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China is Fast Outpacing U.S. STEM PhD Growth

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Executive Summary

This paper compares the STEM PhD pipelines of the United States and China. We find that China has consistently produced more STEM doctorates than the United States since the mid-2000s, and that the gap between the two countries will likely grow wider in the next five years. Based on current enrollment patterns, we project that by 2025 Chinese universities will produce more than 77,000 STEM PhD graduates per year compared to approximately 40,000 in the United States. If international students are excluded from the U.S. count, Chinese STEM PhD graduates would outnumber their U.S. counterparts more than three-to-one.

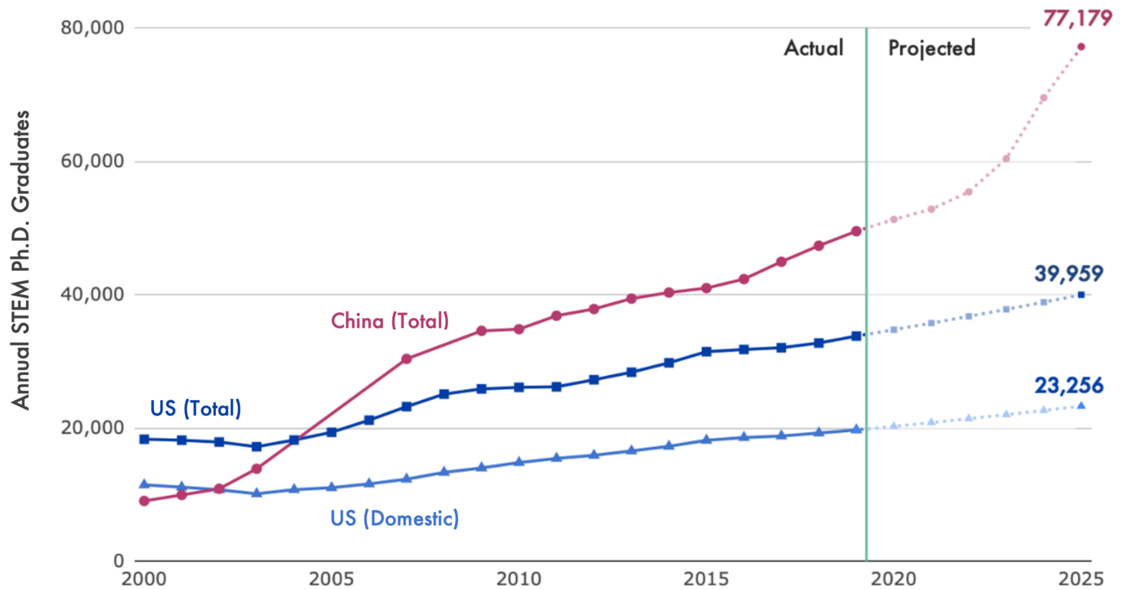
Our findings also suggest the quality of doctoral education in China has risen in recent years, and that much of China's current PhD growth comes from high-quality universities. Approximately 45 percent of Chinese PhDs graduate from Double First Class (A) universities—the country's most elite educational institutions (see Appendix D)—and about 80 percent of graduates come from universities administered by the central government. While it is possible that the growing supply of STEM PhDs in China exceeds current labor market demand, the quality and quantity of a country's doctoral graduates is an important indicator of its future competitiveness, and China's capacity to produce skilled PhD-level STEM experts appears to be growing rapidly.

Our analysis focuses on students who obtained a research-oriented doctoral degree in STEM disciplines. For the United States, this includes data on seven academic fields: life sciences, geosciences, mathematics and statistics, computer science, physical sciences, engineering, and medical sciences. For China, we include four academic fields tracked by its Ministry of Education: science, engineering, agriculture, and medicine. Historical trends and predictions can vary depending on the exact field categorization (e.g., whether the social sciences and/or the health sciences are included in graduate counts), but in all cases, Chinese PhD graduates are expected to clearly outnumber U.S. graduates by 2025.

China Is Projected to Graduate Nearly Twice as Many STEM PhDs as the United States by 2025

Figure 1 shows the annual number of STEM PhDs who graduated from universities in the United States and China (see Appendix A for underlying data). In 2000, U.S. universities awarded twice as many doctorates in STEM fields as Chinese universities, but China surpassed the United States by 2007. Over the last decade, China has steadily increased its lead in PhD production. Based on current enrollment patterns, we project that by 2025 China's yearly STEM PhD graduates will nearly double those in the United States. If compared to domestic U.S. students only, the number of STEM PhD graduates in China will be more than three times as high.

Figure 1. China projected to nearly double U.S. STEM PhD graduates by 2025



Source: National Center for Education Statistics' Integrated Postsecondary Education Data System (IPEDS) for U.S. data, Ministry of Education for Chinese data (see Appendix A).

The Chinese government views human capital as an important component of "comprehensive national power" (综合国力), and over the last two decades it has sought to expand the country's educational capacity through substantial state investment.[1] Between 2003 and 2007, for example, the government stood up more than 1,300 new PhD programs at dozens of institutions that had previously not offered doctoral programs.[2] During that period, the number of annual STEM PhD graduates in China more than doubled. Growth in the number of PhDs subsequently slowed as the Chinese government refocused its efforts on improving the quality of higher education,[3] but state-sponsored higher education has expanded again in recent years.

