Issue Brief

Fueling China's Innovation

The Chinese Academy of Sciences and Its Role in the PRC's S&T Ecosystem

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Executive Summary

The Chinese Academy of Sciences is one of the most important scientific research organizations not only in China but also globally. Through its network of research institutes, universities, companies, and think tanks, CAS is a core component of China's science and technology innovation ecosystem. This brief first traces the organization's historical significance in China's S&T development, outlining key reforms that continue to shape the institution today. It then details CAS's core functions in advancing S&T research, fostering commercialization of critical and emerging technologies, and contributing to S&T policymaking. Using scholarly literature, we provide insights into CAS's research output in the science, technology, engineering, and mathematics (STEM) fields as well as in certain critical and emerging technologies, including artificial intelligence (AI).

Our key takeaways are as follows:

Research

- CAS is the top producer of STEM research globally, both in terms of total number of papers and number of highly cited papers.

- CAS is a hub of top-tier S&T researchers and plays an important role in training the next generation of experts. In 2022, CAS ranked second globally among institutions by number of top-cited researchers, trailing only Harvard University.

- CAS's 115 research institutes work on a diverse range of S&T subjects. CAS institutes publish most frequently in the field of industrial technology, which accounted for 35 percent of their published papers in 2021.

- CAS institutes also advance research in critical and emerging technologies, such as AI. The majority of AI-related research published by CAS is conducted by a narrow subset of institutes. The Institute of Automation, the Shenyang Institute of Automation, and the Institute of Computing Technology are top producers of AI-related research within CAS.

Commercialization

- CAS fosters technology transfer from research organizations to industry through various commercialization mechanisms, including making investments via asset management companies and venture capital firms, licensing proprietary research, and offering contract research services.
- CAS provides research, financing, and personnel to support the founding and development of technology companies.
- Notable companies founded with CAS support include AI company iFLYTEK, PC manufacturer Lenovo, supercomputer company Sugon, AI chip developer Cambricon, and CPU designer Loongson.

Policymaking

- CAS plays a key role in the development and implementation of China's S&T policies. CAS has contributed to major S&T policy initiatives such as the founding of the National Natural Science Foundation of China and to S&T development projects such as the 863 Program and the 973 Program.
- CAS academicians are among the most important individuals in China's S&T ecosystem. They influence resource allocation to S&T projects and often serve in important policymaking roles.

In sum, CAS is a global leader in STEM fields and a pillar of China's S&T development ecosystem. It has facilitated the rise of globally competitive technology companies and continues to influence China's S&T policy. At the same time, CAS's expansive set of responsibilities as a research organization, a commercial entity, and a bureaucratic actor complicate its mission. Understanding the tensions that may exist among these functions is important, as Beijing continues to commit extensive resources to CAS. The organization's success—or lack thereof—will affect Beijing's own ability to effectively achieve its S&T development ambitions.

Table of Contents

Introduction

The Chinese Academy of Sciences (中国科学院) is a key actor in China's science and technology ecosystem. Directly managed by the State Council, CAS plays a critical role in advancing Beijing's S&T ambitions and is deeply involved in shaping and implementing national policies.[1] As technological innovation is a core aspect of the intensifying competition between the United States and China, it is imperative that U.S. policymakers understand CAS's contributions to China's S&T development.

In this brief, we seek to advance a better understanding of CAS, which is one of the largest and most prolific research bodies in the world and home to many top science, technology, engineering, and mathematics (STEM) researchers.[2] CAS oversees hundreds of subsidiary organizations, including 115 research units,[*] three universities, numerous companies, and several think tanks. Comprising an expansive network of researchers, students, and policymakers, CAS directly contributes to both the design and implementation of Chinese S&T policies.

This brief proceeds as follows. First, we describe CAS's history and trace successive reforms to the institution, highlighting its role in China's rise as a major S&T power. We then detail CAS's core functions in China's S&T ecosystem: advancing research, promoting the commercialization of key technologies, and contributing to policymaking. We conclude with an examination of CAS's central position in China's S&T ecosystem and its implications for U.S. policymakers.

[*] Throughout this piece, we refer to CAS's research units (研究单位) as CAS institutes.

Methodology

Our analysis draws on a variety of publicly available sources, including Chinese government policy documents, annual reports of publicly listed companies, and an array of other primary and secondary sources. Our analysis of CAS's research output relies on two distinct data sources to present trends in CAS's English- and Chinese-language STEM research.

First, we draw from CSET's merged corpus of scholarly literature published between 2010 and 2023, which includes journal articles, also referred to in this brief as papers, from Clarivate's Web of Science, Semantic Scholar, the Lens, OpenAlex, arXiv, and Papers With Code. CSET's merged corpus primarily consists of English-language journal articles. We use CSET's fields of study methodology to classify papers by field.[3] We focus on CAS's STEM research because one of the organization's core responsibilities is advancing China's S&T development and self-reliance.[*] We define STEM publications as papers in the fields of biology, physics, geology, mathematics, chemistry, computer science, engineering, environmental science, and materials science.

Second, we leverage data from the China National Knowledge Infrastructure, which is largely composed of Chinese-language papers, to analyze CAS's STEM publications within China's domestic research ecosystem. For this report, we draw on CNKI papers published between 2010 and 2021.[†] For CNKI papers, we define STEM publications as those in the fields of industrial technology, astronomy and geoscience, agricultural sciences, mathematical sciences and chemistry, environmental science, life sciences, aviation and aerospace, and transportation.[‡] Finally, we use the CNKI dataset to classify AI-related publications in order to better understand CAS's contributions to China's AI development ecosystem.[4]

By analyzing both CSET's merged corpus and CNKI, we are able to conduct a more comprehensive analysis of CAS's research output. Using the merged corpus, we assess CAS's research output alongside that of other global research institutions. CNKI, on the other hand, includes more detailed paper publication information for each subsidiary

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[*] We are also particularly interested in CAS's contributions to AI-related research and development, given its strategic importance to Beijing and relevance in U.S.-China tech competition.

[†] We are unable to analyze CNKI publication data in 2022 and 2023 due to incomplete data.

[‡] CNKI employs the Chinese Library Classification system, which categorizes publications by subject field. Every paper in CNKI receives a CLC code that corresponds to a specific field of study. The CLC fields of study are not the same as those used in CSET's merged corpus.

organization within CAS, which allows us to analyze the publications of specific entities, such as its 115 research institutes.

That said, our methodological approach has some limitations. First, our dataset of CAS research is not exhaustive. Within both CSET's merged corpus and CNKI, CAS research is often attributed to the organization's subsidiaries, rather than to CAS itself. As a result, querying the datasets for publications strictly attributed to CAS would miss a significant portion of CAS-affiliated research. To address this issue, we use two approaches. First, CSET's entity resolution methodology helps to match subsidiaries to their parent organizations in the merged corpus dataset. Second, we use CNKI-provided organizational information to carefully identify all the publications of each CAS institute, which is not possible using the merged corpus data. This methodology enables a more comprehensive assessment of CAS's research. At the same time, our methodology does not capture all publications of every CAS subsidiary organization. For example, our analysis of the CAS institutes' publications does not account for some CAS-authored research papers published by other CAS subsidiary organizations, such as universities and laboratories.

Second, we use several proxies for evaluating research quality, such as highly cited research publications, top-cited research publications, and number of top-cited researchers.[*] Although imperfect, these metrics allow us to compare measures of high-impact research and researchers for CAS with those of other international research institutions. Importantly, these metrics do not provide insight into the production of highly cited research relative to size, research expenditures, or other relevant factors that may contribute to the output of research institutions. While important to consider, these cross-institutional analyses are largely outside the scope of this report.

