf, Figure 3. Whereas most other figures in the table are for FY2017, this percentage is available for FY2018.

66. “Characteristics of H-1B Specialty Occupation Workers: Fiscal Year 2017 Annual Report to Congress,” U.S. Citizenship and Immigration Services, https://www.uscis.gov/sites/default/files/files/nativedocuments/Characteristics_of_H-1B_Specialty_Occupation_Workers_FY17.pdf, Table 6.

67. USCIS has, to our knowledge, not released information about the educational fields that H-1B holders received their training in. We estimate that more than 35 percent of H-1B holders got their training in AI-relevant fields because roughly 70 percent of H-1B holders work in “computer-related occupations,” and, because H-1B workers are required to have degrees relevant to the job they work in, it seems very likely that at least half of these workers trained in computer science or computer engineering. See

"Characteristics of H-1B Specialty Occupation Workers," Tables 8A and 8B.

68. CSET calculations from Department of Labor PERM data (see Appendix A). Percentages indicate proportions among principal applicants, excluding dependents.

69. Neil G. Ruiz and Abby Budiman, "Number of Foreign College Graduates Staying in U.S. to Work Climbed Again in 2017, but Growth has Slowed," *Pew Research Center*, July 25, 2018, <https://www.pewresearch.org/fact-tank/2018/07/25/number-of-foreign-college-graduates-staying-in-u-s-to-work-climbed-again-in-2017-but-growth-has-slowed/>.

70. Specifically, master's students account for 57 percent of all OPT grantees between 2004-2016 (for a total of 841,000), with doctoral students accounting for approximately another 15 percent. Among master's students, 27 percent of OPT grantees had degrees in engineering and 22 percent in computer and information sciences. Among doctoral students, 34 percent of grantees had degrees in engineering and 6 percent in computer and information sciences. The data reported by Pew is not disaggregated within the field of engineering. See Ruiz and Budiman, "Number of Foreign College Students."

71. "F-1 Students Obtaining Another Non-Immigrant Classification: Fiscal Year 2008-2018 Approvals," U.S. Citizenship and Immigration Services, https://www.uscis.gov/sites/default/files/USCIS/Resources/Reports/Report_-_F-1_Students_Obtaining_Another_Nonimmigrant_Classification.pdf.

72. Neil G. Ruiz, "Key Facts About the U.S. H-1B Visa Program," *Pew Research Center*, April 27, 2017, <https://www.pewresearch.org/fact-tank/2017/04/27/key-facts-about-the-u-s-h-1b-visa-program/>.

73. Note that this data is on applicants for permanent residency, not those actually granted permanent residency. However, because the PERM process "involves a set of technical, expensive, and highly time-consuming steps [and] complex strategies that extend over a period of typically six to eight months," employers are likely to complete the process only for highly desirable employees with a strong chance of obtaining green cards and staying employed in the United States; see Anna Angel, "5 Key Considerations When Initiating a PERM Labor Certification for Your Employee," *Ogletree Deakins*, published June 9, 2017, <https://ogletree.com/insights/2017-06-09/5-key-considerations-when-initiating-a-perm-labor-certification-for-your-employee/>. For more on the permanent residency application process, see Maggio Kattar, "The Three Stages of Employer Sponsored Permanent Residence via PERM," <https://maggio-kattar.com/three-stages-employer-sponsored-permanent-residence-perm/>.

74. Michael G. Finn and Leigh Ann Pennington, *Stay Rates of Foreign Doctorate Recipients from U.S. Universities*, 2013 (Oak Ridge Institute for Science and Foundation: January 2018), <https://orise.orau.gov/stem/reports/stay-rates-foreign-doctorate-recipients-2013.pdf#page=13>. CSET plans to calculate AI-specific naturalization rates in future research pending the necessary data access.