The Chinese Ministry of Education roughly doubled its spending on higher education between 2012 and 2021, fueling an increase in new PhD enrollments.[4] Between 2016 and 2019, the number of students entering STEM doctoral programs at Chinese universities increased nearly 40 percent, from 59,670 to 83,134. We expect to see the number of Chinese PhD graduates grow at a similar rate between 2022 to 2025 as these students complete their degrees (see Appendix B for methodological details). By contrast, there is no evidence to suggest a similar spike in new enrollments in STEM PhD programs at U.S. universities during this period.[5]

The remainder of this paper contextualizes these findings by discussing: (1) the challenges of defining and measuring "STEM" graduates; (2) the quality of PhD production in China and the United States; and (3) the number and share of international PhD students in each country.

Challenges of Assessing "STEM" Degree Data

There is no consistent definition of "STEM" that is used across countries or even among different organizations within the same country. This ambiguity—combined with differences in how academic fields and degrees are categorized—complicates efforts to draw direct comparisons between STEM education in different countries.

In our analysis, we include students obtaining a research-oriented doctoral degree in a range of selected disciplines.[6] For the United States, we selected seven academic fields as defined by the National Science Board: life sciences, geosciences, mathematics and statistics, computer science, physical sciences, engineering, and medical sciences. For China, we selected four academic fields as defined by its Ministry of Education: science, engineering, agriculture, and medicine.[7]

The health sciences ("medical sciences"/"medicine") are particularly difficult to classify given the wide variety of disciplines that fall under this umbrella—some of which are more research-oriented while others are more clinical—and differences in how medical practitioners are credentialed in China and the United States. However, as shown in Table 1, even if we removed health science from our STEM measures, China would still maintain its lead over the United States in PhD production (see Appendix C for more detailed background and data).

This paper focuses on "STEM" fields. Therefore, the numbers differ from the widely-cited National Science Board's *Science and Engineering Indicators*, which focus on "Science and Engineering" ("S&E") fields. NSB's definition of this concept includes the social sciences.[8] The social sciences are more popular in the United States than in China, so much so that using the S&E definition, the United States still led China in PhD production in 2019 (Table 1).[9] These findings are consistent with prior NSB reports, which noted that "when comparing only natural sciences and engineering doctoral degrees, China surpassed the United States as the world's largest producer in 2007 and has remained so ever since."[10]

Table 1. PhD graduates in the United States and China across different field categories

	STEM (including health sciences)		STEM (excluding health sciences)		Science & Engineering (includes social science)	
	U.S.	**China**	**U.S.**	**China**	**U.S.**	**China**
2025 (projected)	39,959	77,179	35,622	59,053	49,538	61,326
2019	33,759	49,498	30,609	39,830	43,398	41,890
2010	26,076	34,801	24,824	29,039	34,670	31,410
2000	18,289	9,038	17,395	7,518	26,331	8,219

Source: NCES IPEDS Completions Survey for U.S. data, Ministry of Education for Chinese data; 2019 is the most recent year with available data.

Are Chinese PhDs High-Quality?

One concern with focusing on graduate counts is that they do not capture differences in quality between Chinese and U.S. graduate education. Although it is hard to make any absolute statements regarding quality, we can derive some insights by examining the universities from which PhDs graduate and the demand for their skills on the labor market.

There are around 3,000 universities and colleges in China, which range widely in quality.[11] About 800 of them award graduate degrees.[12] At the pinnacle of Chinese higher education sit 42 universities that are designated as "Double First Class" (DFC) institutions—these receive a large share of central government education and research resources.[13] These universities are also part of a larger group of universities administered by the central government. This larger group includes around 75 institutions directly funded and administered by the Ministry of Education, the "Seven Sons of National Defense" under the Ministry of Industry and Information Technology, and various other elite universities administered by other ministries.[14] In 2020, 36 of the 42 “Double First Class” universities were ranked in the top 500 universities globally, and 21 were ranked in the top 200.[15] The rising quality of China’s top universities is also visible in other metrics. For example, China-based authors are producing an increasingly large share of top STEM publications (defined as the top 1 percent of cited articles), already exceeding that of U.S.-based authors in certain disciplines, including several subfields of artificial intelligence.[16]

Table 2 shows the number of Chinese PhD graduates across these different quality tiers; note that this data is not available for STEM specifically (though around 80 percent of Chinese PhD graduates are in STEM fields; see Appendices C and D for more details). In recent years, a little under half of all Chinese PhD graduates have come from “Double First Class” universities, and about 80 percent come from universities administered by national ministries. Only about 20 percent come from locally or privately administered universities, whose average quality is lower. Moreover, most of the recent and rapid growth in Chinese PhD enrollments comes from universities within the higher-quality tiers. Between 2015 and 2019, the number of students entering PhD programs at universities run by central ministries and agencies rose approximately 34 percent, from 59,039 to 79,031. This group of universities accounted for roughly 65 percent of the total increase in first-time PhD enrollments across China during that period. In sum, a large share of Chinese PhD graduates comes from universities with high quality standards.