[*] We define highly cited papers as papers in at least the 90th percentile of citations in their field in a given year, top-cited papers as papers in the 99th percentile of citations in their field in a given year, and top-cited researchers as in the 99th percentile of individual researchers most frequently cited in their field and year.

History, Development, and Reform

Established in November 1949, CAS has played an instrumental role in laying the foundation for China's modern S&T ecosystem. Tracing CAS's history of development and reform is essential to understanding its position in Chinese S&T development today.

The Early Days: Defense S&T and Building on the Soviet Model

In the 1950s, the Academy of Sciences of the Soviet Union strongly influenced CAS's development.[5] Collaboration with the Soviet Union helped propel China's strategic weapons development programs. In February 1953, for example, a delegation of Chinese scientists led by the director of the Institute of Physics of CAS traveled to the Soviet Union to discuss atomic research collaboration.[6] In 1957, CAS and the Soviet Academy of Sciences signed joint agreements to construct nuclear reactors in Chongqing, Xi'an, Beijing, and Shenyang.[7]

CAS played a critical role in China's strategic weapons and space technologies development throughout the 1950s and 1960s. At the instruction of Premier Zhou Enlai (周恩来), CAS made significant contributions to China's "Nuclear Bombs, Ballistic Missiles, and Earth Satellites" (两弹一星) program, which led to the development of the country's nuclear and space capabilities.[8]

Another example of CAS's success in supporting Chinese military modernization occurred in March 1965, when the Chinese Communist Party tasked CAS with developing a guidance computer for long-range missiles, called Project 156.[9] The consortium of six CAS institutes working on the project formed the Xi'an Microelectronics Technology Institute (also known as the 771 Institute; 西安微电子技术研究所) in 1975, which developed into an important supplier of computing and microelectronics products to the People's Liberation Army.[10] Notably, ZTE (中兴通讯股份有限公司), one of the largest telecommunications companies in the world, was spun out of the Xi'an Microelectronics Technology Institute in the early 1980s.[11]

Reform and Revitalization

In the 1970s and 1980s, CAS suffered from an aging workforce, insufficient research facilities, and outdated research agendas, all of which hampered its ability to advance indigenous innovation and other S&T development priorities.[12] During the 1980s, national reforms decreased government funding for research institutions and incentivized the organization to become more responsive to market competition. These reforms discouraged CAS entities from undertaking large-scale research projects with uncertain commercial outcomes and ultimately led to the underfunding of CAS's basic research activities.[13]

In the late 1990s, responding to Beijing's calls to strengthen China's national research capabilities, CAS initiated a series of efforts to expand its role in China's innovation ecosystem.[14] The most significant of these efforts was the Knowledge Innovation Program (中国科学院知识创新工程), a set of initiatives and reforms intended to address fundamental issues within CAS and develop it into one of the world's top scientific research institutions.[15]

The KIP reduced the number of CAS institutes by converting some into commercial entities and reorganized others to address overlapping research missions.[16] The KIP included several initiatives to bolster CAS's research workforce, such as expanding training for graduate students, introducing stringent evaluation requirements for researchers, and leveraging national-level initiatives like the Hundred Talents Program (百人计划) to recruit top scientists from abroad.[17] Later, the KIP encouraged collaborations between CAS and provincial and city governments to support local innovation, leading to the creation of seven new institutes.[18] By the end of the 12-year program, CAS reemerged as a hub of basic research and S&T development in China.[19]

In 2011, CAS unveiled a new initiative called Innovation 2020 (创新 2020), which aimed to continue the work of the KIP and further strengthen China's S&T ecosystem. Innovation 2020 focused on improving international collaborations, including through deepening scientific partnerships with developed nations and promoting cooperation with developing countries.[20] As part of the KIP, CAS played an active role in China's Belt and Road Initiative. For example, between 2013 and 2019, it provided around 268 million USD in funding for BRI S&T projects and initiated collaborative research with over 40 institutions from 14 BRI partner countries.[21]

CAS's 13th Five-Year Plan (2016–2020) placed greater emphasis on converting basic research into commercial technologies that can help drive economic growth.[22] During this period, CAS established joint research and development (R&D) centers with major industry players, set up business incubators for startups, improved patenting processes and standards, and further promoted collaboration with local governments. It also reformed its performance assessment system—which directly affects resource allocations—to place a greater emphasis on conducting impactful, high-quality research, replacing its previous focus on using quantitative metrics to evaluate impact.[23]

Since the 1950s, CAS has been a key driver of S&T development in China. Successive reforms over the past four decades have led to CAS's modernization and have better aligned incentive structures to advance domestic S&T innovation. These reforms have also promoted CAS's integration into the international scientific landscape. In the following section, we build on this context to outline CAS's contemporary contributions to China's S&T ecosystem.

Examining CAS's Core Functions: Research, Commercialization, and Policymaking

In this section, we examine CAS's three main functions: advancing research in critical fields, fostering the commercialization and adoption of key technologies, and aiding in the development and implementation of China's S&T policy initiatives. In the first section on CAS's role in driving research, we detail the organization's size, funding, and research output in the context of other leading global research institutions. We also include analysis of the CAS institutes' research activities by field of study to better understand CAS's research output in the context of China's STEM ecosystem, paying special attention to the institutes' AI-related publications. The second section describes CAS's role in fostering the commercialization of key technologies and highlights several key case studies of successful CAS spin-off companies. The third section describes CAS's role in shaping Chinese S&T policy.

Advancing S&T Research

One of CAS's primary responsibilities is to advance China's S&T research capabilities in order to strengthen the national innovation ecosystem, boost technological self-reliance, and help China become a global leader in STEM research.[24] CAS oversees 115 institutes, which advance research across a wide range of critical fields. CAS also directly manages two universities, the University of Science and Technology of China (USTC) and the University of Chinese Academy of Sciences (UCAS), and co-administers ShanghaiTech University with the Shanghai Municipal People's Government.[25] Additionally, CAS is an important actor in China's State Key Laboratory system, which is composed of hundreds of research facilities tasked with conducting cutting-edge research and fostering cooperation among universities, research institutes, and companies.[26] CAS oversees 83 (roughly 30 percent) of China's government-managed SKLs, many of which are co-located with CAS institutes and universities.[27] Finally, CAS sponsors 267 academic journals, some of which are published by Springer and Oxford Academic.[28]

Taken together, these universities, research institutes, and SKLs form a network of research entities that work in concert to advance scientific progress and bolster China's STEM workforce. CAS universities, for example, work with CAS institutes and CAS SKLs to provide students with opportunities to contribute to research projects. Some scientists at CAS institutes and SKLs serve as part-time department leaders at CAS universities or otherwise contribute to CAS's talent training system.[29] According to CAS, it employs around 71,000 individuals, almost 62,000 of whom are professional researchers. Around 79,000 graduate students study at CAS and its universities.[30]

CAS is an important hub for basic research in China. CAS-affiliated researchers account for 40 percent of all principal investigators overseeing scientific research funded by the National Natural Science Foundation of China (NSFC; 国家自然科学基金委员会).[31] As of May 2016, CAS oversaw 80 percent of China's large-scale science facilities, including the China Spallation Neutron Source in Dongguan, which supports research on physics and materials science, among other fields, and the Experimental Advanced Superconducting Tokamak in Hefei, which facilitates research on nuclear fusion technology.[32]

Figure 1 shows CAS's basic R&D expenditures between 2012 and 2023, collected from CAS's annual budget reports. CAS's basic R&D expenditures have nearly quadrupled since 2012 and have grown markedly in the last few years, increasing from 36 billion RMB (5.6 billion USD) in 2021 to 62.8 billion RMB (8.9 billion USD) in 2023.[33]

Figure 1. CAS Basic R&D Expenditure and Percent of China's Total Basic R&D Expenditure, 2012-2023

Year	CAS Basic R&D Expenditure (billions RMB)	Percent of PRC Total Basic R&D Expenditure
2012	16.1	32%
2013	18.7	34%
2014	21.3	35%
2015	23.7	33%
2016	26.7	33%
2017	28.6	29%
2018	31.5	29%
2019	38.1	29%
2020	35.9	25%
2021	36	20%
2022	52.7	26%
2023	62.8	28%

Source: CAS Budget (2012–2023), National Bureau of Statistics.[34]

Figure 1 underscores CAS's consequential role in China's basic research ecosystem. As shown above, CAS's basic R&D expenditures accounted for 28 percent of all such spending in China in 2023. While this proportion has declined from its 2014 peak, CAS remains a key actor in China's basic research landscape.

