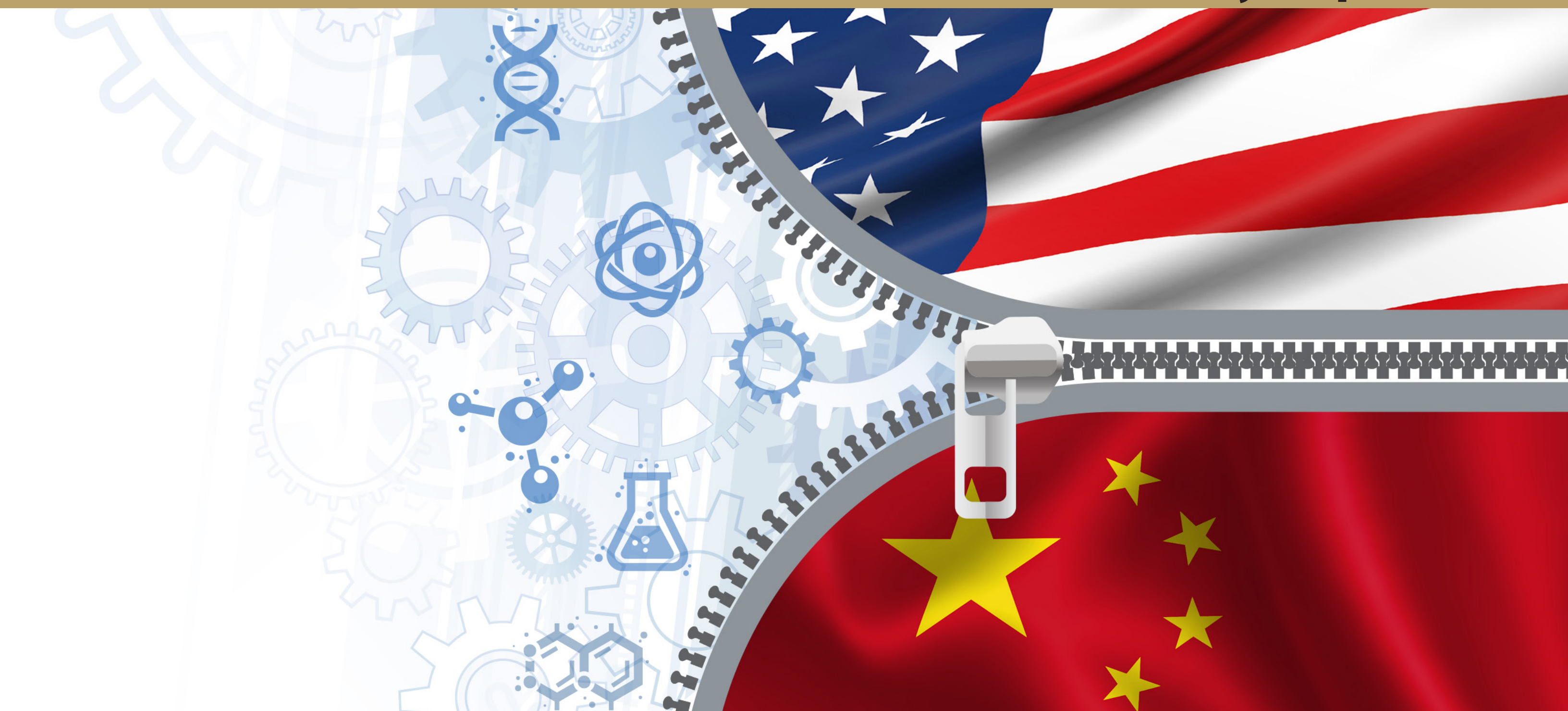
US–CHINA STEM TALENT "DECOUPLING"

Background, Policy, and Impact

National Security Report



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Contents

Figures v

Tables v

Foreword vii

Summary ix

The Problem 1

Background: US–China Academic Talent Flows 2

Chinese Students and Scholars in the United States 3

US Students and Scholars in China 6

Policy: Regulating Talent Flows 6

Past and Possible US Measures 7

Past and Possible Chinese Measures 9

Impact: Possible Consequences for the United States and China 10

Effects on US Economic and National Security 10

Effects on Chinese Economic and National Security 16

Implications for US Policy 20

Bibliography 25

Acknowledgments 35

About the Author 35

Figures

Figure 1. Post-Graduation Intention-to-Stay Rates among Chinese STEM PhD Graduates from US Universities, 2000–2017 12

Tables

Table 1. Number of Chinese Students Enrolled at US Universities by Degree Level and Field, 2018 4

Table 2. Chinese Students as a Percentage of Undergraduate and Graduate Students at US Universities, 2018 5

Table 3. Estimated Number of Chinese Scholars (Including Postdoctoral Researchers and Visiting Researchers) at US Universities, 2018 6

Foreword

This paper is part of the "Measure Twice, Cut Once: Assessing Some China–US Technology Connections" research series sponsored by the Johns Hopkins University Applied Physics Laboratory.

As competition has intensified between the United States and China, actions to disengage their technology establishments from one another have also intensified. The two countries' systems for research and development, production, and sale of cutting-edge technologies have been substantially, though by no means uniformly, commingled. More recently, there have been concerted efforts by both nations' governments to reverse some or all of that commingling. Policymakers' priorities include perceived risks to national security, worry about economic disadvantage from proliferation, and concern about uses of technologies that intentionally or indifferently may harm civil liberties or the environment.

To explore the advisability and potential consequences of decoupling, the Johns Hopkins University Applied Physics Laboratory commissioned papers from experts in specific technology areas. In each of these areas, the authors have explored the feasibility and desirability of increased technological separation and offered their thoughts on a possible path forward. Other papers in this series include:

- *Two Worlds, Two Bioeconomies: The Impacts of Decoupling US–China Trade and Technology Transfer* by Rob Carlson and Rik Wehbring
- *The History and Future of US–China Competition and Cooperation in Space* by Matthew Daniels
- *Symbiosis and Strife: Where Is the Sino–American Relationship Bound? An Introduction to the APL Series "Measure Twice, Cut Once: Assessing Some China–US Technology Connections"* by Richard Danzig and Lorand Laskai
- *An Entwined AI Future: Resistance Is Futile* by Christine Fox
- *Cutting off Our Nose to Spite Our Face: US Policy toward Huawei and China in Key Semiconductor Industry Inputs, Capital Equipment, and Electronic Design Automation Tools* by Douglas B. Fuller
- *The Telecommunications Industry in US–China Context: Evolving toward Near-Complete Bifurcation* by Paul Triolo
- *Addressing the China Challenge for American Universities* by Rory Truex

Summary

One of the most difficult and controversial questions in US policy toward China is how to manage the risk associated with Chinese students and researchers in the United States. There is no doubt that the Chinese government actively seeks to use talent based abroad to advance its technological and strategic aims. Yet openness to international talent has been a key US economic and national security asset for decades. Despite the stakes involved, the US policy debate on this question has been too high on heat and too low on light. Many analyses look at only one side of the cost–benefit equation, and arguments on both sides are often insufficiently grounded in evidence.

To help elevate this debate, this paper—one of two commissioned on science, technology, engineering, and mathematics (STEM) issues—provides an overview of the relevant questions, reviews what we know and do not know about those questions, and distills priorities and principles for analysts and policymakers. While many empirical and policy questions remain unanswered, the arguments and evidence examined in the paper suggest six takeaways.

(1) **Large-scale reductions in US-based Chinese students and researchers are, at present, unlikely to be in the US national interest.** Openness carries inevitable risk, but it also brings important benefits. There are many scenarios in which US restrictions on Chinese talent hurt the United States more than they hurt China. This assessment is based on the substantial benefits the United States derives from Chinese talent; uncertainty about whether restrictions would significantly reduce China's ability to acquire technology from abroad; and Chinese officials' fears of losing valuable talent to the United States.

(2) **Without allied coordination, reductions in US–China talent flows are unlikely to thwart China's technology ambitions.** Much of the world's cutting-edge research and development (R&D), including in emerging dual-use fields, happens outside of the United States, and other countries actively compete with the United States for international talent. Unilateral US restrictions would mainly displace, not decrease, Chinese technology transfer activities. Coordination with allies and partners should therefore be a top priority.

(3) **It is currently unclear what technologies or capabilities the US government wants to protect and whether restrictions on Chinese talent could protect them.** Lack of specificity about what needs to be protected, and the application of private sector frameworks to university research, makes it difficult to craft targeted policies and contributes to miscommunication between government and academia. Depending on the specific technology transfer concern, limits on US–China talent flows will not eliminate risk; transfers will continue to happen where alternative collection methods are available, such as cyber operations for written documentation. A successful US technology protection strategy will require clearer thinking about both ends and means.

(4) **Researchers generally pose more risk than students, and different students have very different benefit and risk profiles.** Despite their higher average risk level, researchers receive less attention than students in US policy debates. Among students, those in bachelor's and master's programs differ from PhD students in significant ways, for example whether they contribute or cost money and whether they acquire cutting-edge skills or knowledge. Sound policy requires greater recognition of such differences.

(5) **A successful risk management strategy will require emphasizing transparency and improving intelligence collection and dissemination.** Policies that stress research integrity and transparency resonate within academia and help universities manage risk. The US government needs to invest in better open-source intelligence collection and analysis and improve data integration and sharing between federal agencies. Without this infrastructure, it will be difficult to assess risk and take targeted countermeasures.

(6) **Building out the domestic talent base and diversifying international intake can prevent US dependence on Chinese talent.** Circumstances can change such that US–China talent flows are, or need to be, reduced. The United States should therefore avoid being dependent on China, or any other country, for talent. US policymakers can accomplish this goal by strengthening other talent pipelines, from abroad and especially domestically.