Table 2. Number of PhDs awarded in China by university category, 2010–2019

	All Universities	All Universities Administered by Central Gov.		MOE-Administered Universities		Double First Class (A) Universities	
Year	Graduates	Graduates	% of Total	Graduates	% of Total	Graduates	% of Total
2019	62,578	49,540	79%	36,779	59%	26,792	43%
2015	53,778	43,245	80%	31,903	59%	24,687	46%
2010	48,987	40,200	82%	29,212	60%	n/a	n/a

Source: Chinese Ministry of Education, Double First Class University Employment Quality Reports.

A second way to assess degree quality is to consider whether PhD graduates and their skills are in demand on the labor market. The evidence on this question in China is spotty. The unemployment rate among China's PhD graduates appears to be significantly lower than among other workers, though still high by the standards of other economies.[17] A growing number of Chinese PhD graduates are working in the private sector in China, and some studies suggest a majority end up in positions that involve little or no R&D work.[18] This could be because PhD programs are not teaching in-demand skills, or because certain Chinese industries are not yet well-developed enough to absorb large numbers of high-skilled technical talent. Attempts to understand the labor market dynamics of Chinese STEM PhD graduates are complicated by the fact that official Chinese employment statistics are often unreliable.[19] Without better data, it is hard to judge the extent to which Chinese PhD programs are producing graduates with advanced knowledge and skills.

Some level of mismatch between PhD programs and the labor market is hard to avoid even in fully developed economies, and some of the issues that appear in discussions of Chinese PhD quality also come up in discussions of U.S. degrees. For example, less than half of U.S. PhD graduates are involved in R&D work.[20] Frequent reports suggest that occasional overproduction of PhDs in certain STEM fields, such as the life sciences, have led to periods of persistent underemployment among PhD graduates.[21] Experts also commonly criticize U.S. doctoral education for not sufficiently preparing graduates for careers outside academia.[22] Such findings and critiques do not mean U.S. universities are low-quality or systematically produce too many graduates across all STEM fields; research indicates there is unfilled demand among U.S. employers for PhDs in many fields and sectors.[23] But they do suggest that some of the issues with China's PhD graduates are not unique to the Chinese context.

In summary, although economic signals suggest Chinese PhD production is not perfectly matched with labor market needs, the number of PhDs who graduate from elite Chinese universities, and the growing international reputation of those institutions, does suggest that the number of high-quality Chinese PhD graduates is on the rise. Furthermore, because more than three-quarters of Chinese doctoral graduates specialize in STEM fields, this evidence indicates China's STEM talent pipeline is becoming more robust (see Appendix C for more details).

Domestic versus International Students

One significant difference between the STEM PhD graduates from U.S. and Chinese universities is the share of international students. International students made up about 42 percent of STEM PhD graduates in the United States between 2010 and 2019, with especially high shares in computer science and engineering.

By contrast, the vast majority of PhDs graduating from Chinese universities are Chinese nationals. According to Chinese Ministry of Education data, international students accounted for only about 7 percent of doctoral enrollments in China in 2018, and the share was lower in prior years.[24] We could not find data that breaks down the percentage of international students in Chinese PhD programs by academic field.

While the large share of international students in U.S. PhD programs opens the door to potential security risks, it also highlights a key strategic advantage of the American higher education system: its ability to attract international talent. The attractiveness of U.S. universities creates far-reaching economic benefits, as a large majority of international graduates choose to remain in the United States after completing their degrees. Multiple studies and data sources suggest at least 75 percent of STEM PhD graduates have historically stayed in the United States for at least 10 years.[25] By comparison, China attracts relatively few international students, and it is unclear how many international PhD graduates from Chinese universities stay in China upon graduation. However, as bottlenecks in the U.S. immigration system worsen and international competition for talent increases, it remains to be seen whether the United States can maintain its strategic advantage by continuing to attract and retain as many international STEM PhDs in the years ahead.[26]

Conclusion

As artificial intelligence, quantum computing, biotechnology, and other emerging technologies reshape the global security and economic landscapes, STEM talent is becoming an increasingly critical national asset. PhD-level experts make up a small but important component of the STEM workforce, spearheading research and development efforts that push the boundaries of their fields and educating the next generation of science and technology leaders.

The number of doctoral graduates a country produces is one indicator of its future competitiveness in STEM fields. Currently, Chinese universities graduate roughly three STEM PhDs for every two graduated by U.S. universities each year. By 2025, we project

China will produce roughly twice as many STEM PhDs as the United States. Given the scale of China's investments in higher education and the high-stakes technology competition between the United States and China, the gap in STEM PhD production could undermine U.S. long-term economic and national security.

There remain many open questions regarding the strength of the STEM talent pipelines in China and the United States. Future research into the labor market prospects of Chinese STEM PhD graduates, the quality and supply of Chinese and U.S. university faculty, and the direction of investments in Chinese higher education would add valuable context to our findings and improve our understanding of the international competition for STEM talent. These trends will be especially important to monitor in the wake of the social, economic, and political disruptions caused by the COVID-19 pandemic.