At the same time, these figures should be understood within the broader context of China's R&D environment, which continues to favor expenditures on later-stage projects over basic research. Moreover, China's proportional spending on basic R&D continues to trail that of other leading S&T countries. According to a 2018 U.S. National Science Foundation study, for example, China's basic R&D expenditure accounted for just 5 percent of total R&D spending, the lowest of any surveyed country.[35] In the United States, basic R&D spending accounted for 16 percent of all R&D expenditures in 2018.[36]

In short, CAS is a major player in China's R&D efforts, driving S&T advancements through its vast network of institutes, universities, and SKLs. The organization also contributes to the training of China's next generation of scientists, oversees major basic research projects, and manages large-scale scientific facilities. To provide further insight into CAS's research contributions, we examine its research output in STEM fields in the following section.

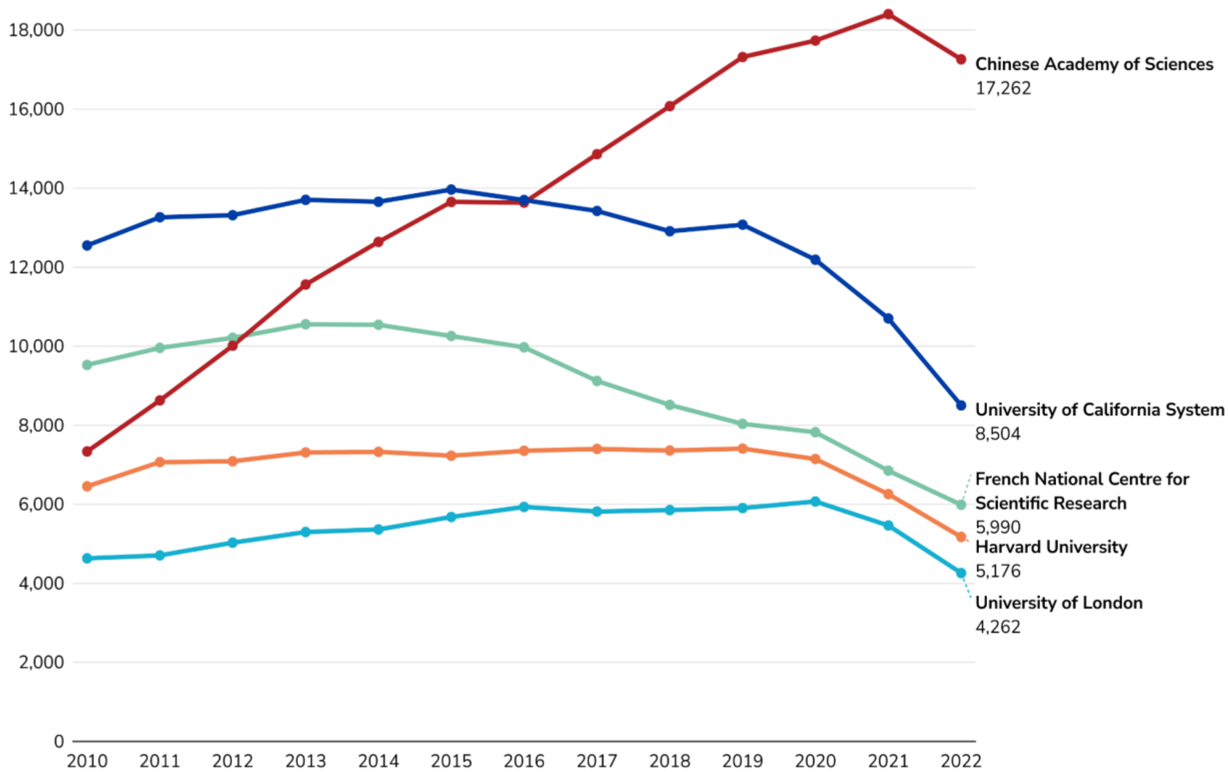
CAS Research on the Global Stage

CAS is the world's top producer of STEM research in terms of volume of papers produced, ahead of the French National Centre for Scientific Research and the University of California system (see Figure A1 in Appendix A), according to our analysis of CSET's merged corpus data. Since 2012, CAS has also topped the annual Nature Index, which ranks the top five hundred global research institutions based on counts of papers published in top international natural science and health science journals.[37] In 2023, UCAS and USTC—the two universities managed by CAS—ranked fifth and seventh on the Nature Index, respectively.[38]

Even when only accounting for highly cited STEM papers, CAS tops all other global research institutions.[*] We focus on highly cited papers, as previous bibliometric research has found that citations can be an indicator, albeit an imperfect one, of relatively high-impact research.[39] As previous research has shown, Chinese researchers are strongly incentivized to write and publish frequently.[40] This dynamic has led to a proliferation of low-quality papers published, sometimes by so-called paper mills that eschew rigorous reviews in favor of charging authors fees in order to publish papers.[41] Yet, as shown in Figure 2, CAS researchers are producing an increasing number of highly cited papers relative to other global research institutions.

[*] We define highly cited papers as papers in at least the 90th percentile of citations in their field in a given year.

Figure 2. Top Research Institutions by Highly Cited STEM Publications, 2010–2022



Source: CSET Merged Corpus.