The Problem

In December 2017, the White House released a National Security Strategy that proclaimed a new era of great power competition with China. Its policy priorities included "review[ing] visa procedures to reduce economic theft by non-traditional intelligence collectors" and "consider[ing] restrictions on foreign STEM [science, technology, engineering, and mathematics] students from designated countries to ensure that intellectual property is not transferred to our competitors."[1] Soon after, the administration reportedly came close to banning Chinese students altogether.[2] While it ultimately decided against a ban after a high-level Oval Office meeting—reasoning that the economic costs to US higher education would be too steep—the question of what, if anything, to do about Chinese students and researchers remains at the forefront of the administration's mind.

Many acknowledge that the vast majority of Chinese students—"ninety-nine point nine percent," according to one senior counterintelligence official—do not come to the United States with malicious intent.

Security concerns about foreign talent are nothing new. In the final decade of the Cold War, there were heated debates about the scientific exchange programs with Soviet researchers that had been built up during the detente period in the 1970s.[3] After 9/11, when it turned out that one of the hijackers had entered the United States on a student visa, George Borjas, a prominent Harvard economist, called the US foreign student program "a national security fiasco."[4] Student visa rejection rates spiked in subsequent years.[5]

The most recent iteration of these debates, centered on potential economic and security threats posed by Chinese students and scholars, has been particularly intense. A prominent 2018 Pentagon report warned that "Chinese science and engineering students [in the United States] frequently master technologies that later become critical to key military systems."[6] Others, including the Federal Bureau of Investigation (FBI), link students to China's history of intellectual property theft and the dangers such theft poses to US competitiveness.[7] Many acknowledge that the vast majority of Chinese students—"ninety-nine point nine percent," according to one senior counterintelligence official—do not come to the United States with malicious intent.[8] They argue, however, that the nature of China's regime allows it to compel Chinese researchers to become intelligence collectors, or that students can engage in technology transfer "unwittingly."[9] As one US government official put it, "no Chinese student who's coming here is untethered from the state."[10]

In response, some allege that the concerns about Chinese researchers are based in whole or in part on racism; one website has labeled its coverage of recent scrutiny its "Sinophobia Tracker."[11] They point to several recent cases in which charges of economic espionage had to be dropped for lack

1 White House, *National Security Strategy*, 22.

2 Mitchell and Sevastopulo, "US Considered Ban."

3 Krige, "National Security and Academia."

4 Borjas, *Evaluation of the Foreign Student Program*.

5 Yale-Loehr, Papademetriou, and Cooper, *Secure Borders, Open Doors*.

6 Brown and Singh, *China's Technology Transfer Strategy*.

7 FBI, *China: The Risk to Academia*.

8 Gertz, "China Using Students as Spies."

9 Williams, "HASC Republicans"; and White House, *China's Economic Aggression*, 14.

10 Zengerle and Spetalnick, "Fearing Espionage."

11 SupChina, "The U.S. Sinophobia Tracker."

of evidence.[12] Some also argue that the overall threat is overblown or that the proposed cures can be worse than the disease. When the American Physical Society received a briefing in which the FBI compared the danger posed by US-based Chinese scientists to cancer (because it can do significant damage while remaining invisible for a long time), its leadership responded by noting that "an overactive immune response to cancer leads to autoimmune disease, which is potentially even more deadly."[13] Yet many also acknowledge that there are real issues. Since 2018, the academic community has launched several efforts to address technology transfer and transparency concerns.[14]

Concerns are often expressed only in very general terms, important assumptions are left unstated, and policy recommendations are not grounded in systematic evidence.

These debates about Chinese students and researchers have been thrust into the spotlight during the Trump administration. But this is not the first time they have taken place,[15] nor are they likely to disappear anytime soon. Many of the questions involved are complicated and uncomfortable. But with technology occupying an increasingly central role in a volatile US–China relationship, and with China becoming ever more aggressive in its attempts to control and leverage the "overseas Chinese," it is clear these debates are here to stay.

Unfortunately, the debate's high stakes have not been matched by a depth of relevant analysis. Concerns are often expressed only in very general terms, important assumptions are left unstated, and policy recommendations are not grounded in systematic evidence. Some focus solely on risks, whereas others only emphasize benefits, making cost–benefit assessments difficult. Strategies conceived in this way are unlikely to effectively promote—and may even actively hurt—the US national interest. This paper's goal is to provide an evidence-based overview of the core issues that US policymakers have to grapple with when crafting a strategy that balances the benefits and risks associated with Chinese talent in the United States.

Outline. The first section presents disaggregated data, including new estimates, on the number of Chinese STEM students and researchers in the United States. The next section lays out the policy tools that the United States or China could use to regulate the flow of people or ideas between the two countries' research communities. The third section analyzes the potential costs and benefits to both sides if the flow of people and ideas were substantially reduced. The final section highlights takeaways for US policymakers.

Background: US–China Academic Talent Flows

This section outlines what we know—and what we don't know—about how many Chinese students and researchers there are in the United States and vice versa.[16]

12 Kim, "Prosecuting Chinese 'Spies.' "

13 Gross et al., "Openness, Security, and APS Activities."

14 See, e.g., AAU, "Actions Taken by Universities"; Schrag et al., *Engagements in Academic Research*; and Academic Security and Counter Exploitation Program, "Annual Seminar."

15 See, e.g., US House of Representatives Select Committee, *Concerns with People's Republic of China*; and Hannas, Mulvenon, and Puglisi, *Chinese Industrial Espionage*, chap. 6.

16 This paper focuses on talent flows, setting aside other important issues, such as institutional linkages and research collaborations, that affect academic knowledge flows between the United States and China.

Key Points: US–China Academic Talent Flows

- There are an estimated 46,000 Chinese undergraduates, 41,000 master's students, 36,000 doctoral students, and at least 30,000 postdoctoral or visiting scholars currently studying or researching STEM in the United States.
- Chinese students account for 3 percent of all US STEM students at the undergraduate level and for 16 percent at the graduate level.
- Chinese students receive more attention than researchers in US policy conversations about technology transfer, even though most known examples of concerning behavior involve relatively senior scholars.
- There are around 20,000 US students in China, most of whom are exchange students. The number of US researchers in China is likely in the hundreds or low thousands.

Chinese Students and Scholars in the United States

Students. Much of the conversation about Chinese talent in the United States focuses on students. At a dinner in 2018, President Trump reportedly said of Chinese students that "almost every student that comes over to this country is a spy."[17] Robert Spalding, a former senior National Security Council official, has written that "sending students [to the United States] is part and parcel of China's goal to obtain technology."[18] Some refer to all Chinese students as potential threats,[19] but FBI documents and policymaker statements on the risks posed by Chinese students often place special emphasis on "post-graduate students and post-doctorate researchers studying [STEM]."[20] A recent White House order on visas for Chinese students and researchers also focused on graduate students, and exempted students in fields not related to China's military–civil fusion strategy.[21] This section therefore takes care to distinguish students by their specific degree level and field.

The number of Chinese students in the United States grew rapidly from around 60,000 in 2000 to around 370,000 in 2019.[22] In 2000, only 13 percent of Chinese students were undergraduate students, but today more than half are undergraduates. Table 1 shows the number of enrolled undergraduate and graduate students by field in 2018, focusing on the six main STEM fields at US universities. Publicly available data sets do not differentiate master's and PhD students, but it is possible to estimate how many of each there are using field-specific master-to-PhD enrollment rates (see the note for a methodological explanation).[23] The rightmost two columns in Table 1 show estimates for the number of master's and PhD students. Across STEM fields, there are around 46,000 Chinese undergraduates, an estimated 41,000 master's students, and an estimated 36,000 PhD students.

17 Karni, "Trump Rants behind Closed Doors."

18 Spalding, *Stealth War*, 141.

19 Gertz, "China Using Students as Spies."

20 FBI, *China: The Risk to Academia*, 2.

21 White House, "Proclamation on the Suspension of Entry."

22 The 370,000 number includes approximately 70,000 participants in the Optional Practical Training (OPT) program, which allows students to work in the United States for one to three years after graduating. These individuals are still on student (F) visas, but they no longer take classes and are not included in Tables 1 and 2. Nondegree students (e.g., those in exchange or language programs) are also excluded.

23 Available data sources on Chinese students do not distinguish between master's and PhD degrees at the graduate level, but it is possible to estimate these numbers using field-specific master-to-PhD enrollment ratios. For example, while Chinese-specific numbers are not available, we know that in computer science there are approximately four international master's students for every one international PhD student in the United States. By assuming this 4:1 ratio also holds for Chinese graduate students, we can estimate—undoubtedly with some error—how many Chinese master's and PhD students there were in computer science. This calculation is performed separately for each field because master-to-PhD ratios differ significantly by field. These ratios are not known outside of STEM fields, so the bottom two rows of Table 1 are left blank. For more details, see Feldgoise and Zwetsloot, *Estimating the Number of Chinese STEM Students*.

Table 1. Number of Chinese Students Enrolled at US Universities by Degree Level and Field, 2018

	Number of Chinese Undergraduate Students	Number of Chinese Graduate Students		
		Overall	Master's (*est.*)	PhD (*est.*)
Agricultural Sciences	1,390	1,400	511	889
Biological Sciences	4,120	5,980	1,585	4,395
Computer Sciences	11,710	16,990	13,608	3,382
Engineering	12,890	31,450	16,448	15,002
Mathematics and Statistics	12,090	12,740	7,440	5,300
Physical Sciences	3,520	7,500	892	6,608
Total STEM	45,720	76,060	40,484	35,576
Total	143,310	129,430	*Not estimated*	*Not estimated*

Sources: NSB (National Science Board), NSF (National Science Foundation), "Higher Education in Science and Engineering" (see Tables S2-13 and S2-14); estimates of Chinese master's and PhD numbers were calculated using data from the NSF "Survey of Graduate Students and Postdoctorates in Science and Engineering" (see Table 2-4). Nondegree students and those on OPT are excluded. Methodological notes are in Feldgoise and Zwetsloot, *Estimating the Number of Chinese STEM Students*.