Authors

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Appendices

Appendix A. Data Table for Figure 1

Table 3 shows the annual number of STEM PhD graduates in the United States and China from 2000–2019, as well as projections for 2020–2025. We use data from the NCES Integrated Postsecondary Education Data System completion survey (accessed through the National Science Foundation data portal) for the United States, and data from the Ministry of Education for the PRC for China.[27]

Table 3. Number of STEM PhDs awarded in the United States and China, 2000–2025

	United States		China
Year	STEM PhD (Total)	STEM PhD (Domestic)	STEM PhD (Total)
2025 (projected)	39,959	23,256	77,179
2024 (projected)	38,852	22,612	69,519
2023 (projected)	37,775	21,985	60,387
2022 (projected)	36,728	21,376	55,396
2021 (projected)	35,711	20,784	52,803
2020 (projected)	34,721	20,208	51,261
2019	33,759	19,682	49,498
2018	32,729	19,219	47,325
2017	32,020	18,773	44,921
2016	31,751	18,543	42,312
2015	31,426	18,132	40,963
2014	29,753	17,228	40,298
2013	28,341	16,529	39,390
2012	27,211	15,877	37,830
2011	26,153	15,413	36,816

2010	26,076	14,789	34,801
2009	25,836	13,983	34,548
2008	25,064	13,317	n/a
2007	23,181	12,297	30,340
2006	21,150	11,591	n/a
2005	19,327	11,020	n/a
2004	18,176	10,726	n/a
2003	17,167	10,105	13,859
2002	17,871	10,708	10,852
2001	18,145	11,106	9,931
2000	18,289	11,442	9,038

Source: NCES IPEDS for U.S. data, Ministry of Education for Chinese data.

Appendix B. Methodology for 2020–2025 Projections

To project total STEM PhD graduates up to 2025 (Figure 1), we used historical data on Chinese and U.S. PhD enrollments up to 2019.

China: The Chinese Ministry of Education publishes data on the number of students who enter PhD programs each year. In recent years, for every 100 students who enter a Chinese STEM PhD program, an average of 93 students obtains a PhD six years later.[28] We used this ratio to predict the number of Chinese PhD graduates for 2025 based on entrants in 2019, graduates for 2024 based on entrants in 2018, and so forth (Table 4). The rapid growth in projected graduates after 2022 is due to rapid growth in PhD entrants after 2016.

Table 4. Annual number of Chinese STEM PhD entrants and projected graduates up to 2025

STEM PhD entrants		STEM PhD graduates	
2019	83,134	**2025** (projected)	77,179
2018	74,883	**2024** (projected)	69,519
2017	65,046	**2023** (projected)	60,387
2016	59,670	**2022** (projected)	55,396
2015	56,877	**2021** (projected)	52,803
2014	55,216	**2020** (projected)	51,261
2013	52,928	**2019**	49,498
2012	50,890	**2018**	47,325
2011	48,487	**2017**	44,921
2010	45,548	**2016**	42,312
2009	44,462	**2015**	40,963

Source: Chinese Ministry of Education.

United States: Official U.S. government sources do not publish data on PhD entrants equivalent to Chinese data, so the same projection approach is not possible for U.S. graduates. However, the Council of Graduate Schools releases annual enrollment summary statistics based on a survey of U.S. graduate departments. From 2015 through 2019, the number of U.S. STEM PhD entrants grew by 2.85 percent per year on average (Table 5). By assuming the number of PhD graduates will grow by this same percentage with a six-year delay, we can project U.S. graduates up to 2025.[29]

Table 5. Average annual growth in first-time U.S. PhD enrollments by STEM field

	Avg. Annual Growth (2014-19)
Engineering	2.0%
Health Sciences	3.5%
Life Sciences	2.8%
Math/Computer Science	4.7%
Physical Sciences	1.4%
STEM (weighted average)	**2.85%**

Source: Council of Graduate Schools.[30]

These projections rely on a number of key assumptions. For Chinese data, our approach assumes the historical ratio of entrants-to-graduates over a six-year period will carry forward into the future. This assumption could be incorrect if the recent rapid growth in Chinese PhD enrollments causes instruction to suffer and decreases completion rates. On the other hand, Chinese sources suggest that most Chinese doctoral students currently complete their degree within 3-5 years, so our estimates may be somewhat conservative. For the U.S. data, our approach assumes that graduate growth will roughly match enrollment growth, i.e., that completion rates or duration will not change significantly during the next several years. To project domestic U.S. PhD numbers specifically, we also assume that the recent average share of U.S. PhD degrees that goes to international students (42 percent) will remain at the same level up to 2025 (the share has been between 41 and 43 percent since 2010).

Appendix C. Data Across Different Field Categories

Assessments of STEM education trends are complicated by the fact that there is no standard typology of scientific fields or consensus on which fields qualify as "STEM." In the absence of a consensus definition or measurement, the best approach is to show how conclusions change under different definitions and measures.