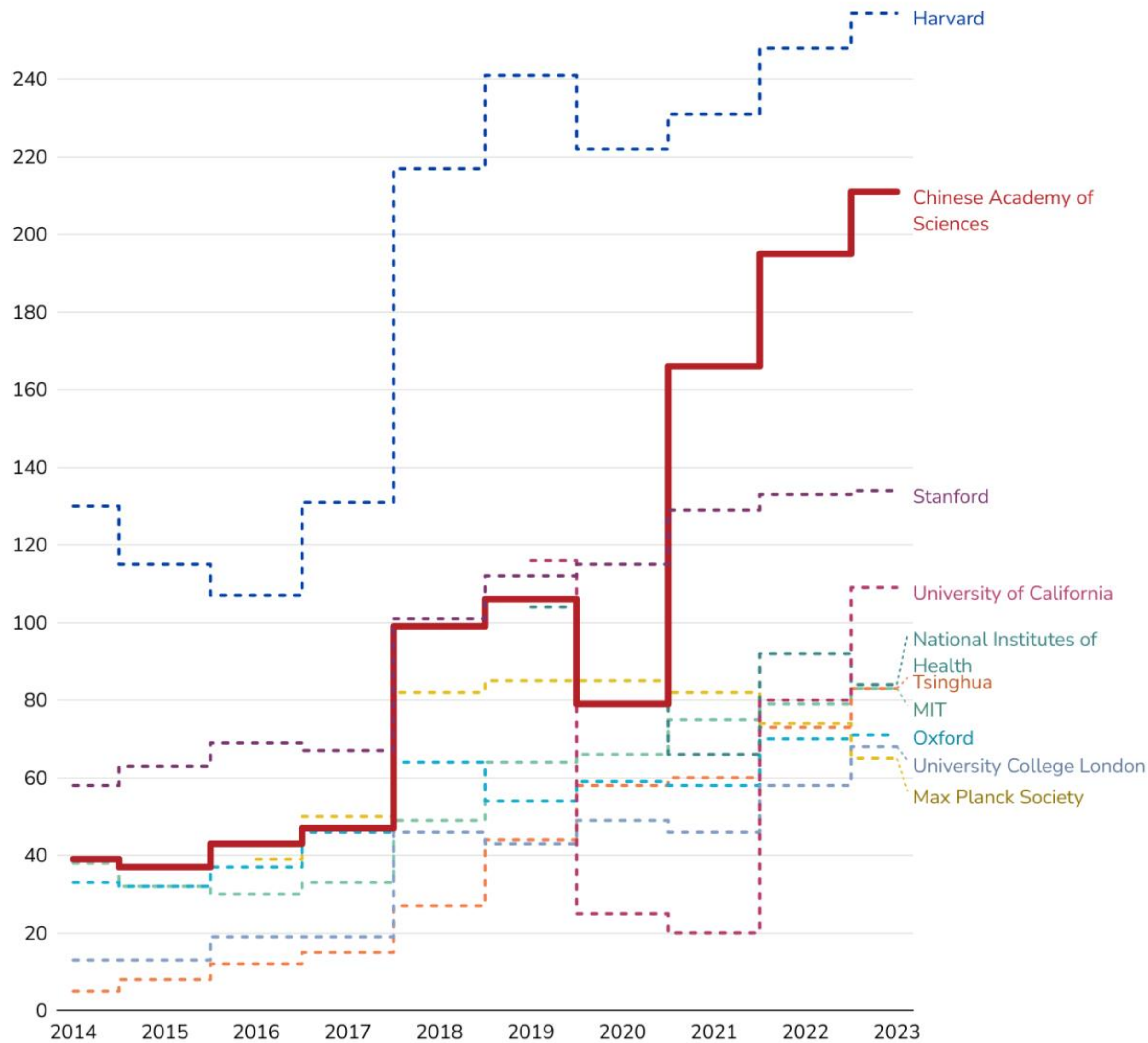
Note: See Figure A2 in Appendix A for the top 15 global research organizations for counts of both total and highly cited STEM papers.

Between 2010 and 2022, CAS's highly cited STEM research output more than doubled, its growth outpacing other leading global hubs of STEM research. Highly cited STEM papers from the University of California system and Harvard University increased only modestly over the same period, and yearly publications of highly cited papers from the other four institutions shown in Figure 2 have declined since 2020, likely due in part to the COVID-19 pandemic. In contrast, the number of CAS's highly cited STEM research publications has not declined nearly as much. Accounting only for top-cited STEM papers, our research shows that CAS passed the University of California system, the largest university system in the United States, in 2018.* Figure A3 in Appendix A shows the growth in top-cited STEM papers over time among the leading five producers of top-cited research in the world.

* We define top-cited papers as papers in the 99th percentile of citations in their field in a given year.

Not only is CAS a leading global research institution in terms of highly cited and top-cited STEM research, but individual CAS researchers are often among the leaders in their fields. Since 2014, Clarivate has published an annual list of top-cited researchers, which tracks the affiliations of individuals that rank within the top 1 percent of the most frequently cited researchers in their field and year.[42] Clarivate's list of top-cited researchers includes both STEM and non-STEM fields. As Figure 3 shows, the number of top-cited researchers affiliated with CAS has increased dramatically over the past decade, growing from 39 in 2014 to 211 in 2023, trailing only the number of those at Harvard University.

Figure 3. Highly Cited Researchers by Institution, 2014–2023



Source: Clarivate.[43]

Note: In earlier years, highly cited researchers were not aggregated for the University of California system (aggregated after 2018), the National Institutes of Health (aggregated after 2018), and the Max Planck Society (aggregated after 2015).

To be sure, readers should be judicious when drawing conclusions from the above figures, as the featured institutions are not immediately comparable without additional context. Among other differences, the size of these institutions varies, both in terms of research expenditures and number of researchers. Harvard University and Stanford University, for example, both spent around 1.3 billion USD on R&D in 2022, compared to CAS's more than 15 billion USD.[44] As of 2019, Harvard reported 7,579 R&D

personnel, much smaller than the 56,000 reported by CAS.[45] On the other hand, in both total operating budget and number of faculty and staff, CAS is smaller than the University of California system.[46] In short, while our data allows us to assess measures of STEM research output, we do not offer analysis of leading research institutions' publications relative to other important factors, including R&D expenditures and number of R&D personnel.

Still, the data presented above suggests CAS is publishing not only more STEM research papers but also a growing share of the world's most highly cited research. Over the last decade, the number of highly cited CAS publications and researchers has increased substantially, representing a rise in impactful research. CAS institutes have played an especially important role in fostering CAS's growth in high-quality research. We further detail the function and research output of the CAS institutes below.

CAS Institutes

CAS institutes are tasked with leading China's basic and applied research to solve major strategic and technological challenges, boost China's S&T self-reliance efforts, and make China's S&T ecosystem more internationally competitive.[47] The 115 CAS institutes are spread across 25 provinces and municipalities, with 35 in Beijing, 15 in Shanghai, and seven in both Jiangsu and Guangdong (see Appendix B for a complete list of CAS institutes). Below, we turn our attention to the role CAS institutes play in advancing STEM research within China's S&T ecosystem and provide some quantitative measures of their research output. We pay particular attention to the institutes' research output in critical and emerging technology fields, including in AI, to better understand CAS's efforts to advance China's capabilities in technologies deemed strategically important by Beijing.

While each institute is responsible for its own research and administration, CAS headquarters oversees the CAS institute system. CAS appoints each institute's leadership, authorizes research strategies, allocates resources, and assesses research output quality and performance. All CAS institutes are expected to adhere to the "One-Three-Five" guideline, which instructs them to have one R&D direction, to make three major breakthroughs within five to 10 years, and to establish five key line-of-research priorities every five years.[48] As a result of this organizational structure, each CAS institute specializes in specific scientific areas.

In addition to their role in advancing S&T research, CAS institutes help develop China's S&T workforce by providing graduate students with training and hands-on research opportunities. For example, UCAS offers a "two-stage" (两段式) program, which allows graduate students to first take courses at the university and then complete degree-related scientific research at one of the CAS institutes.[49] Moreover, some faculty hold joint appointments at a CAS university and a CAS institute, helping to bring additional scientific expertise from practicing scientists directly into the classroom.[50] Several CAS institutes offer graduate degree programs, sometimes in partnership with neighboring universities.[51] These mechanisms provide graduate students enrolled at CAS universities with valuable research experience and access to scientific research facilities.

Below, we draw on CNKI data to assess the 115 CAS institutes' publications by field of study. Each scientific paper in CSET's repository of CNKI data includes information about the authors and their organizational affiliations. Some CAS-affiliated authors may list their affiliation to a certain CAS institute but not to CAS itself. By assessing the publications attributed to CAS institutes, we are able to capture a more comprehensive sample of CAS-affiliated research within China's S&T research ecosystem.

In Figure 4, we present the STEM papers of the CAS institutes alongside those of the top fifteen research organizations that appear in CSET's CNKI dataset. Taken together, CAS institutes are the most prolific producers of STEM research in China, demonstrating the importance of CAS-affiliated research organizations in China's S&T ecosystem. Although the research institutions in Figure 4 are not directly comparable, as they each vary in size and structure, it is nonetheless noteworthy that the CAS institutes produced more than three times as many STEM publications as the next leading Chinese research institution. The CAS institutes accounted for 178,318 papers published between 2010 and 2021, over 125,000 more than Tongji University, the second largest producer of STEM research in China. UCAS—the largest of the three CAS-managed universities—ranked third.