Table 2 puts these numbers in context by showing what percentage of US STEM students are Chinese. At the undergraduate level, Chinese students make up 31 percent of international students and 3 percent of all US students in STEM. At the graduate level, Chinese students account for 37 percent of international students, close to the proportion at the undergraduate level. But because US graduate education is more internationalized, they are a larger percentage of US totals: Chinese students account for 16 percent of US STEM graduate students.[24]

Scholars. There are also a substantial number of international scholars at US universities, including postdoctoral and visiting researchers. They tend to get less attention than students in policy discussions and media coverage, but their skills and access are arguably more relevant to national security than those of most students. As Richard Lester, an associate provost at MIT, points out, "There's been a lot of talk about limits on [Chinese] students . . . but actually if you look at reports of breaches of national security at universities, most of them have involved not students but senior [researchers]."[25] A report on People's Liberation Army (PLA) scientists trained abroad estimates that about half of them "are sent overseas for short-term trips, spending up to a year as visiting scholars," with the remainder studying as PhD students, also often in a visiting capacity.[26]

Unfortunately, there is a lack of good data on international researchers in the United States.[27] Perhaps the best information available comes from the Institute for International Education (IIE), which tracks "international scholars" at US

[24] Note that this proportion is lower than that estimated in a Defense Innovation Unit Experimental (DIUx) report, which, based on a mix of aggregate statistics from several different data sources, "infer[red] that 25% of the graduate students in STEM fields are Chinese foreign nationals"; see Brown and Singh, *China's Technology Transfer Strategy*, 18. It is not clear from the DIUx report how it arrived at its 25 percent estimate, but the estimate appears to be based on a misreading of secondary sources; for a discussion, see Feldgoise and Zwetsloot, *Estimating the Number of Chinese STEM Students*.

[25] Lester, "Collateral Damage?" 59:10.

[26] Joske, *Picking Flowers, Making Honey*.

[27] Teitelbaum, *Falling Behind?*, 150–151.

Table 2. Chinese Students as a Percentage of Undergraduate and Graduate Students at US Universities, 2018

	Chinese Students as % of Undergraduate Students at US Universities		Chinese Students as % of Graduate Students at US Universities	
	% of International	% of Total	% of International	% of Total
Agricultural Sciences	44%	1%	31%	10%
Biological Sciences	24%	1%	36%	7%
Computer Sciences	33%	3%	26%	14%
Engineering	23%	2%	37%	19%
Mathematics and Statistics	72%	11%	64%	33%
Physical Sciences	42%	3%	40%	14%
Total STEM	31%	2%	37%	16%

Sources: NSB, NSF, "Higher Education in Science and Engineering" (see Table S2-13 and S2-14; for Chinese and international enrollment numbers); NSF, "Survey of Graduate Students and Postdoctorates" (see Table 2-2; for total graduate enrollment numbers); and NCES (National Center for Education Statistics), "Integrated Postsecondary Education Data System" (author calculations; for total undergraduate degree numbers). NCES data is from 2017. Methodological notes are in Feldgoise and Zwetsloot, *Estimating the Number of Chinese STEM Students*.

universities.[28] Table 3 uses this IIE data, which shows Chinese scholars made up 34 percent of all international scholars in 2018. The second column of Table 3 provides rough estimates for the number of Chinese scholars in each field by assuming that this 34 percent is true not just in general but for each specific field.[29] By these estimates, there are about 28,000 Chinese scholars at US universities across the six STEM fields. If, as seems likely, Chinese researchers are more inclined to work in STEM fields than the average international researcher, the number of Chinese researchers in STEM would be higher than 28,000.

This data refers to international scholars at US universities. This likely accounts for a large majority of international postdocs; a 2014 study estimated that 89 percent of postdocs in the United States worked at academic institutions.[30] However, significant numbers of visiting researchers may be excluded from these estimates. The Department of Energy, for example, said in 2019 that its laboratories host approximately 30,000 foreign visitors each year, of whom 10,000 are from China.[31] These scholars would not be captured in the data sources discussed above.[32] Adding those researchers to the (at least) 28,000 at universities, a reasonable approximate estimate for the total number of Chinese researchers is 30,000 or higher.

[28] IIE defines "international scholar" as "scholars on non-immigrant visas engaged in temporary academic activities and not enrolled as a student at a U.S. college or university. International scholars engaged in academic activities includes, but is not limited to, post-doctoral scholars, visiting lecturers/professors/faculty, visiting researchers, short-term scholars and visiting specialists."

[29] These numbers are almost certainly wrong—Chinese scholars are likely to gravitate to certain fields, meaning they will make up a greater than 34 percent share in some fields and a lesser share in others—but, in the absence of better information, they are nonetheless helpful as rough approximations.

[30] National Academies, *Postdoctoral Experience Revisited*, 22. The remaining 11 percent were spread across federally funded research and development centers (FFRDCs) and industry.

[31] Thomas, "DOE Barring Researchers."

[32] In 2019, there were 1,554 "visits" by Chinese nationals, involving activities such as "attendance at meetings, lectures, and demonstrations," and 9,042 "assignments," including "participation as a team member in a specific research project, including sample preparation, data acquisition, and analysis" (DOE officials' email correspondence with the author).

Table 3. Estimated Number of Chinese Scholars (Including Postdoctoral Researchers and Visiting Researchers) at US Universities, 2018

	International Scholars	Chinese Scholars (*rough est.*)
Agricultural Sciences	5,158	1,767
Biological Sciences	32,028	10,973
Computer Sciences	4,300	1,473
Engineering	22,556	7,728
Mathematics and Statistics	3,800	1,302
Physical Sciences	14,146	4,847
Total STEM	61,688	28,090
Total	135,009	46,256*

Source: IIE, "Open Doors"; Chinese researchers are assumed to make up 34.3 percent of the total scholars per field, based on the overall share of Chinese researchers in the Open Doors international scholars data.

* Not an estimate.

US Students and Scholars in China

Information on US students and scholars is much more sparse, but the limited available data makes clear that the number of US students and scholars in China is much lower than the number of Chinese students and scholars in the United States. Data from the Chinese Ministry of Education (MOE) indicates that there were around 20,000 American students in China in 2018, compared with 10,000 in 2004 and a peak of 25,000 in 2012.[33] The MOE does not provide any further information on US students' degree levels or fields of study, but data from IIE, which tracks US study abroad activity, suggests that at least half of these students (around 12,000 in 2018) are there on short-term exchange programs.[34] Most US students in China face restrictions on their activities and are instructed separately from their Chinese counterparts.

Even less is known about US researchers in China. There are anecdotal examples of US scholars with part- or full-time affiliations with Chinese universities, several of which recently made headlines due to prominent indictments. For instance, Charles Lieber, a prominent Harvard chemist, was arrested for hiding his affiliation with Wuhan University of Technology, obtained through a Chinese government talent program. Most US scholars' Chinese jobs or affiliations are undoubtedly legitimate and public, but there is no public data source that tracks how many there are. It is still relatively rare for international scholars to work in China,[35] so a ballpark estimate of US scholars working in China would likely be in the hundreds or perhaps the low thousands.[36]

Policy: Regulating Talent Flows

This section describes the policy tools the United States and China could use if either or both decided to decrease the flow of students and researchers between the two countries and what preliminary steps have already been taken.

[33] Chinese Ministry of Education, "2018 Statistics on International Students Studying in China."

[34] IIE, "Open Doors."

[35] Zwetsloot and Peterson, "China's Immigration Disadvantage."

[36] Some American researchers and faculty in China will be engaged in research activities, but others are primarily instructors, administrators, or consultants.

Key Points: Regulating Talent Flows

- US policymakers and commentators have focused on three types of policies:
  - (1) Visa restrictions, which could take the form of enhanced screening, selective restrictions, or wholesale bans on Chinese students and researchers. Limited restrictions have already been imposed, though their exact scope is unclear.
  - (2) Requirements on federal funding to universities, focused either on increasing transparency or on restricting access to government-funded research projects. Actions have so far focused on reporting requirements and enforcement.
  - (3) Reforms to the export control system that would weaken or remove exemptions for research done at US universities. For now, such reforms appear unlikely.
- Chinese government measures to reduce US–China talent flows could involve:
  - (1) Selective emigration restrictions on researchers working in sensitive areas or fields where China has reached the research frontier. There is already some evidence of this happening today, though it is unclear to what extent.
  - (2) Broad emigration restrictions on students or researchers seeking to go abroad. China has already threatened individual universities and smaller countries with such restrictions, but it appears unlikely to do so with the United States.

Past and Possible US Measures

Visa-related measures. Visa restrictions can take several forms. First, the US government can tighten preexisting, case-by-case screening processing by evaluating applicants more closely and decreasing acceptable risk thresholds. This approach can lead to higher rejection rates and processing delays, as was the case after 9/11.[37] Some tightening in US screening of Chinese students and researchers has already taken place. In 2019, a survey of a group of more than one hundred mid-degree Chinese aerospace engineering students found that around 70 percent had not been able to return to the United States after a trip home because of screening-related delays.[38] By increasing uncertainty and hassle, some argue that tighter screening could deter Chinese students from applying to US universities in the first place.

Second, visa applicants with certain backgrounds could be barred automatically, instead of being judged on a case-by-case basis. This appears to be the approach taken by a White House proclamation in May 2020, which bars students and researchers who have been affiliated with Chinese entities that contribute to China's "military–civil fusion" strategy, though the proclamation left many of the key concepts undefined.[39] Reports suggest the proclamation may affect 3,000 to 5,000 Chinese applicants per year.[40] Others propose much wider restrictions; one bill would block all Chinese graduate students in STEM fields.[41] Approximately 76,000 students currently in the United States would have been barred by this policy (Table 1). Finally, the US government could stop issuing visas

[37] Yale-Loehr, Papademetriou, and Cooper, *Secure Borders, Open Doors*.

[38] Feng, "Visas Are the Newest Weapon." These delays are likely partly the result of Chinese graduate students studying in certain "sensitive fields" having their visa duration shortened from five years to one year in 2018, requiring annual reapplications. The State Department has said that these measures "do not affect the ability of Chinese applicants to apply for or receive visas to study in the United States." See *Hearing on Student Visa Integrity*, Ramotowski responses.

[39] White House, "Proclamation on the Suspension of Entry."