Table 6 shows the number of U.S. and Chinese PhD graduates across field categories that differ from the one we used in Figure 1 and Appendix A. First, the “STEM (excluding health sciences)” column shows the number of doctoral graduates in the United States and China if “medical sciences” (for U.S. sources) and “medicine” (for Chinese sources) were not included in our definition of STEM. Second, we show how STEM numbers differ from the concept of “Science and Engineering” (“S&E”), which is used by the National Science Board in its prominent *Science and Engineering Indicators* reports.[31] This concept includes the social sciences. Because the social sciences are much more popular in the United States than China, data on the number of S&E degrees shows the United States in the lead until 2023, with smaller gaps thereafter.[32]

Table 6. Number of STEM PhDs awarded in the United States and China, 2000–2025

	STEM (excluding health sciences)		**S&E (including social sciences)**	
	United States	**China**	**United States**	**China**
2025 (projected)	35,622	59,053	49,538	61,326
2024 (projected)	34,733	53,337	48,458	55,532
2023 (projected)	33,866	47,077	47,401	49,200
2022 (projected)	33,020	43,140	46,367	45,153
2021 (projected)	32,196	41,315	45,355	43,392
2020 (projected)	31,393	40,013	44,366	42,151
2019	30,609	39,830	43,398	41,890
2018	29,876	37,626	42,537	39,768
2017	29,423	35,354	41,735	37,506
2016	29,318	33,101	41,702	35,147
2015	29,278	32,256	41,190	34,440

2014	27,872	31,841	39,033	34,103
2013	26,625	31,162	37,182	33,490
2012	25,714	30,017	35,890	32,331
2011	24,647	29,825	34,245	32,208
2010	24,824	29,039	34,670	31,410
2009	24,516	28,962	34,783	31,423
2008	23,771	n/a	33,984	n/a
2007	21,929	24,433	31,770	26,582
2006	20,002	n/a	29,768	n/a
2005	18,312	n/a	27,613	n/a
2004	17,326	n/a	26,311	n/a
2003	16,285	11,034	25,174	12,238
2002	17,007	8,686	26,323	9,523
2001	17,249	8,157	26,427	8,832
2000	17,395	7,518	26,331	8,219

Source: NCES IPEDS for U.S. data, Ministry of Education for Chinese data.

To show how these numbers break down by field, Tables 7 and 8 show the number of U.S. and Chinese PhD graduates in 2019 broken down by specific STEM and S&E areas. For the United States, engineering is the most popular field, closely followed by the life sciences (including the biological and biomedical sciences and agriculture). The field categorization is taken from the NCES IPEDS framework.

Table 7. Number of PhD graduates from U.S. universities by STEM/S&E field, 2019

Field	PhD Graduates
STEM fields	
Engineering	10,978
Computer Science	1,987
Mathematics and Statistics	2,015
Physical Sciences	5,205
Geosciences	934
Life Sciences	9,490
Medical Sciences	3,150
Additional S&E fields	
Social Sciences	5,219
Psychology	4,420

Source: NCES IPEDS.

China categorizes its fields differently. Chinese data does not break down between different fields within "Science," though it is clear engineering is the most popular STEM field in China (Table 8). The field "Medicine" is hardest to categorize. According to a subfield catalog of Chinese degrees published by the Ministry of Education, "Medicine" includes fields such as epidemiology and pharmacology that would be included under STEM in U.S. sources, but it also includes some clinical fields as well as Chinese medicine.[33] Unfortunately, the Chinese data sources we were able to find did not publish data beyond the high-level field categorization, meaning we do not know how its graduates are distributed across these "Medicine" (or other) subfields. We include "Medicine" in our main STEM counts because we expect a significant number of Chinese PhD graduates to have significant research experience, but our counts will also include some individuals with non-STEM or non-research degrees.[34]

Table 8. Number of PhD graduates from Chinese universities by STEM/S&E field, 2019

Field	PhD Graduates
STEM fields	
Science	13,562
Engineering	23,384
Agriculture	2,884
Medicine	9,668
Additional S&E fields	
Economics	2,060

Source: Chinese Ministry of Education.

For China, we follow the NSB's methodology in counting "Economics" as a social science. However, this approach may undercount social science graduates. The Chinese MOE subfield categorization scheme mentioned above shows that "Political Science" and "Sociology" are grouped under the broad field of "Law" in Chinese degree counts. It is unclear how many graduates there are in those fields ("Law" in total had 2,731 graduates in 2019 but also includes the subfields "Law," "Ethnology," and "Marxist Theory," which typically would not be counted as social science in the United States).

If we broaden our analysis to include the full pool of doctoral graduates, the gap between the United States and China disappears completely. Though it trails in the production of STEM PhDs, the United States still leads China in the overall number of doctoral degrees awarded each year (Table 9). The difference is that the share of PhDs who pursue degrees in STEM fields is significantly larger in China than the United States. Between 2009 and 2019, about 45 percent of all U.S. doctoral graduates specialized in STEM fields, while in China more than 75 percent of PhDs specialized in STEM.

Table 9. Number of PhDs awarded at U.S. and Chinese universities across fields

	United States		China	
Year	**PhD Graduates (Total)**	**STEM PhD (% of Total)**	**PhD Graduates (Total)**	**STEM PhD (% of Total)**
2019	73,052	46%	62,578	79%
2015	67,843	46%	53,778	76%
2010	62,203	42%	48,987	71%
2005	49,162	39%	n/a	n/a
2000	44,981	41%	11,004	82%

Source: NCES IPEDS for U.S. data, Ministry of Education for Chinese data.