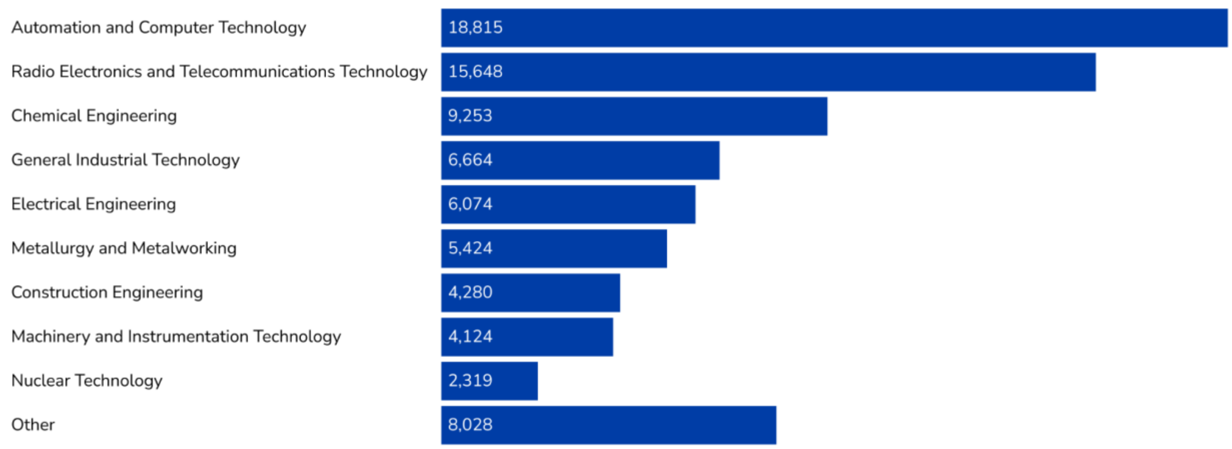
Figure 4. STEM Paper Publications by Top Publishers in China, 2010–2021

	Organization	Papers
1	**CAS Institutes**	178,318
2	Tongji University	53,243
3	University of Chinese Academy of Sciences	51,054
4	Tsinghua University	47,109
5	Zhejiang University	45,424
6	Shanghai Jiao Tong University	39,996
7	South China University of Technology	39,695
8	Central South University	39,325
9	Sichuan University	36,410
10	Wuhan University	36,304
11	Harbin Institute of Technology	36,284
12	Tianjin University	35,777
13	Chongqing University	35,753
14	Southwest Jiaotong University	35,545
15	Northwestern Polytechnical University	33,579

Source: CNKI.

The research output of the CAS institutes encompasses a wide range of disciplines. Reflecting CAS's focus on research in critical and emerging technology fields, CAS institutes published most often in the industrial technology field, which encompasses technologies related to autonomy, information and communication technologies, chemical engineering, and more. Industrial technology accounted for 35 percent of CAS institute papers in 2021, followed by astronomy and geoscience, environmental science, and agricultural sciences. See Figure A4 in Appendix A for CAS institute papers over time by field. Figure 5 shows CAS industrial technology papers by subfield. CAS institutes published most frequently in the subfield of automation and computer technology, which includes AI-related research, followed by radio electronics and telecommunications technology and chemical engineering.

Figure 5. CAS Institutes Industrial Technology Papers by Subfield, 2010–2021



Source: CNKI.

CAS is especially important to China's AI research. According to *China's New Generation Artificial Intelligence Technology Industry Development Report 2022*, published by the Chinese Institute of New Generation Artificial Intelligence Development Strategies, CAS is a key node within China's AI innovation network and an important source of basic research for China's top AI companies.[52] Our analysis of the research output of the CAS institutes further supports CAS's role in China's AI ecosystem. Between 2010 and 2021, the CAS institutes published 23,431 AI-related papers in STEM fields, more than twice as many as Wuhan University, the second leading Chinese institution in AI-related publications. See Figure A5 in Appendix A for the top ten publishers of AI-related publications in China.

Some CAS institutes are focused on advancing AI research. The Institute of Automation (自动化研究所), the Shenyang Institute of Automation (沈阳自动化研究所), and the Institute of Computing Technology (计算技术研究所) are among the top producers of AI-related research within CAS. Over half of all papers published by these institutes were AI-related, as shown in Figure 6.

Figure 6. CAS Institutes by Percentage of AI-Related Papers, 2010–2021

CAS Institute	AI Papers	Total Papers	AI Papers, Percent of Total
Institute of Automation	1,380	1,635	84%
Shenyang Institute of Automation	1,963	2,744	72%
Institute of Computing Technology	1,615	2,737	59%
Aerospace Information Research Institute	417	863	48%
Institute of Software	781	1,770	44%
Institute of Information Engineering	614	1,463	42%
Suzhou Institute of Biomedical Engineering and Technology	166	534	31%
Institute of Optics and Electronics	426	1,495	29%
Hefei Institutes of Physical Science	429	1,525	28%
Institute of Acoustics	759	2,925	26%
Academy of Mathematics and Systems Science	350	1,447	24%
Changchun Institute of Optics, Fine Mechanics, and Physics	1,984	8,266	24%
Xi'an Institute of Optics and Precision Mechanics	415	1,791	23%
National Space Science Center	238	1,041	23%
Shanghai Institute of Technical Physics	438	2,191	20%

Source: CNKI.

Note: This figure only includes CAS institutes that published at least one hundred AI-related papers between 2010 and 2021.

Notably, a small number of CAS institutes conducted the majority of CAS's total published AI-related research. Eight of them accounted for half of all AI-related papers published by CAS institutes between 2010 and 2021. This degree of specialization likely reflects their adherence to the "One-Three-Five" guideline, which encourages CAS institutes to deepen their expertise in more specialized research fields.

As shown above, CAS is a hub for top-tier S&T talent and a leader in STEM research, both on the global stage and within China's domestic innovation ecosystem. But CAS is not only a research institution. In the following section, we highlight CAS's efforts to commercialize research in key technology areas.

Fostering Commercialization of Critical Technologies

A top priority for Beijing, commercializing S&T research is another of CAS's core functions. The CAS 13th Five-Year Plan stipulates that the organization incubate five thousand "'popular entrepreneurship and mass innovation' enterprises, strengthen and expand a batch of globally competitive innovative enterprises and 'hidden champion' (隐形冠军) enterprises, and provide the 'four technology' services (technology development, technology ownership transfer, technology consulting, and technology services) for no less than 20,000 enterprises."[53] Moreover, in recent years CAS has implemented policies urging universities and research institutes to allow academics to work part-time at companies and has added technology transfer metrics to the research institution evaluation system.[54] These efforts suggest that CAS is redoubling its efforts to be a bridge between basic and applied research initiatives, as well as to promote technology diffusion and adoption.

CAS has various commercialization mechanisms at its disposal to encourage technology transfer from research institutions to industry. These include offering contract research services, licensing proprietary technology, launching new companies out of CAS institutes, providing industry access to CAS research facilities, and providing financing for companies through investment mechanisms.[55]

Chinese Academy of Sciences Holding Co., Ltd. (中国科学院控股有限公司), for instance, is CAS's primary investment arm. Established in 2002, CASH invests in five key sectors: new materials, energy, and environmental protection; technology services and financial technology; publishing and media; high-end equipment; and information technology.[56] CAS also operates a venture capital investment arm—CAS Investment Management Co., Ltd. (中国科技产业投资管理有限公司)—which primarily makes early-stage investments in areas such as biotechnology, medical technology, AI, battery technology, semiconductors, and aerospace.[57]

USTC, one of the universities CAS manages, also funds a state-owned asset management company called USTC Holdings Company Limited (中科大资产经营有限责任公司), which is responsible for the commercialization of scientific research and management of university assets. According to its website, USTC Holdings owns stakes in more than 20 companies, including iFLYTEK.[58]