[40] Spetalnick and Pamuk, "U.S. Planning to Cancel Visas." It is difficult to assess the order's likely impact because its central concept, "military–civil fusion," is difficult to define and operationalize. A broad definition of "military contributions" could include nearly all elite universities in China; see, e.g., Joske, *China Defence Universities Tracker*.

[41] Cotton, "Bill to Restrict Chinese STEM Graduate Student Visas."

The importance of federal funding provides agencies with leverage that they could use to influence US universities' training and hiring practices.

to Chinese students and researchers altogether. This, at least with respect to students, is reportedly what the Trump administration considered but decided against in 2018.

Funding-related limitations. A second category of possible restrictions involves requirements or limits written into government grants and contracts. About 29 percent of PhD students and 52 percent of postdocs in STEM fields at US universities are primarily funded through federal government money. The government also funds more than 50 percent of US academic R&D.[42] While international students and researchers are generally ineligible for direct fellowship support, principal investigators at US universities can hire foreign nationals for assistantships and postdoctoral positions funded by federal research grants.[43] The importance of federal funding provides agencies with leverage that they could use to influence US universities' training and hiring practices.

In recent years, federal science funders—primarily the National Institutes of Health (NIH), NSF, and the Departments of Defense and Energy—have taken steps to address growing concerns about what has come to be known as "research security."[44] So far, the focus has been on enhancing reporting requirements and on investigating researchers for failure to disclose affiliations with Chinese institutions or talent programs.[45] Charles Lieber, for example, was indicted not for accepting Chinese funds—which the FBI has made clear is "not illegal"—but for failing to report this funding source on Department of Defense grant applications.[46] Some policymakers want to go beyond this focus on reporting requirements. One legislative proposal, for example, would limit Chinese students' participation in federally funded research projects designated as "sensitive."[47] The bill currently seems to have little chance of passing, but it illustrates a type of measure that could be adopted if US–China tensions escalate further.

[42] For funding sources, see NSF, "Survey of Graduate Students," Table 3-1 (for PhDs) and Table 3-2 (for postdocs). On R&D happening in academia, see NSF, "Higher Education Research and Development Survey."

[43] Principal investigators are sometimes thought to prefer foreign researchers to domestic ones, especially for postdoctoral positions, because they are thought to stay in the job longer and to accept lower salaries and longer work hours. Teitelbaum, *Falling Behind?*, 168–169.

[44] For an overview, see, e.g., Redden, "Science vs. Security." As of July 2020, the NSF reported it had taken action in sixteen to twenty cases in which foreign ties were not properly reported, while the NIH said it had identified 399 grantees of concern. The NIH contacted the institutions for 189 scientists, of whom 54 subsequently resigned or were terminated. See Silver, "US National Science Foundation Reveals First Details"; and Lauer, "ACD Working Group on Foreign Influences."

[45] The NSF has also created a chief of research security position. The White House Office of Science and Technology Policy is leading a Joint Committee on the Research Environment to coordinate research security efforts across the federal government. There are also some exceptions to this focus on disclosure. The Department of Energy, which directly employs many more researchers than other science-focused agencies, has barred employees and contractors from participating in Chinese talent programs, but it has not applied these restrictions to its grantees. The Department of Defense has also begun tying restrictions to its language grants, but these have focused on Confucius Institutes, not on individual researchers. The Department of Education is investigating funding for US universities from Chinese institutions.

[46] *Hearing on Securing the U.S. Research Enterprise from China's Talent Recruitment Plans*, Brown testimony.

[47] Specifically, the Protect Our Universities Act, a bill introduced in early 2019, would charge federal agencies with creating lists of "sensitive" research topics and questions. For any federally funded project designated as sensitive, universities would have to limit participation by Chinese (as well as Russian and Iranian) students until they pass a government background check.

Export control–related measures. Under US law, the transfer of technical information, source code, and so forth to a temporary resident of the United States is "deemed" an export even if no technology leaves US soil. But for any export controls to affect students and researchers, the US government would have to overturn how it treats academic research for export control purposes.[48] Currently, the "fundamental research exclusion" (FRE), which exempts from controls any academic research that is intended to be published, means that most university-based research cannot be export controlled.[49] The FRE is based in National Security Decision Directive (NSDD) 189, a Reagan administration executive order that states that US policy is for the products of fundamental research to remain unrestricted "to the maximum extent possible" and that "where the national security requires control, the mechanism for control of information . . . is classification."[50]

A bipartisan Senate investigation on Chinese threats to the US research enterprise, released in November 2019, calls for the administration to "consider updating NSDD-189" and to impose export controls on "areas of fundamental research" as deemed "appropriate and necessary."[51] Others have pushed back against this idea, arguing that, as the JASON advisory group put it in a December 2019 report, "it is neither feasible nor desirable to control areas of fundamental research beyond the mechanisms put in place by NSDD-189."[52] Past pushes to reform deemed export controls and the NSDD-189 have generally not led to significant change.

Past and Possible Chinese Measures

The main way the Chinese Communist Party (CCP) could reduce the flow of talent and ideas between China and the United States is by placing restrictions on its own citizens seeking to go abroad.[53] Such restrictions could be either targeted or broad.

Targeted emigration restrictions. Targeted restrictions would focus on those possessing specific cutting-edge skills or knowledge. Reporting by the *South China Morning Post* indicates that there are already instances of Chinese scientists with specific skills being discouraged from leaving the country "because [Chinese] authorities feared they would leak technical secrets to overseas rivals." One example is Shao Yangyang, a PhD graduate of the Shanghai Institute of Plant Physiology and Ecology, who was reportedly " 'persuaded' to drop her application for a postdoc position at a competing laboratory in New York."[54] It is unclear whether this was an isolated case or whether this reflects a deliberate

48 Whether academic researchers would be affected would also depend on whether their work is related to any technologies listed on the control lists of the Departments of Commerce and State. In late 2018, Commerce began a congressionally mandated evaluation to determine which "emerging" and "foundational" technologies, if any, should be added to its control list. It is unclear whether any changes to the list will actually be made.

49 National Academies, "Export Control Regulations."

50 NSDD-189 defines "fundamental research" as "basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community." See White House, *National Security Decision Directive 189*.

51 US Senate Permanent Subcommittee, *Threats to the U.S. Research Enterprise*, 12.

52 JASON, *Fundamental Research Security*, 32.

53 China could also place further limits on incoming US students and researchers. This would not be unprecedented; China has long denied visas to many US researchers, often for political reasons, and foreign students in China already face many restrictions. Indeed, American officials and commentators cite "reciprocity" as one of the justifications for increased scrutiny of Chinese researchers' visas. However, the number of US students and researchers in China is comparatively small, and most known cases of visa denials involve non-STEM researchers (e.g., political scientists, historians), and the Chinese government clearly places a priority on recruiting international STEM talent. It therefore seems unlikely that China would try to reduce the number of incoming US students or researchers in STEM fields.

54 Chen, "China's Brain Drain."

policy choice.[55] But, as more Chinese research labs reach the forefront of their fields, the practice could become more widespread.

Broad emigration restrictions. Broad restrictions would affect larger groups of Chinese students or researchers. When political tensions rose between China and Australia in 2017 and 2020, the Chinese government signaled it might restrict the flow of students to Australia, whose universities are significantly more dependent on Chinese students than those in any other country.[56] Threats have also been directed at individual universities, for example those that host the Dalai Lama on campus.[57] These threats are made for coercive purposes, not to reduce talent flows per se—but if they are carried out, talent flows would be reduced nevertheless. Still, it seems unlikely, though not impossible, that such threats would be used against the United States, which is both too powerful and too popular as a place of study among the Chinese elite for the threat to be effective.

Impact: Possible Consequences for the United States and China

This section examines the potential economic and national security impacts of decreasing the number of Chinese students and scientists in the United States. It considers this question first from a US perspective and then from a Chinese perspective.[58]

Effects on US Economic and National Security

Benefits Associated with US-Based Chinese Talent

Chinese students and researchers can support US competitiveness in at least three ways: through their contributions to US universities' revenue, to US science and innovation, and to US national security.

University revenues. One much-discussed economic benefit is the revenue that US institutions gain from Chinese students, which is estimated to be around fourteen to eighteen billion dollars per year.[59] But while Chinese students are typically characterized as a fiscal boon for universities, whether they are in fact a source of revenue depends on students' degree level and university.

At the undergraduate level, 84 percent of international students use personal funds to pay for tuition; 9 percent were funded primarily by their US institutions, and 6 percent by a foreign government or university.[60] At the master's level, international students also mostly pay their own way.[61] However, many international PhD students and postdocs are funded through federal research grants, as noted in the section on policy, and much of the remainder are funded by universities: 91 percent of STEM PhD students and 89 percent of postdocs are supported by either institutional (university) funds or federal research funds.[62] In short, while bachelor's and master's students can be sources of revenue, PhDs

[55] There are several other known cases of restrictions on emigration, but they mostly involve researchers who worked on military-related projects.

[56] Babones, *China Student Boom*; and Ross, "China Warns of Student Boycott."

[57] Fischer, "For American Colleges."

[58] The focus is on science and technology, thus mostly setting aside issues related to soft power and societal influence, another important theme in US policy discussions around Chinese students.

[59] See IIE, "Open Doors"; and Choudaha, *Beyond $300 Billion*, 14.

[60] IIE, "Open Doors." Note that these numbers are for international students as a whole; China-specific numbers for US students are not available, but data from the Chinese Ministry of Education suggests the vast majority of Chinese undergraduates and master's students based abroad are self-funded.

[61] IIE, "Open Doors."

[62] For funding sources, see NSF, "Survey of Graduate Students," Table 3-1 (for PhD students) and Table 3-2 (for postdocs).