Appendix D. Data on Quality of STEM PhD Graduates in China

According to the Chinese Ministry of Education, around 800 institutions in China award graduate degrees. Around 300 of these are administered by institutions under "central ministries and agencies."[35] About 75 of these fall under the MOE (the exact total varies slightly year-by-year), though MOE-affiliated institutions graduate more PhDs than those under other ministries and agencies. The bulk of non-MOE graduates are likely to come from a small number of large universities under the Ministry of Industry and Information Technology (MIIT), including the "Seven Sons of National Defense."[36] Table 10 shows the total number of PhDs who graduated from different types of universities in China.

Table 10. Number of PhDs awarded in China by university category, 2010–2019

	All Universities	All Universities Administered by Central Gov.		MOE-Administered Universities		Double First Class (A) Universities	
Year	Graduates	Graduates	% of Total	Graduates	% of Total	Graduates	% of Total
2019	62,578	49,540	79%	36,779	59%	26,792	43%
2018	60,724	48,438	80%	36,005	59%	26,012	43%
2017	58,032	46,179	80%	34,212	59%	25,106	43%
2016	55,011	44,139	80%	32,531	59%	25,564	46%
2015	53,778	43,245	80%	31,903	59%	24,687	46%
2014	53,653	43,198	81%	31,955	60%	n/a	n/a
2013	53,139	42,794	81%	31,830	60%	n/a	n/a
2012	51,713	38,249	74%	31,203	60%	n/a	n/a
2011	50,289	40,879	81%	30,296	60%	n/a	n/a
2010	48,987	40,200	82%	29,212	60%	n/a	n/a

Source: Chinese Ministry of Education, Double First Class University Employment Quality Reports.

The most elite of China's centrally-administered educational institutions are 42 universities that were designated "Double First Class" in 2015. This group is further subdivided into 36 "Class A" and 6 "Class B" universities. The number of graduates from these universities is not available from central Chinese statistical sources, but CSET has collected "Employment Quality Reports" issued by individual universities that list their number of PhD graduates. We were able to locate annual reports back to 2015 for 35 of the 36 Class A universities (the one exception was the National University of Defense Technology).[37] Based on this data, we conclude that approximately 45 percent of China's PhD graduates come from its most elite universities (Table 10). We were unable to find equally good data for the Class B universities, but the little data that was available suggested the annual number of PhD graduates from this group is relatively small (in the hundreds or low thousands).

Endnotes

[1] In the Chinese context, "comprehensive national power" (CNP) refers to the combination of all the powers and resources possessed by a country. Components of CNP generally include the economy, military, science and technology infrastructure, educational system, natural resources, and international influence. For more information, see QI Haixia, "From Comprehensive National Power to Soft Power: A Study of the Chinese Scholars' Perception of Power" (Griffith Asia Institute and Institute of International Relations, Tsinghua University, 2017), https://www.griffith.edu.au/__data/assets/pdf_file/0022/206644/Griffith-Tsinghua-WP-7-final-web.pdf.

[2] The Chinese government approved seven new doctorate-granting institutions and 442 new doctorate programs in 2000, 35 institutions and 728 programs in 2003, and 19 institutions and 605 programs in 2006. For more information, see Rui Yang, "Up and Coming?: Doctoral Education in China," *Australian Universities Review* 54, no. 1 (2012), https://files.eric.ed.gov/fulltext/EJ968526.pdf.

[3] National Science Foundation | National Science Board, "Higher Education in Science and Engineering: International S&E Higher Education," September 2019, https://ncses.nsf.gov/pubs/nsb20197/international-s-e-higher-education#u-s-position-in-global-s-e-higher-education.

[4] Anna Puglisi, Ryan Fedasiuk, and Alan Omar Loera Martinez, "Chinese University Investments in Science and Technology" (Center for Security and Emerging Technology, forthcoming).

[5] Between 2014 and 2019, U.S. universities saw first-time enrollments in STEM doctoral programs grow at an average rate of 2.85 percent per year (see Appendix B). This growth approximately mirrors the increase in funding levels for scholarships and research grants, which fund most PhD education in the United States. Between 2010 and 2018, funding for academic R&D increased about 2.3 percent per year on average; see Josh Trapani and Michael Gibbons, "Science and Engineering Indicators 2020: Academic Research and Development," National Science Foundation | National Science Board, January 15, 2020, Figure 5B-4, https://ncses.nsf.gov/pubs/nsb20202/academic-r-d-in-the-united-states.

[6] NCES and some other organizations include students obtaining professional degrees such as M.D.s in their counts of “doctoral” graduates. We exclude these non-research oriented degrees from our analysis.

[7] For more details on Chinese degree categories, see China Academic Degrees and Graduate Education Information, “学科、专业目录” [“Catalog of Academic Disciplines and Majors”], https://archive.ph/iAP71. For more background on the similarities and differences between the U.S. and Chinese education systems, see Dahlia Peterson, Kayla Goode, and Diana Gehlhaus, “AI Education in China and the United States: A Comparative Assessment” (Center for Security and Emerging Technology, forthcoming).