Commercialization: CAS University Spin-Off

Case Study: iFLYTEK

In 1999, a group of USTC students founded iFLYTEK—an AI company known for voice-recognition technology—using a prototype of speech synthesis technology first created at a lab at USTC.[59] Since the company's founding, iFLYTEK and USTC have maintained close research, workforce, and financial ties. For example, iFLYTEK and USTC jointly built the National Engineering Research Center of Speech and Language Information Processing (语音及语言信息处理国家工程研究中心), and in 2021 together participated in the Open Automatic Speech Recognition Challenge organized by the U.S. National Institute of Standards and Technology.[60] The two entities also maintain workforce- and education-development programs through on-campus training mechanisms and encouraging iFLYTEK employees to serve as part-time doctoral advisers.[61] USTC Holdings is iFLYTEK's fourth largest shareholder, and the chairman and founder of iFLYTEK holds professorial and supervisory positions at USTC and is the chairperson of CAS's Artificial Intelligence Industry-University-Research Innovation Alliance (中科院人工智能产学研创新联盟).[62] Notably, iFLYTEK is listed on the U.S. Commerce Department's Bureau of Industry and Security's (BIS) Entity List for its role in enabling the surveillance of Uyghurs in Xinjiang.[63]

Some CAS institutes also manage their own investment companies. For example, the Institute of Computing Technology—which is on the BIS Entity List "for acquiring and attempting to acquire U.S.-origin items in support of China's military modernization"—operates Beijing Zhongke Suanyuan Asset Management Co., Ltd. (北京中科算源资产管理有限公司), a wholly owned asset management company focused on computing technology investments.[64] According to its website, the company has helped the Institute of Computing Technology launch a number of China's computing and microelectronics companies, including supercomputing manufacturer Sugon (曙光信息产业股份有限公司), AI chip developer Cambricon (中科寒武纪科技股份有限公司), and CPU designer Loongson (龙芯中科技术股份有限公司), all of which are on the BIS Entity List.[65] Connections to CAS institutes afford these spin-off companies access to technical expertise, scientific facilities, increased resources, and other intangible benefits. In turn, successful spin-off companies often invest in and support other promising companies.[66]

Commercialization: CAS Institute Spin-Off

Case Study: Lenovo

In 1984, the CAS Institute of Computing Technology provided seed funding to 11 institute researchers to found the New Technology Development Company (中国科学院计算所新技术发展公司). In 1988, NTD Co. was reorganized into Legend Computer Group Co., which later rebranded to Lenovo Group (联想集 团), or Lenovo in 2003.[67] The company's first product was an extension card, which is a hardware component that enhances a computer's functionality. This innovation allowed the company to secure financial backing, partner with firms to establish a manufacturing joint venture, and expand into Hong Kong.[68] In 1994, Legend Holdings, owner of the company, transferred 65 percent of its shares to CAS.[69] CAS's backing helped the company expand its operations, enter international markets, and eventually go public.[70] By 2004, Lenovo had become the world's third-largest PC company.[71] Today, Lenovo is one of the world's largest consumer electronics manufacturers.[72] Legend Holdings maintains a 31 percent stake in Lenovo Group; in turn, CAS maintains a 29 percent share of Legend Holdings.[73]

The case studies of iFLYTEK and Lenovo help reveal CAS's role in fostering the commercialization of critical technologies. CAS promotes the development of technology companies by providing financial support and personnel to help found them. Once established, these companies often maintain strong connections with CAS through joint research projects, financial ties, and talent development programs. Still, while these examples provide important insights into how CAS has contributed to China's technology commercialization, more work is needed to better understand CAS's overall contributions to facilitating tech transfer in China.

Advising S&T Policymaking

Beyond advancing S&T research and facilitating technological commercialization, CAS is a powerful player in China's S&T policymaking process and has a long history of shaping some of the country's most important scientific initiatives. For example, CAS recommendations resulted in the creation of the 863 Program (also known as the National High-Tech Development Plan), which fueled progress in supercomputing and aerospace technologies.[74] A CAS proposal also led to the development of the 973 Program, which was a key source of funding for basic research in important S&T fields until it was folded into China's National Key R&D Program in 2016.[75] In addition to being a powerful stakeholder in China's S&T bureaucracy, CAS influences the Chinese S&T policymaking process through its academicians (院士) and think tanks.

CAS academicians are among the most influential individuals in China's S&T ecosystem. They affect the allocation of resources to various research and commercial units, manage significant budgets, and in recent years have featured prominently in China's foremost political offices.[76] For instance, Yin Hejun (阴和俊), an academician who was previously the vice president of CAS, currently leads the Ministry of Science and Technology.[77] A total of 20 CAS academicians are currently in the 205-member 20th Central Committee, up from 18 in the 19th Central Committee (2017–2022) and eight in the 18th Central Committee (2012–2017).[78] CAS academicians do not need to hold official government positions to shape S&T policy. For instance, recommendations authored by CAS academicians resulted in the founding of the NSFC and the Chinese Academy of Engineering, both major players in China's S&T ecosystem today.[79]

Academicians also lead the research conducted by major science and technology think tanks such as the Academic Divisions of the Chinese Academy of Sciences (CASAD; 中国科学院学部) and the Institutes of Science and Development (CASISD; 中国科学院科技战略咨询研究院).[80] Established in 1955, CASAD advises the State Council and other government agencies on the formation and coordination of S&T policy and is intended to increase communication between researchers and policymakers.[81] Starting in 2019, for instance, CASAD conducted joint research with the NSFC to study future development paths of various emerging technologies and scientific fields of research critical to China's development.[82] The Research on the Development Strategy of Chinese Disciplines and Frontier Fields (中国学科及前沿领域发展战略研究) project brought together over three thousand scientists, including four hundred of the roughly eight hundred total CAS academicians, resulting in the publication of 38 books, each of which outlines a development strategy for a scientific discipline or frontier technology field.[83]

CASISD, founded in 2016, emerged out of a Chinese government initiative to form twenty-five “New Think Tanks with Chinese Characteristics” (中国特色新型智库) and a directive from Xi Jinping for CAS to create a “first-class” S&T think tank.[84] It is intended to improve China’s assessment and policymaking capabilities.[85] CASISD uses its ties to CAS to assess progress in China’s S&T ecosystem and makes S&T policy recommendations for both CAS and China generally.[86] According to the CAS 13th Five-Year Plan, CASISD is also tasked with promoting international scientific exchanges.[87]

Conclusion

The top global producer of STEM papers and home to many of the world's leading researchers, CAS is one of the most important S&T institutions in the world and plays a pivotal role in advancing China's S&T development. Our analysis of CAS's research output underscores the institution's key position in China's STEM ecosystem. CAS also fosters the commercialization and adoption of important technologies. Moreover, CAS actors, including academicians and think tanks, often help shape Chinese S&T policy.

To be sure, CAS has made progress in achieving the organizational goals set out in various policy documents.[88] CAS is a leading producer of impactful research and is the world's largest producer of highly cited and top-cited STEM publications. Successful tech companies have emerged from CAS research and investments, contributing to China's competitiveness in critical and emerging technologies. National S&T policies are often developed with input from CAS policymakers and academicians.