Key Points: Effects on US Economic and National Security

- There are three categories of benefits the United States derives from attracting and retaining Chinese students and researchers:
  (1) Chinese students are often said to be an important revenue source for US universities. In reality, this is true only for bachelor's and master's students.
  (2) Chinese talent contributes to US science and innovation, both during their studies and afterward. In nearly all STEM fields, data suggests 85–90 percent of Chinese PhD students stay in the United States after graduating.
  (3) In fields with labor shortages, the presence of Chinese talent in the United States encourages US companies to do more R&D at home and eases government hiring of domestic talent. However, contrary to popular perception, not all STEM fields have labor shortages.
- There are two categories of costs, which have to be weighed against these benefits:
  (1) Chinese students and researchers may "crowd out" domestic STEM talent. This appears most likely to happen in PhD and postdoc programs, although evidence is mixed. In contrast, at the bachelor's and master's level, international enrollments generally subsidize additional domestic enrollments.
  (2) Chinese talent facilitates the transfer of technology from the United States to China. It is unclear, however, to what extent reducing the number of Chinese students and researchers would hurt China's ability to acquire technology.

and postdocs can be a cost. Harvard, for example, has said it "spends approximately $20 million annually" to support Chinese PhD students.[63]

Whether Chinese students are a source of revenue, even at the bachelor's and master's level, can also depend on the type of university. At public universities, where tuition for international students is much higher than for domestic (in-state) students, they indeed bring in income.[64] But the same is not always true for private universities, which do not charge different tuition rates based on nationality and which, at least at more elite universities, often provide need-based scholarships. An MIT official explained that "we lose money on foreign [including Chinese] students, and that's why we can't take more . . . we have to cap them."[65] About 70 percent of Chinese undergraduates are at public universities.[66]

Science and innovation. The second way the United States could derive economic benefits from Chinese students and researchers is through their contributions to US science and innovation. Indeed, universities often argue that they recruit and accept Chinese students—especially at the PhD and postdoc levels—not for revenue but simply because they are highly talented.

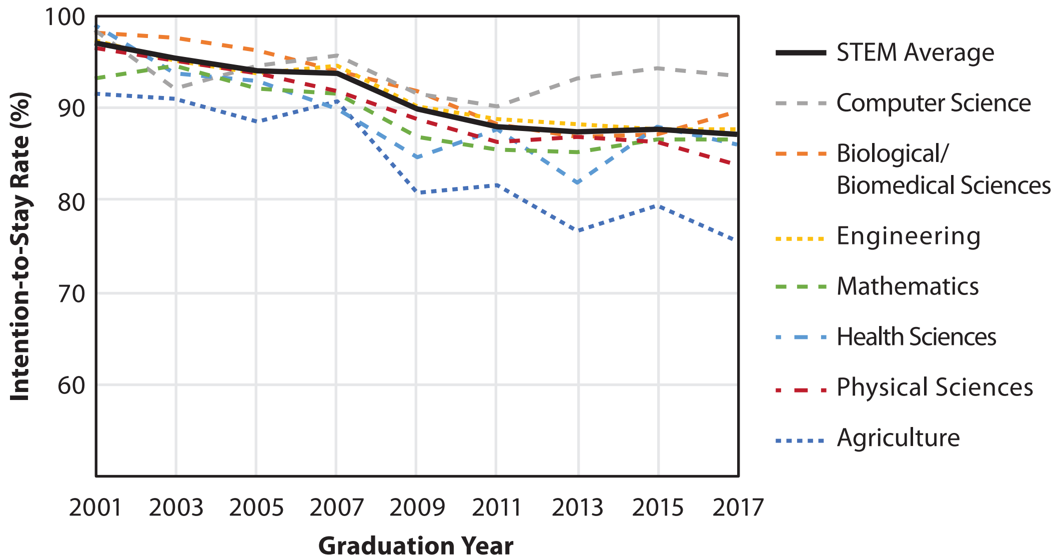
The evidence suggests Chinese students' scientific contributions are significant. Economists have found that "international graduate students and

63 Kirby, "Why Do So Many Chinese Students?" 223.

64 Choudaha, "Are International Students 'Cash Cows'?" There are few data showing to what extent public US universities have become financially dependent on international students. Some have questioned whether international students add to even public universities' net tuition revenue at all; see, e.g., North, "Foreign Students Do Not Help the Economy." The quantitative evidence is relatively thin on both sides of this argument. Universities' behavior is perhaps the best indication of Chinese students' fiscal importance. One public university, for example, has taken out insurance against revenue drops resulting from drops in Chinese enrollments; see Yu and Liu, "Chinese Students and US Universities."

65 Lester, "Collateral Damage?" 56:40. It is unclear how many private universities provide need-based scholarships to international students. Anecdotally, many private universities still see international students as an important revenue source.

66 Author calculations based on IIE data. At the graduate level, 50 percent of Chinese students are at a public institution; IIE does not separate master's and PhD students.



Source: Zwetsloot, Feldgoise, and Dunham, *Trends in U.S. Intention-to-Stay Rates*, based on NSF data.

Figure 1. Post-Graduation Intention-to-Stay Rates among Chinese STEM PhD Graduates from US Universities, 2000–2017

postdocs . . . play lead roles in university research."[67] In engineering fields and computer science, more than two-thirds of US graduate students are international, with China being the biggest source.[68] One study, which compared the quality of US PhD students by country of origin, found that Chinese students' work was better than that of any other group and that they "perform about as well as the awardees of the NSF doctoral fellowship program—America's best and brightest in science and engineering." The authors argue this is because they represent China's crème de la crème: Chinese PhD students who get accepted to US programs mainly did their undergraduate work at a "very restricted set of extremely selective Chinese universities."[69]

Another important question from an innovation perspective is whether Chinese students and researchers actually stay in the United States after graduating. Most of a researcher's contributions are made after they complete their training. If Chinese researchers are educated in the United States but then leave to work elsewhere—possibly at companies competing with their American counterparts—the result may be a net loss to US innovation and competitiveness. As one expert described US policymakers' concerns, "Why should American universities be training China's top minds in things like AI [artificial intelligence] when they will then just compete with the US globally?"[70]

Contrary to widespread concerns about a "reverse Chinese brain drain," the data that exists on this question shows high and stable stay rates among Chinese graduates.[71] Figure 1 shows the percentage

67 Black and Stephan, "Economics of University Science," 156.

68 Zwetsloot, Heston, and Arnold, *Strengthening the U.S. AI Workforce*.

69 Gaulé and Piacentini, "Chinese Graduate Students," 698.

70 Fischer, "Why US Universities."

71 Unfortunately, data on the post-graduation stay rates of Chinese students are available only at the doctoral level. While ideally stay-rate data would also cover bachelor's and master's students, PhD students are the most highly educated subset and they make up a significant portion of US-trained Chinese talent; estimates in Table 1 suggest that there are around 36,000 Chinese STEM PhD students at US universities, accounting for a little under half of Chinese graduate students and a little under one-third of all Chinese students in STEM fields. The most recent PhD graduation cohort for which data are available is in 2018; it is currently unknown whether stay rates may have

of Chinese PhD graduates who intend to stay in the United States immediately after graduation, based on data from an annual NSF census of US PhD graduates. While intention-to-stay rates decreased slightly between 2000 and 2010, in recent years stay rates have held steady between 85 percent and 90 percent in most STEM fields. Other studies show this data on intentions correlates strongly with actual stay rates. One study, which used manually collected career data on PhD graduates in AI, found similar results; five-year stay rates among Chinese AI PhD graduates were around 90 percent.[72] Another study, using data from a separate NSF survey, found that ten-year stay rates among Chinese PhD graduates in science and engineering were around 85 percent.[73] The vast majority of Chinese PhD graduates thus go on to teach, research, and innovate in the United States upon graduation.

National security. Related to but separate from these economic benefits are possible national security benefits. For example, US-based Chinese researchers can improve US understanding of scientific developments within China, which is valuable from an intelligence perspective. Yet Chinese citizens, like other foreign nationals, typically cannot work directly on national security technologies—at least until they naturalize—because much of this work requires security clearances available only to citizens. Still, the presence of Chinese talent can also bolster US national security indirectly.

In fields where there are domestic labor shortages, and so long as post-graduation stay rates remain high, Chinese students and researchers can contribute to national security in at least two ways.[74] First, their presence could decrease tightness in the overall labor market and thus ease government hiring of domestic talent in national security–relevant fields like AI. Second, their presence encourages US companies to keep their R&D operations at home; economists have found that US labor shortages drive American multinationals abroad, including to China, in search of R&D talent.[75] If having US-based Chinese talent means fewer US companies doing R&D in China, this could, on net, be positive from a technology transfer perspective.[76] However, while there is good evidence for labor shortages in certain emerging fields such as AI, there do not appear to be shortages in other STEM fields, such as many of the life sciences.[77] The magnitude of Chinese researchers' contributions will thus vary by field.

Most of these benefits—contributions to university revenue, to US science and innovation, and to national security—apply not just to Chinese but to all international talent. China is simply the largest and fastest-growing source of international research talent in the United States. India and South Korea, the second- and third-largest sources of international students at US universities, provide 202,000 and 52,000 students respectively, compared to China's 370,000.[78] Chinese students went from

decreased in subsequent years. For a discussion of data sources on the post-graduation stay rates of international students in the United States, see Zwetsloot et al., *Keeping Top AI Talent*.

72 Zwetsloot et al., *Keeping Top AI Talent*, Figure 7.

73 Finn and Pennington, *Stay Rates of Foreign Doctorate Recipients*.

74 Several other arguments have been made about the national security benefits from having Chinese STEM researchers. While there is no space to go into them here and the evidence for some is thin, they include possible downstream diplomatic benefits if formerly US-trained students or researchers get into positions of power, intelligence value derived from a better understanding of Chinese scientists' interests and work, and a greater understanding of China among US citizens.

75 Branstetter, Glennon, and Jensen, "IT Revolution."

76 On policymaker concerns about US companies doing R&D in China, see, e.g., *Hearing on Risks, Rewards, and Results*.

77 On labor shortages in AI, see Zwetsloot, Heston, and Arnold, *Strengthening the U.S. AI Workforce*. On debates about labor shortages in STEM fields more broadly, see Teitelbaum, *Falling Behind?*; Stephan, *How Economics Shapes Science*; and Nager and Atkinson, *Ten Myths*.