[8] Another difference between our data and that of the National Science Board is that the NSB excludes the field of “medicine” from its Chinese counts, whereas we include “medicine” in our main figures. The NSB excludes “medicine” from its Chinese counts because Chinese data do not distinguish between research-oriented and clinical medical degrees. In contrast, NSB does include research-oriented “medical science” degrees in its count of S&E doctoral graduates in U.S. data. See Appendix C for more discussion of this question.

[9] In the United States, the National Science Board includes nine fields in the “S&E” category for PhD graduates: life sciences, geosciences, mathematics and statistics, computer science, physical sciences, engineering, medical sciences, social sciences, and psychology. In China, we included four fields in the S&E category: science, engineering, agriculture, and economics. NSB includes health science in the S&E category for U.S. doctoral students, whose degree programs are largely research-oriented, but not other students. For more information, see: https://ncses.nsf.gov/pubs/nsb20197/glossary.

[10] Josh Trapani and Katherine Hale, “Science and Engineering Indicators 2020: Higher Education in Science and Engineering,” National Science Foundation | National Science Board, September 4, 2019, https://ncses.nsf.gov/pubs/nsb20197/international-s-e-higher-education.

[11] Mini Gu, Rachel Michael, Claire Zheng, and Stefan Trines, “Education in China,” *World Education News + Reviews*, December 17, 2019, https://wenr.wes.org/2019/12/education-in-china-3.

[12] “中国教育概况: 2019年全国教育事业发展情况,” [“General Development Summary of Chinese Education in 2019”], Ministry of Education of the People’s Republic of China, August 31, 2020, https://archive.ph/kiVkS.

[13] This includes the C9 League, known as China's Ivy League, consisting of Tsinghua, Peking, Fudan, Shanghai Jiaotong, Nanjing, Zhejiang, Xi'an Jiaotong University, University of Science and Technology of China (all administered by MOE), and Harbin Institute of Technology (administered by MIIT). For more background on the Double First-Class initiative, see Charlotte Gao, "A Closer Look at China's World-Class Universities Project," *The Diplomat*, September 22, 2017, https://thediplomat.com/2017/09/a-closer-look-at-chinas-world-class-universities-project/.

[14] For a full list of Ministry of Education-affiliated universities and colleges, see "Ministry of Education 2019 Departmental Budget" in Ryan Fedasiuk, Emily Weinstein, Ben Murphy, and Alan Omar Loera Martinez, "Chinese State Council Budget Tracker" (Center for Security and Emerging Technology, February 2020), https://cset.georgetown.edu/wp-content/uploads/t0155_MOE_budget_2019_EN.pdf. For a grouping of defense-related universities by "supervising agency," see Alex Joske, "The China Defence Universities Tracker" (Australian Strategic Policy Institute, November 2019), https://www.aspi.org.au/report/china-defence-universities-tracker.

[15] Calculated based on the Academic Ranking of World Universities (also known as the "Shanghai Ranking"), available at https://www.shanghairanking.com/rankings/arwu/2020.

[16] Field Cady and Oren Etzioni, "China May Overtake the US in AI Research," *Medium*, March 13, 2019, https://medium.com/ai2-blog/china-to-overtake-us-in-ai-research-8b6b1fe30595; Dewey Murdick, James Dunham, and Jennifer Melot, "AI Definitions Affect Policymaking" (Center for Security and Emerging Technology, June 2020), https://cset.georgetown.edu/research/ai-definitions-affect-policymaking/.

[17] A study by the Chinese recruitment firm Zhaopin found that approximately 11.2 percent of PhD graduates in 2020 were still searching for jobs around the time of graduation, compared to 15.9 percent of master's recipients and 27.9 percent of undergraduates. However, it is unclear how representative these numbers are of general labor market trends, and it is possible they reflect employment difficulties unique to the COVID-19 pandemic. See 张思思 [Zhang Sisi], "《就业困难大学生群体研究报告》出炉 大专学历就业最困难" ["The 'Research Report on the Group of College Students with Employment Difficulties' Is Released: Junior College Graduates Gave the Highest Difficulty"], *Xi'an Daily*, August 14, 2020, http://www.sn.xinhuanet.com/2020-08/14/c_1126366649.htm.

[18] A 2019 study by Peking University found roughly two-thirds of PhD graduates working in the private sector had jobs that did not involve research and development. It is unclear whether this study is representative of the broader labor market for doctoral graduates. See Zhang Ruomei, "The Problem with China's PhD Programs? They're All Academic," *Sixth Tone*, September 26, 2019, https://www.sixthtone.com/news/1004555/the-problem-with-chinas-Ph.D.-programs%3F-theyre-all-academic.

[19] "Trying to Count China's Jobless," *The Economist*, August 19, 2015, https://www.economist.com/free-exchange/2015/08/19/trying-to-count-chinas-jobless; Brian Peach and Sidney Leng, "China Unemployment Rate: How Is It Measured and Why Is It Important?," *South China Morning Post*, November 17, 2020, https://www.scmp.com/economy/china-economy/article/3110193/china-unemployment-rate-how-it-measured-and-why-it-important.

[20] Jean Opsomer, Angela Chen, Wan-Ying Chang, and Daniel Foley, "U.S. Employment Higher in the Private Sector than in the Education Sector for U.S.-Trained Doctoral Scientists and Engineers: Findings from the 2019 Survey of Doctorate Recipients," National Science Foundation | National Center for Science and Engineering Statistics, April 21, 2021, https://ncses.nsf.gov/pubs/nsf21319, Table 2.