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 - An active lawsuit by the Washington Alliance of Technology Workers arguing that the Department of Homeland Security overstepped its regulatory authority in creating OPT.
 - A proposed rule on the DHS Fall 2019 regulatory agenda making changes to the OPT program (discussed and referenced in Chapter 2 of this paper).
 - A proposed bill that would eliminate OPT, the Fairness for High-Skill Americans Act of 2019, H.R. 3564, 116th Cong. (2019).
- For more background, see Elizabeth Redden, "Is OPT in Peril?", *Inside Higher Ed*, November 26, 2019, <https://www.insidehighered.com/news/2019/11/26/lawsuit-challenges-program-allows-international-students-work-us-after-graduating>.
89. Erica L. Green, "Visa Delays at Backlogged Immigration Service Strand International Students," *The New York Times*, June 16, 2019, <https://www.nytimes.com/2019/06/16/us/politics/visas-international-students.html>.
 90. Elizabeth Redden, "Waiting for Work Authorization," *Inside Higher Ed*, June 25, 2019, <https://www.insidehighered.com/news/2019/06/25/international-students-applying-work-authorization-face-longer-wait-times>. Attorneys report that even when the rule was in place, USCIS had stopped adhering to it in recent years. Reinstatement of the formal rule would thus have to be paired with supportive guidance and, where necessary, additional resources.

91. Congress recently conducted its first backlog oversight hearing: “Policy Changes and Processing Delays at U.S. Citizenship and Immigration Services,” U.S. House Committee on the Judiciary, July 16, 2019, <https://judiciary.house.gov/legislation/hearings/policy-changes-and-processing-delays-us-citizenship-and-immigration-services>.
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94. International students in fact do sometimes start companies today, either during their OPT time or by structuring their company in such a way that they can technically be employed by it so that they become eligible for an employment visa such as an H-1B. Both of these options involve large downsides, however. The former means that students are only guaranteed residency in the United States for three years (the maximum duration of OPT), which is often too short a timeline for an ambitious entrepreneur. The latter often involves the immigrant founders having to forfeit legal ownership, which makes the prospect of starting companies less attractive. A third option is to use an O visa, but only a small number of prospective entrepreneurs will be eligible. See Pavithra Mohan, “With the U.S. Startup Visa on Hold, Immigrant Entrepreneurs Get Creative,” *Fast Company*, September 17, 2019, <https://www.fastcompany.com/90403404/what-immigrant-entrepreneurs-can-do-without-a-startup-visa>.
95. CSET interview with U.S. immigration lawyer (anonymous), August 2019.
96. For a more detailed discussion, see Arnold et al., *Immigration Policy and the U.S. AI Sector*, 17-22.
97. William R. Kerr, *The Gift of Global Talent* (Stanford: Stanford University Press, 2019), 174.
98. To obtain a labor certification from the Department of Labor, as is currently required for EB-2 and EB-3 green card applicants, sponsoring companies are required to attempt recruitment of alternative candidates for a certain period with proscribed methods, request a “prevailing wage determination” for the job they are hiring for, and submit complex paperwork. This can take months or even over a year, thereby making hiring prospective green card applicants burdensome (or, for certain short-term needs, impossible). If the Department of Labor added AI professionals (appropriately defined) to its “Schedule A” list of occupations with labor shortages, employers sponsoring AI professionals for EB-3 green cards would be exempted from the recruitment requirements. Currently, only physical therapists and professional nurses are counted at Schedule A professions; see “Permanent Labor Certification Details,” Department of Labor, https://www.foreignlaborcert.doleta.gov/perm_detail.cfm#schedule.
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100. For concerns about diploma mills and labor market pressures, see Ron Hira, “Congressional Testimony: The Impact of High-Skilled Immigration on U.S. Workers,” *Economic Policy Institute*, March 1, 2016, <https://www.epi.org/publication/congressional-testimony-the-impact-of-high-skilled-immigration-on-u-s-workers-4/>. On the possibility that automatic green cards could incentivize dual residency, analyst Matt Sheehan explains: “I’ve spoken to multiple Chinese PhDs in Silicon Valley who told me they stayed in

the United States *until* they got a green card. Once they had the security of knowing they could return to the United States any time for the next ten years, they headed back home for better opportunities.” Matt Sheehan, “Who Loses from Restricting Chinese Student Visas?” *Macro Polo*, May 31, 2018, <https://macropolo.org/who-loses-from-restricting-chinese-student-visas/>.

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www.realcleardefense.com/articles/2019/08/27/in_military-civil_fusion_china_is_learning_lessons_from_the_united_states_and_starting_to_innovate_114699.html.

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