78 IIE, "Open Doors."

accounting for about 10 percent of US international students in 2005 to more than 30 percent in 2019—had it not been for Chinese students, overall international enrollments at US universities in 2019 would have fallen compared to prior years.[79]

Costs Associated with US-Based Chinese Talent

There are also possible costs or risks associated with US-based Chinese students and researchers: the crowding out of domestic talent and technology transfer to China. These have to be weighed against the potential benefits outlined above.

Crowding out domestic talent. One possible cost is Chinese students and scholars "crowding out" domestic talent from STEM fields. In discussing the possible benefits above, there was an implicit assumption that if a Chinese student or researcher were no longer present, they would not be replaced by someone else. If they would be replaced—especially by someone who is equally talented—then the "counterfactual" contribution of that Chinese student or researcher might not be significant, and many of the possible benefits discussed above would be moot.

This argument can be applied to all international talent, but security concerns have made it especially salient for Chinese citizens. For example, a recent paper arguing that foreign students and scholars undercut national security states that US universities "are contributing to [the] withering away of native capacity at the expense of many nationalities whose governments are actively hostile to, or global competitors of, the United States." The paper suggests universities do this because they "recognize the monetary benefits of accepting foreign students."[80]

The evidence on this argument is mixed. First, as noted above, PhD students and postdocs are generally not revenue sources for universities, and elite private universities lose money on international students. Universities emphasize that they recruit students and researchers primarily for merit and that China is simply a large source of high-quality talent, although in certain cases—especially at the bachelor's and master's levels at public institutions—revenue motivations undoubtedly play a role as well.[81]

Second, scholars disagree about whether international students "crowd out" domestic students.[82] Some economists have found evidence in favor of the idea, whereas others have found evidence against it.[83] A recent literature review suggests that crowding out is most likely to happen at the PhD and postdoc levels, because those slots are expensive for universities to fill and their number cannot easily be increased, but even at these levels evidence is mixed. In contrast, at the bachelor's and master's levels, international enrollments tend to "crowd in" domestic enrollment—more international students mean more revenue, which allows programs to expand and bring in more domestic students as well.[84] Economists also note that, for many American students, high-paying fields like law and business are simply more attractive than STEM fields. Even if international enrollments drop significantly, it is unclear to what extent domestic STEM enrollments would increase.[85]

79 Zhou, "Decline of New International Students."

80 Cadman, *U.S. Foreign Student and Exchange Visitor Policies*, 1.

81 Usher, "Has President Trump Scared Away?"

82 Crowding out can happen in one of two ways. One is direct: assuming a fixed number of enrollment slots, adding an international student means losing a domestic one. The other is indirect: foreign talent can create slack in a labor market, decreasing wages and job opportunities, thereby making certain fields less attractive for prospective students.

83 See, e.g., Borjas, *Evaluation of the Foreign Student Program*; Orrenius and Zavodny, "Does Immigration Affect?"; and Shih, "Do International Students Crowd-Out?"

84 Kerr, *Gift of Global Talent*, 86–94; and Chen, "Are Public Universities Still Public?"

85 Black and Stephan, "Economics of University Science," 157–158.

Technology transfer. Another category of possible costs involves the transfer of technology to China in service of Chinese companies or the country's military and security services. On this front, there can be little debate about the CCP's intentions. It is clear from official documents and statements that the CCP intends to use students and researchers abroad for technology transfer, and it has built an extensive policy infrastructure, including but not limited to talent recruitment initiatives such as the Thousand Talents Program, in pursuit of this goal.[86] Many of these policies are in conflict with traditional research norms, for example by requiring nondisclosure of professional affiliations or funding sources.[87] Similarly, there is little doubt that technology transfer activities have contributed to China's growing economic and military power.[88]

It is unclear whether China would be more or less competitive if fewer of its researchers were based abroad—where they could potentially transfer technology—and more worked at home—where they could contribute full-time to domestic education and innovation.

There is more disagreement, however, about how successful the Chinese government's attempts to leverage overseas talent have been. As discussed in more detail below, Chinese officials often lament China's loss of talent to the United States. Having students and researchers based abroad could be positive from a technology transfer perspective, but it also carries potential costs. It is unclear whether China would be more or less competitive if fewer of its researchers were based abroad—where they could potentially transfer technology—and more worked at home—where they could contribute full-time to domestic education and innovation.

Another question for US policymakers is whether reducing the number of US-based Chinese students and researchers would significantly reduce technology flows to China, or whether many of the same transfers would simply happen through other means. One prominent alternative to person-based transfer is cyberattacks. Such attacks can yield nonpublic data, email exchanges, and notes on ongoing projects. Where possible, China much prefers to use cyber operations rather than human assets for technology acquisition.[89] CCP-linked hacking groups are already known to have penetrated accounts and networks at more than two dozen US universities and medical research centers.[90] Academics also note that most products of university research—data, code, findings, and so forth—are published online, meaning they can be accessed anywhere. Cyberattacks and open-source exploitation will proceed regardless of whether US–China talent flows are reduced.[91]

One component of technology that can be transferred exclusively through talent flow is "tacit knowledge." Such knowledge cannot be taught purely through oral or written description—it can be learned only through in-person instruction and trial and error. A classic example is riding a bicycle; a scientific equivalent is working with advanced equipment or learning complicated laboratory techniques.[92] Without the movement of people,

86 See, e.g., Hannas, Mulvenon, and Puglisi, *Chinese Industrial Espionage*.

87 US Senate Permanent Subcommittee, *Threats to the U.S. Research Enterprise*.

88 See, e.g., Cheung et al., *Role of Technology Transfers*.

89 Mulvenon, "Beyond Espionage," 8.

90 Volz, "Chinese Hackers"; and Lyngaas, "Chinese Spies."

91 Of course, cyber operations are often facilitated by on-premise personnel, but having on-premise personnel is not required for successful operations.

92 On tacit knowledge in science, see, e.g., Stephan, *How Economics Shapes Science*, 28–29, 66.

tacit knowledge cannot be transferred—and in fields where tacit knowledge is an important input, preventing such transfers could be significant.[93] For example, it is likely that Chinese scientists who worked in US laboratories transferred important tacit knowledge about nuclear weapons and delivery systems to China when they returned; according to the *South China Morning Post*, "so many scientists from Los Alamos [National Laboratory] have returned to Chinese universities and research institutes that people have dubbed them the 'Los Alamos club.'"[94] In sum, whether reducing US–China talent flows will meaningfully reduce technology transfer depends on which specific aspect of technology (research findings, data, tacit knowledge, etc.) one is concerned about.

Finally, the extent to which US restrictions on students and researchers would hamper China's technological ambitions also depends on how other countries would respond. The United States does not have a monopoly on cutting-edge research, and many top Chinese scientists who have spent time abroad got their training not at US universities but in other technologically advanced countries. If these countries respond to US restrictions by competing to recruit the affected Chinese students and researchers—as seems likely—then US restrictions would simply displace, not reduce, any technology transfer activities.[95] A group of Canadian policy experts recently argued that "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."[96] Western scholars in China observe that Chinese students "are already looking to the European Union as a more attractive place . . . because it is seen as more open and accepting of Chinese collaborations than the United States. . . . If visa problems continue, Chinese researchers will simply try to strengthen their relationships with researchers in Europe."[97]

Effects on Chinese Economic and National Security

Benefits from Having Students and Researchers in the United States

China first started sending students and scientists abroad in large numbers in the late 1970s, as part of broader reforms aimed at opening up the economy. From the beginning, the goal was to "catapult China into the top ranks of the global scientific community" by absorbing technical know-how from abroad.[98] Deng Xiaoping, who was responsible for the opening up policies, initially hoped 90 percent of those who went abroad would come back.[99]

Things didn't go as planned. At first, most Chinese researchers who went abroad were mid-career scientists selected by the government who, because they had families and jobs at home, almost always returned. But after further liberalization allowed Chinese citizens to go abroad on their own initiative, return rates dropped precipitously, leading to

93 In an essay titled "Why China Has Not Caught up Yet," Gilli and Gilli argue that individual and organizational tacit knowledge are key to the United States' persistent technology advantage over China. They mainly focus on defense contractors and complex military systems. Further analysis is needed to assess whether the same is true for research within some or all academic fields. One instructive study of a Japanese terrorist group's attempt to create biological and chemical weapons found that tacit knowledge is much more important in biology than in chemistry; see Danzig et al., *Aum Shinrikyo*.

94 Chen, "America's Hidden Role." On tacit knowledge in nuclear weapons design and missile technology, see, e.g., MacKenzie and Spinardi, "Tacit Knowledge, Weapons Design"; and Gormley, *Missile Contagion*.

95 Zwetsloot, *China's Approach to Tech Talent Competition*.

96 Asia Pacific Foundation of Canada, *Technology and Geopolitics: Navigating a Future*, 9.

97 Silver, Tollefson, and Gibney, "US-China Political Tensions."

98 Zweig and Chen, *China's Brain Drain to the United States*, 7.

99 Simon and Cao, *China's Emerging Technological Edge*, 219.

Key Points: Effects on Chinese Economic and National Security

- China accrues both benefits and costs from having large numbers of students and researchers based in the United States.
- The main benefit is technology transfer. The CCP has built up an extensive policy infrastructure for attracting science and engineering talent from overseas. Chinese returnees have played an important role in building up the country's technology base.
- The main cost is loss of talent. Chinese government policies and statements suggest dissatisfaction with the status quo, especially the low full-time return rates among students and researchers overseas.

concerns about "brain drain" and heated policy debates within CCP leadership about whether to limit the outward flow of talent. The party's general secretary favored continued openness, arguing in 1987 that "the brain drain was in reality a case of 'storing brainpower overseas' that would be useful in the future."[100] This argument ultimately won out, and attracting returnees has been a mainstay of Chinese talent strategy ever since. As part of this strategy, the government has built an extensive policy and intelligence infrastructure to spot and recruit scientists working in high-priority fields abroad.[101]

Returnees and technology transfer. From the Chinese government's perspective, returnees are valuable primarily because they can contribute valuable technology and know-how not available domestically. Sometimes, contributions follow top-down planning: Pan Jianwei, known as the "father" of quantum science in China and himself a returnee, notes that when Chinese quantum technology research was still "relatively backward," his team "took the initiative to send students to top research groups abroad to learn related technologies," and later, they "returned back to work in China."[102] Other times, people on their own initiative seek out technology areas for which there is a domestic market in China, and which they can later commercialize in government-sponsored and technology-focused "returnee parks."[103] While technology transfer can involve illicit methods, such as cyber operations or intellectual property theft, most talent-related transfer practices are not illegal.[104]

While technology transfer can involve illicit methods, such as cyber operations or intellectual property theft, most talent-related transfer practices are not illegal.