At the same time, CAS continues to face various challenges. While the organization has rapidly climbed global research rankings in recent years, only a handful of researchers from CAS have been awarded the world's most prestigious scientific awards.[89] No CAS scientist has ever received the Turing Award or Nobel Prize, for example. In addition, ongoing reforms to China's S&T bureaucracy, first announced in March 2023, could affect CAS's core functions and responsibilities. Intended to centralize and streamline S&T decision-making authorities under the newly announced Central Science and Technology Commission, these reforms will likely impact CAS's role in shaping national S&T policy.[90]

Furthermore, CAS's core functions—advancing research, commercializing technologies, and shaping S&T policy—may be in tension with one another. As a basic research organization, CAS is incentivized to meet or exceed its research goals. As a commercial entity, CAS must promote the growth of its spin-off enterprises and prioritize applied research projects that might lead to greater revenues for the organization. As an influential policymaking actor, CAS's leaders are incentivized to increase the organization's relative political power and influence within China's S&T bureaucracy. If CAS over-prioritizes its commercial activities, CAS scientists might invest less time in basic research in favor of projects that can be more easily commercialized. On the other hand, if CAS over-invests in developing its basic R&D programs at the expense of its commercial endeavors, it may negatively affect CAS's business interests, which are an essential source of revenue for the organization. CAS is tasked with shaping Chinese S&T policies, but it is also invested in protecting its own organizational interests, and therefore it may advocate against policies that threaten to weaken its position in

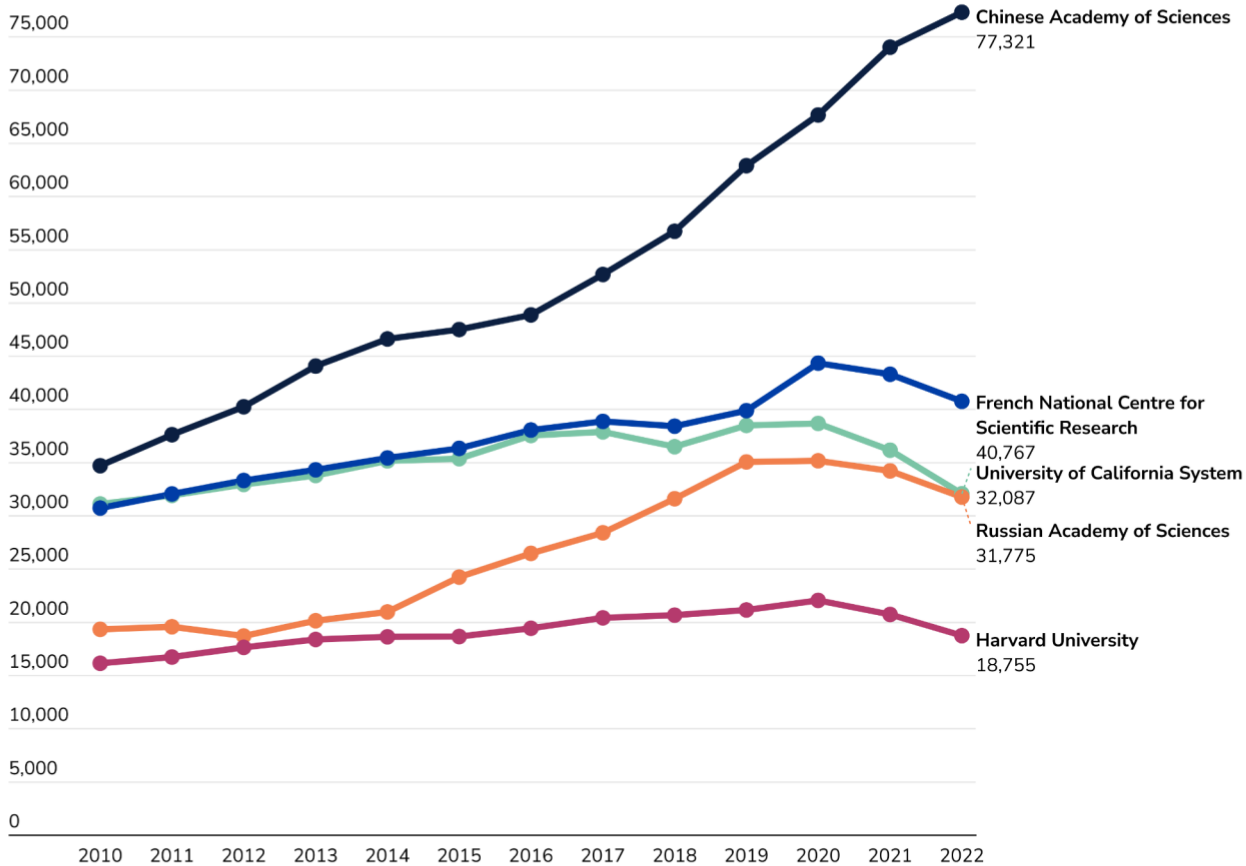
China's S&T ecosystem, even if those policies might better advance the country's S&T development.

The tensions among CAS's core functions described above could pose challenges to the organization's ability to simultaneously advance all three functions. Moreover, CAS's success in certain metrics—such as research output and number of top-cited researchers—relative to other leading STEM research institutions does not necessarily suggest that China's model of S&T development is more effective than that of other countries. As shown in this report, Beijing has committed extensive resources to CAS to push forward its S&T development goals. Consequently, CAS's success, or lack thereof, will affect Beijing's ability to achieve its own strategic objectives.

Despite these challenges, CAS's importance to Beijing's S&T ambitions underscores the need for U.S. policymakers to better understand the organization. While this report does not offer an exhaustive account of CAS's activities, it provides an important foundation for understanding CAS, which will remain a key driver of China's S&T development for the foreseeable future.

Appendix A: Additional Figures

Figure A1. Annual STEM Publications, Top Publishing Organizations, 2010–2022



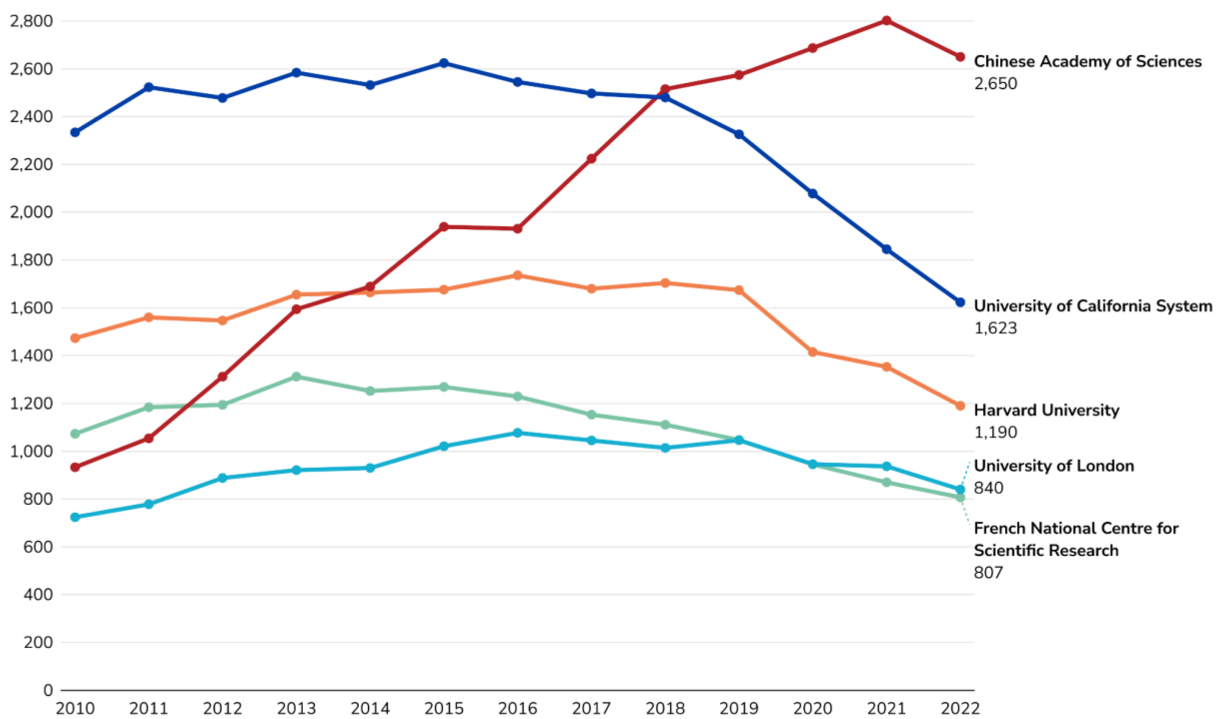
Source: CSET Merged Corpus.