[21] "The Next Generation of Biomedical and Behavioral Sciences Researchers: Breaking Through" (The National Academies of Sciences, Engineering, and Medicine, 2018).

[22] Sarah Anderson, "Make Science PhDs More Than Just a Training Path for Academia," *Nature*, August 28, 2019, https://www.nature.com/articles/d41586-019-02586-5.

[23] Yi Xue and Richard C. Larson, "STEM Crisis or STEM Surplus? Yes and Yes," Monthly Labor Review: U.S. Bureau of Labor Statistics, May 2015, https://www.bls.gov/opub/mlr/2015/article/stem-crisis-or-stem-surplus-yes-and-yes.htm; Diana Gehlhaus and Ilya Rahkovsky, "U.S. AI Workforce: Labor Market Dynamics" (Center for Security and Emerging Technology, April 2021), https://cset.georgetown.edu/research/u-s-ai-workforce/.

[24] We calculated the percentage of international students in Chinese PhD programs in 2018 by dividing the total number of international doctoral students enrolled at Chinese universities (25,618) by the total enrollment in Chinese PhD programs (389,518). This data comes from the Ministry of Education of the People's Republic of China: "2018年来华留学统计," Ministry of Education of the People's Republic of China, April 12, 2019,

http://www.moe.gov.cn/jyb_xwfb/gzdt_gzdt/s5987/201904/t20190412_377692.html and “分学科研究生数 (总计),” Ministry of Education of the People’s Republic of China, http://www.moe.gov.cn/s78/A03/moe_560/jytjsj_2018/qg/201908/t20190812_394203.html.

[25] Remco Zwetsloot, James Dunham, Zachary Arnold, and Tina Huang, “Keeping Top AI Talent in the United States” (Center for Security and Emerging Technology, December 2019), https://cset.georgetown.edu/publication/keeping-top-ai-talent-in-the-united-states/.

[26] Zwetsloot et al., “Keeping Top AI Talent in the United States,” Chapter 2.

[27] Chinese MOE data is spread across separate annual spreadsheets. The 2019 data can be found at “分学科研究生数 (总计),” Ministry of Education of the People’s Republic of China, https://perma.cc/ALK2-8JS7. MOE data is widely used in assessments of Chinese higher education. While some have expressed concerns about the integrity of information published by the MOE, we were unable to independently verify any data quality issues.

[28] The historical rate was calculated based on the number of graduates in the 2015–2019 period and did not vary significantly year-to-year.

[29] The CGS report does not include absolute entrant numbers comparable to official U.S. statistics, so this projection is based on (weighted) growth rates.

[30] “Graduate Enrollment and Degrees: 2009-2019,” Council of Graduate Schools, October 2020, Tables B6 and C12, https://cgsnet.org/graduate-enrollment-and-degrees.

[31] National Science Foundation | National Science Board, “Higher Education in Science and Engineering.”

[32] We use the same methodology described in Appendix B to project the total number of PhD graduates for these different field categories. For the U.S. data, the weighted annual growth rate is 2.56 percent for STEM (excluding health science) and 2.23 percent for “S&E” fields. In China, every 100 new enrollments in STEM (excluding medicine) corresponded to roughly 88 graduates six years later, and every 100 new enrollments in “S&E” fields corresponded to roughly 87 graduates six years later.

[33] China Academic Degrees and Graduate Education Information, “学科、专业目录” [“Catalog of Academic Disciplines and Majors”], https://archive.ph/iAP71.

[34] Many clinical tracks in China require only a master’s degree, whereas others require a doctorate; see Lijuan Wu et al., “Development of a Medical Academic Degree System in China,” *Medical Education Online* 19 (2014), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3895259/. As such, our PhD counts will include some clinical doctors who do not engage in significant research work.

[35] Exact numbers vary slightly by year. For 2019 data, see “分举办者研究生数（总计）,” Ministry of Education of the People’s Republic of China, http://www.moe.gov.cn/s78/A03/moe_560/jytjsj_2019/qg/202006/t20200611_464784.html.

[36] In 2019, approximately 13,000 graduates received PhDs from universities that were administered by central government ministries or agencies other than the MOE. We know from Employment Quality Report data that a handful of MIIT-administered universities account for a large share of this group. The Chinese Academy of Sciences is likely also included in this count. The more than 200 other “central ministries and agencies” that award graduate degrees likely include institutions such as the China Meteorological Society, which are often allowed to run small graduate programs. For information on the Seven Sons of National Defense, see Ryan Fedasiuk and Emily Weinstein, “Universities and the Chinese Defense Technology Workforce” (Center for Security and Emerging Technology, December 2020), https://cset.georgetown.edu/publication/universities-and-the-chinese-defense-technology-workforce/.

[37] A small number of universities did not publish EQRs every year or did not include PhD-specific numbers in all of their EQRs. For years where data was missing, we imputed a university’s number of PhD graduates as the average number of PhD graduates during years for which data was available. For more background on EQRs, see Fedasiuk and Weinstein, “Universities and the Chinese Defense Technology Workforce.”