There are two types of returnees: those who return full-time, and those who return part-time while still maintaining a position abroad. Part-time returnees are part of the Chinese government's "two bases" (两个基地) and "serving the country by multiple means" (以多种形式为国服务) strategies, developed in the 1990s and early 2000s.[105] They split their time between China and other countries, often coming to China for summers or several shorter trips per year. While full-time returnees contribute to Chinese technological progress by utilizing their

[100] Zweig and Chen, *China's Brain Drain to the United States*, 17.

[101] Hannas, Mulvenon, and Puglisi, *Chinese Industrial Espionage*, chaps. 2, 4–7.

[102] Whalen, "Quantum Revolution." Pan himself notes that, when he studied abroad in Germany, he and other Chinese researchers in quantum "had a basic commitment, to bring this technology back to [China] when the moment comes. If not, . . . how did about a dozen of us on this team all return around almost the same time in 2008? We had a very serious agreement, or say promise, that we must return and do things for the final major objective," cited in Kania and Costello, *Quantum Hegemony?*, 12. See also Joske, *Picking Flowers, Making Honey*.

[103] Zweig, Chung, and Vanhonacker, "Rewards of Technology."

[104] Hannas and Chang, *China's Access to Foreign AI Technology*, 4.

[105] Hannas, Mulvenon, and Puglisi, *Chinese Industrial Espionage*, 171–174.

skills on domestic projects, part-time returnees can use their positions abroad to provide intelligence, to facilitate international collaborations, to recruit other returnees, or to use resources from their non-Chinese employers to pursue Chinese government-directed research priorities.[106]

It is difficult to assess how successful China has been in attracting returnees or how much it has gained from them. First, as discussed above, only around 10–15 percent of Chinese STEM PhD graduates from US universities return to China, a number that does not appear to have increased recently despite CCP investments (Figure 1). However, return-rate data on other student groups—bachelor's and master's students in the United States, or those who studied abroad elsewhere—is much more sparse. And part-time return rates, or the rate at which Chinese researchers "serve the country by multiple means" from abroad, are even harder to estimate.

Second, it is difficult to assess the quality of Chinese returnees' work. On the one hand, anecdotal examples of high-profile returnee scientists and business leaders suggest China is indeed able to attract top talent. It is also clear that returnees have made important contributions, both commercially and militarily.[107] On the other hand, some studies suggest that returnees are of lower quality than those who remain abroad, and that highest-quality returnees typically come part time, not full time.[108] These studies typically focus on a small number of talent programs and the data is often a few years old, so it is hard to know how representative of current talent flows such findings are. Returnees' impact will also depend on whether they work in fields where a single key insight or skill can unlock an important technological capability, in which case even a small number of people can make a big difference. In contrast, for policymakers and agencies more concerned with overall scientific competitiveness and innovation, average returnee quality and overall quantity may matter more.

Finally, the "returnee" label is ambiguous, since many returnees leave China again within a few years. Two prominent Chinese scholars note that "attracting overseas Chinese talent back is just the first step" and that "the crucial issue is devising ways of ensuring that they stay in China." One survey they conducted among 918 returnees in 2017 showed that 68 percent wanted to go overseas again.[109] Experts have described Chinese talent efforts as "good at recruitment, bad at retention."[110]

Of the 2,800 participants in a top AI conference who received their undergraduate degrees in China, only 25 percent lived in China in 2019. And of the roughly 2,100 who lived outside of China, 85 percent were working in the United States.

Costs from Having Students and Researchers in the United States

Having students and researchers go abroad can also carry costs for China. The tension that marked Chinese policy debates in the 1980s is still alive today. Whereas having top talent go abroad can involve "storing brainpower overseas" and be a useful conduit for technology transfer, it can also stymie the development of a local research ecosystem and contribute to high-skill labor shortages. These possible costs from students going abroad continue to loom large among Chinese officials today. In 2013, after decades of government

106 Hannas, Mulvenon, and Puglisi, *Chinese Industrial Espionage*, chap. 7.

107 See, e.g., Chen, "America's Hidden Role."

108 Simon and Cao, *China's Emerging Technological Edge*, chap. 6; and Zweig, Siqin, and Huiyao, "'The Best Are Yet to Come.'"

109 Miao and Wang, *International Migration of China*, 58.

110 Lewis, *Learning the Superior Techniques*, 21.

investment in talent efforts, the head of the CCP's Central Talent Work Coordination Small Group still complained that "the number of top talents lost in China ranks first in the world."[111] This concern is also echoed in more recent books published by Wang Huiyao, a prominent advisor to the Chinese government on talent policy.[112]

Talent loss. Available evidence suggests China's talent losses could be large. One recent study looked at data on Chinese participants at NeurIPS (the Conference and Workshop on Neural Information Processing Systems), a top AI conference, between 2009 and 2018. Of the 2,800 participants who received their undergraduate degrees in China, only 25 percent lived in China in 2019. And of the roughly 2,100 who lived outside of China, 85 percent were working in the United States.[113] This large-scale talent loss has occurred despite the fact that the Chinese government has seen AI as a strategic economic and military priority since at least 2017.

Research also shows that Chinese students going abroad tend to be the best students from the best schools, and that this lowers the quality of the domestic research environments.[114] In the words of one professor at an elite university:

> Our best students are taken away by [the United States]. . . . Now what I am really worried about is that our best students choose to go to the best universities in the United States and Europe. This year, nearly 40 per cent of the undergraduates have gone and a group of master's students will also leave. So when it reaches the PhD level, someone blames us for bad training programs but how can we produce an excellent PhD with an incompetent student?[115]

Whether these talent losses outweigh the possible gains from technology transfer depends on several factors. In general, though, Chinese rhetoric and policy suggest dissatisfaction with the status quo. There are two possible issues: first, there could be too few returnees in general, and second, there could be too few full-time returnees specifically. While China does benefit from part-time returnees who can serve from "two bases" by helping transfer technology, evidence suggests the CCP is dissatisfied with the current balance between part-time and full-time returnees.

First, the China Scholarship Council has recently increased the number of scholarships it offers that require the recipient to return to China once they finish their training.[116] This shift to conditional scholarship support may reflect lessons learned from past efforts. When the Thousand Talents Program was first launched, it required full-time return and part-time participants were only allowed once officials realized there was too little interest in full-time return among those already based abroad.[117] Conditional scholarships deny outgoing students the option of remaining abroad.

Second, Chinese leaders and commentators consider private sector workforce shortages a long-term obstacle to success in high-priority technology areas, including quantum information science, biotechnology, and AI.[118] In semiconductors, Chinese assessments put its workforce shortage at more than 200,000 people.[119] Shortages are thought to be especially acute for high-end

111 *Sina*, "China Overseas Scholar Innovation Summit."

112 See, e.g., Miao and Wang, *International Migration of China*, 93; and Wang and Miao, *Talent War 2.0*.

113 Ma, "China's AI Talent Base."

114 Shen, Wang, and Jin, "International Mobility of PhD Students," 346–348.

115 Shen, Wang, and Jin, "International Mobility of PhD Students," 347.

116 Kennedy, *Conflicted Superpower*, 35.

117 Miao and Wang, *International Migration of China*, 38; and Zweig and Wang, "Can China Bring Back the Best?," 606.

118 Zwetsloot and Peterson, "China's Immigration Disadvantage."

119 *EEFocus*, "How Can Chinese Semiconductors Advance?"

jobs that require extensive experience. Part-time returnees can help transfer technical know-how, but only full-time returnees could help fill these shortages.

Third, Chinese writing suggests a desire to capitalize on recent US immigration restrictions and research security measures to bring more researchers based in the United States over to China. As one venture capitalist put it, "While the US is driving talent away, it is the perfect time for us to race to bring them back to China."[120] The deputy editor of the *China Daily USA*, a state-run newspaper, has stated that US expansion of employment-based visas "would pose a huge challenge for China, which has been making great efforts to attract and retain talent."[121] These arguments again suggest a desire for more full-time returnees and a fear that too many Chinese scientists and engineers ultimately prefer to be based abroad.

Implications for US Policy

What US policymakers should do about the considerable flow of people and ideas between China and American universities is among the most complicated and controversial questions in US–China relations today. Some in the United States consider these flows harmful to US economic and national security, especially in light of fears about technology transfer. Others consider them a positive force, emphasizing the immediate and downstream contributions of Chinese talent to US economic and scientific competitiveness. For China, there are also two sides to the debate: one that emphasizes the benefits from returnees who can bring the country closer to the technology frontier, and another that focuses on the costs of continued talent losses to the United States and other countries.

The policy conversation on this question has, unfortunately, been high on heat and low on light. Many analyses look at only one part of the problem, and arguments on both sides are often insufficiently grounded in evidence. This paper seeks to provide a broad, data-driven assessment to fill some of these gaps. While many empirical and policy questions remain unanswered, the arguments and evidence examined in the paper suggest six takeaways for US policymakers.

(1) Large-scale reductions in US-based Chinese students and researchers are, at present, unlikely to be in the US national interest.

The case for broad restrictions on Chinese students and researchers rests on the belief that those restrictions would hurt China's ability to acquire technology from abroad. But even from a purely zero-sum perspective, the relevant policy question for the US government is not whether a measure might hurt China: it is whether it would hurt China more than it would the United States. This is unlikely to be true: in most plausible scenarios, the United States would lose more from broad restrictions on US-based Chinese talent than China would.[122]

First, the United States derives significant benefits from Chinese talent, whose presence strengthens the US science and innovation ecosystem and, in fields where there are labor shortages, aids government hiring of domestic talent and prevents US companies from moving R&D abroad. Second, as discussed in more detail below, it is unclear to what extent restrictions on Chinese talent would hamper China's ability to acquire technology from abroad. Chinese officials, meanwhile, frequently lament US attractiveness to Chinese students and

120 Wong, "Tough US Immigration Policy."

121 Cited in Kennedy, *Conflicted Superpower*, 34.

122 "Broad restrictions" can be defined as measures that would target Chinese students or researchers on the basis of high-level characteristics, such as their degree level and/or broad field of study (e.g., a computer science PhD student).

researchers; the CCP would likely celebrate broad US restrictions.

Even so, the US government should continue to use targeted restrictions—those focused on specific risk factors or narrow technological capabilities—where necessary and possible, recognizing the CCP's technological ambitions and its intent to use its diaspora to fulfill these ambitions. And, if circumstances change, future shifts in US policy may be warranted. For example, economists note that the cost–benefit balance of US universities training large numbers of foreign PhD students depends on how many of them stay in the country after graduating.[123] If stay rates among Chinese PhD students—which have been between 85 and 90 percent in most STEM fields—fall significantly, the conclusions put forward in this paper could change. Further analysis, for instance of the quality and impact of Chinese returnees, would help make that determination.

(2) Without allied coordination, reductions in US–China talent flows are unlikely to thwart China's technology ambitions.

The main reason that US policymakers worry about Chinese students and researchers is that they may end up contributing to Chinese technological prowess. But much R&D in areas of concern—biotechnology, AI, and other emerging dual-use fields—takes place outside of the United States. For example, Pan Jianwei, the "father of quantum" in China, was trained not at a US university but in Germany. If other countries respond to US restrictions by recruiting the Chinese students and researchers that otherwise would have gone to US universities, technology transfer activities would simply move elsewhere instead of being stopped.

This scenario—which, absent US diplomatic efforts and major policy changes in other countries, is the default scenario today—would decrease US competitiveness without meaningfully slowing down China's technological growth. Several proposals exist for initiatives that could help achieve greater multilateral coordination, although research also points to significant obstacles to collective action that such initiatives would need to overcome.[124] Besides the United States, the top destinations for Chinese students today—Australia, the United Kingdom, Canada, Japan, and South Korea—are all US allies.[125]

(3) It is currently unclear what technologies or capabilities the US government wants to protect and whether restrictions on talent could protect them.

Technology protection in the private sector and US export control law focus on specific and known capabilities. Within academia, however, research often explores uncharted territory. In discussions about technology transfer, US officials have not been clear about whether they are mainly concerned about academic research related to specific products or capabilities—and, if so, what those specific products or capabilities are—or whether they mostly fear losing broad academic competitiveness. Defending a specific capability is a different goal from ensuring the competitiveness of a research system: while the former requires informational and physical restrictions, the latter benefits from openness. This lack of clarity, and federal agencies' frequent application of private sector language and concepts to academic research,

123 Stephan, "The 'I's Have It," 83.

124 Relevant obstacles and ideas are discussed in Imbrie and Fedasiuk, *Untangling the Web*; Kliman et al., *Forging an Alliance Innovation Base*; and Zwetsloot, *China's Approach to Tech Talent Competition*.

125 Zwetsloot, *China's Approach to Tech Talent Competition*, Table 1.

has often contributed to miscommunication between government and academia. It also makes crafting targeted protection strategies difficult.[126]

Second, not all aspects of technology are transferred primarily via talent flows, and reducing talent flows will thus only prevent certain kinds of transfers. Research findings, data, and code often diffuse through open literature. When university research involves proprietary data, code, or intellectual property—as it sometimes does—these can be obtained through cyberattacks. In other cases, however, the movement of people is necessary. The diffusion of "tacit knowledge" requires person-to-person instruction and close mentorship. Any strategy to counter technology transfer will need to distinguish between these different components of technology and the different means by which they can be transferred and protected.

(4) Researchers generally pose more risk than students, and different students have very different benefit and risk profiles.

Chinese students are often discussed in very general terms, but the evidence reviewed in this paper highlights important differences between different categories of students and researchers. Policymakers should recognize these differences when crafting a strategy around Chinese students and researchers, for example by not lumping all "graduate students" together.

[126] The boundary between academic and industrial research is blurry, especially in certain fields such as the biomedical sciences; see Mowery et al., *Ivory Tower and Industrial Innovation*. There may thus be compelling reasons to encourage or impose certain restrictions on academic research in situations where the risks associated with possible transfers are judged to be sufficiently high, just as there are limited circumstances under which academic research is regulated for safety or security reasons. However, such decisions should be made on a case-by-case basis and are likely to be the exception rather than the rule.

Undergraduate students. There are 46,000 Chinese STEM undergraduates in the United States. They represent 3 percent of total US STEM undergraduates. About 70 percent of them are at public universities, for which they are an important source of revenue. It is not known how many stay in the United States after graduating.

Graduate students. There are 76,000 Chinese STEM graduate students in the United States, representing 16 percent of total US STEM graduate students. While they are often lumped together under the "graduate" heading, there are important differences between master's students and PhD students.

> **Master's students.** The estimated 41,000 Chinese STEM master's students, like undergraduates, often pay full tuition. There is no data on how many master's students stay in the United States after graduating.
>
> **PhD students.** The estimated 35,500 Chinese STEM PhD students are almost always funded primarily by either federal research or university institutional funds. Their training often involves close mentorship and the acquisition of cutting-edge skills. Across nearly every STEM field, US stay rates among Chinese PhD graduates are between 85 and 90 percent.

Postdocs and visiting researchers. There are at least 30,000 Chinese scholars. Little public data exists on this population, though we know that international postdocs at universities are, like PhD students, mainly funded through US federal research or university institutional funds. Visiting researchers are presumably in the United States temporarily; stay rates among postdoctoral researchers are not known.

While they receive less attention in the public debate, postdocs and visiting researchers are more likely than students to pose a net cost to US competitiveness. Chinese PhD students also receive advanced training, mainly at US expense, but the fact that the vast majority stay in the country after graduating means these investments reap significant rewards. Bachelor's and master's students will generally acquire fewer cutting-edge skills and their financial contributions are important to universities. They may still represent a net benefit to US technological competitiveness even if they leave in greater numbers than PhD students.

(5) A successful risk management strategy will require emphasizing transparency and improving intelligence collection and dissemination.

The Chinese government, in its efforts to attract talent and absorb technology from abroad, has adopted several practices that violate academic norms, including nondisclosure requirements in contracts and limits on sharing and collaboration.[127] Greater emphasis on transparency and research integrity will help the US government and academia find more common ground and will help researchers and universities manage risk.[128] Greater integration of federal science agencies' application and data systems, while bureaucratically challenging, would both help enforce research integrity rules—as concerns flagged in one agency's process would automatically be visible to other agencies as well—and benefit researchers and universities by decreasing administrative requirements. The White House's Joint Committee on the Research Environment should continue prioritizing these reforms.

A targeted approach to countering technology transfer will require policymakers and individuals on the front lines—be they consular officers making visa decisions or university professors setting up research projects—to be able to accurately assess and manage risk. Federal agencies should work with universities to establish and disseminate best practices in research security and risk management. Several universities have already instituted reforms in these areas.[129] The US government should improve collection on Chinese science and technology activities—especially from open sources, which are often neglected within the intelligence community—and find better mechanisms for sharing certain findings with affected parties. To facilitate data sharing with researchers and universities and to avoid politicization, some parts of this open-source intelligence and outreach infrastructure could be located in nongovernmental entities.

(6) Dependence on Chinese talent can be avoided by building out the domestic talent pipeline and diversifying international intake.

Circumstances can change such that US–China talent flows are, or need to be, reduced. If that happens, the United States should not be in a position of dependence. Overreliance on a single external source of talent is risky for any country, but this is especially true when that source is a geopolitical competitor, as China is to the United States. However, reducing flows from that source is not the only way—nor, in most cases, the best way—to reduce dependence. Instead, countries can avoid dependence by tapping other sources of talent, both at home and abroad.

The US government's first priority should be domestic students. In some important STEM fields, such as computer science and electrical engineering, the number of domestic graduate students has not increased since 1990—all US enrollment growth in the past three decades has come from international students, whose numbers

127 US Senate Permanent Subcommittee, *Threats to the U.S. Research Enterprise*.

128 JASON, *Fundamental Research Security*.

129 Zuber, "New Review Process"; and AAU, "Actions Taken by Universities."

tripled in that period.[130] This could hamper US government hiring of technical talent, which is concerning from a national security perspective.[131] Moreover, future international student flows are not guaranteed, as COVID-19 has powerfully illustrated. Policies that are known to have helped increase domestic graduate enrollment in the past include increasing the number of available graduate fellowships and providing undergraduates with research experiences.[132]

Domestic talent alone, however, is not sufficient for the United States to compete with China, a country four times its size. International students and researchers, including those from China, contribute significantly to US science and innovation. The US government's goal should not be to reduce international or Chinese talent flows, but to increase resilience by diversifying its talent supply chain. Unfortunately, recent US trends are in the opposite direction: since 2005, the three top countries of origin (China, South Korea, and India) have gone from accounting for around one-third of international students at US universities to accounting for more than half, with nearly all growth coming from China.[133] Other countries' national strategies for higher education might offer lessons for how to reverse these trends; several of them prioritize diversification in order to avoid overreliance on Chinese students.[134]

130 Zwetsloot et al., *Keeping Top AI Talent*, Figure 1.

131 At the same time, many technical national security roles could be filled by someone with a bachelor's degree and on-the-job training. The extent to which there are graduate-degree-specific shortages in the national security workforce is currently unknown and is likely to differ across roles and technical areas.

132 Freeman, Chang, and Chiang, "Supporting 'the Best.' "

133 Zhou, "Decline of New International Students."

134 Tobenkin, "Time for a U.S. International Education Strategy?"

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