Figure A2. Top Publishing Organizations, Total and Highly Cited STEM Papers, 2010–2022

ALL STEM PAPERS			HIGHLY CITED STEM PAPERS		
Rank	Organization	Papers	Rank	Organization	Papers
1	Chinese Academy of Sciences	759,271	1	Chinese Academy of Sciences	191,451
2	French National Centre for Scientific Research	520,482	2	University of California System	169,959
3	University of California System	479,045	3	French National Centre for Scientific Research	135,335
4	Russian Academy of Sciences	366,441	4	Harvard University	94,180
5	Harvard University	265,000	5	UDICE-French Research Universities	76,079
6	United States Department of Energy	222,098	6	University of London	72,917
7	UDICE-French Research Universities	221,770	7	United States Department of Energy	72,243
8	University of Texas System	213,960	8	The University of Texas System	66,782
9	University of London	212,462	9	Helmholtz Association	66,690
10	Helmholtz Association	211,084	10	Max Planck Society	61,751
11	Indian Institutes of Technology System	194,378	11	Massachusetts Institute of Technology	49,670
12	Shanghai Jiao Tong University	187,910	12	Stanford University	48,736
13	Zhejiang University	187,475	13	Spanish National Research Council	46,966
14	Max Planck Society	181,472	14	Pennsylvania Commonwealth System of Higher Education	46,895
15	Tsinghua University	175,969	15	Tsinghua University	46,356

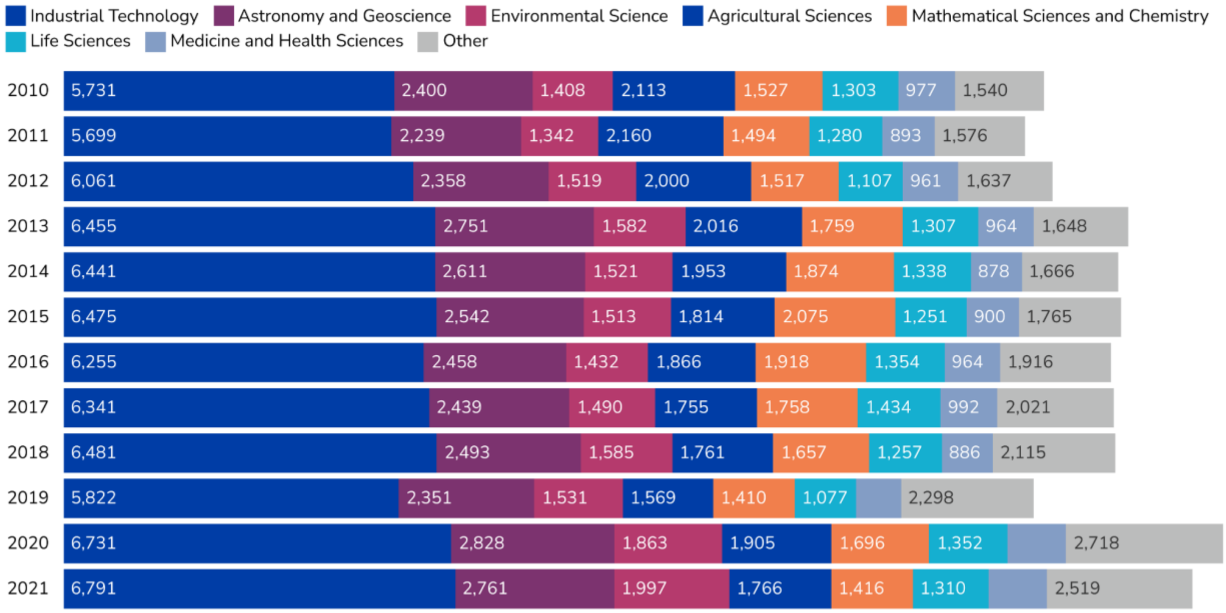
Source: CSET Merged Corpus.

Figure A3. Top Publishing Organizations by Top-Cited STEM Papers, 2010–2022



Source: CSET Merged Corpus.

Figure A4. CAS Institutes' Paper Publications by Fields of Study, 2010–2021



Source: CNKI.

Figure A5. AI-Related Papers by Top Publishers in China, STEM Papers, 2010–2021

	Organization	Papers
1	CAS Institutes	23,431
2	Wuhan University	9,520
3	University of Chinese Academy of Sciences	9,305
4	Nanjing University of Aeronautics and Astronautics	8,902
5	Shanghai Jiao Tong University	8,277
6	Tsinghua University	8,208
7	Northwestern Polytechnical University	8,206
8	Zhejiang University	7,974
9	Harbin Institute of Technology	7,626
10	Beihang University	6,925

Source: CNKI.

Appendix B: List of CAS Institutes

Name (Chinese)	Name (English)	Location	U.S. Government Restriction[91]
数学与系统科学研究院	Academy of Mathematics and Systems Science	Beijing	None
物理研究所	Institute of Physics	Beijing	Entity List[92]
理论物理研究所	Institute of Theoretical Physics	Beijing	None
高能物理研究所	Institute of High Energy Physics	Beijing	None
力学研究所	Institute of Mechanics	Beijing	None
声学研究所	Institute of Acoustics	Beijing	None
理化技术研究所	Technical Institute of Physics and Chemistry	Beijing	None
化学研究所	Institute of Chemistry	Beijing	None
国家纳米科学中心	National Center for Nanoscience and Technology	Beijing	None
生态环境研究中心	Research Center for Eco-Environmental Sciences	Beijing	None
过程工程研究所	Institute of Process Engineering	Beijing	None
地理科学与资源研究所	Institute of Geographic Sciences and Natural Resources Research	Beijing	None
国家天文台	National Astronomical Observatories	Beijing	None
云南天文台	Yunnan Observatories[93]	Kunming	None
南京天文光学技术研究所	Nanjing Institute of Astronomical Optics & Technology[94]	Nanjing	Entity List[95]
新疆天文台	Xinjiang Astronomical Observatory[96]	Urumqi	None
长春人造卫星观测站	Changchun Observatory[97]	Changchun	None

地质与地球物理研究所 (地球科学研究院）	Institute of Geology and Geophysics (Innovation Academy for Earth Science)	Beijing	None
青藏高原研究所	Institute of Tibetan Plateau Research	Lhasa	None
古脊椎动物与古人类研究所	Institute of Vertebrate Paleontology and Paleoanthropology	Beijing	None
大气物理研究所	Institute of Atmospheric Physics	Beijing	None
植物研究所	Institute of Botany	Beijing	None
动物研究所	Institute of Zoology	Beijing	None
心理研究所	Institute of Psychology	Beijing	None
微生物研究所	Institute of Microbiology	Beijing	None
生物物理研究所	Institute of Biophysics	Beijing	None
遗传与发育生物学研究所	Institute of Genetics and Developmental Biology (IGDB)[98]	Shijiazhuang	None
农业资源研究中心	Center for Agricultural Resources Research, (IGDB)[99]	Shijiazhuang	None
北京基因组研究所 (国家生物信息中心)	Beijing Institute of Genomics (China National Center for Bioinformation)	Beijing	None
计算技术研究所	Institute of Computing Technology	Beijing	Entity List[100]
软件研究所	Institute of Software	Beijing	None
半导体研究所	Institute of Semiconductors	Beijing	None
微电子研究所	Institute of Microelectronics[101]	Guangzhou	None
空天信息创新研究院	Aerospace Information Research Institute	Beijing	None
自动化研究所	Institute of Automation	Beijing	None
电工研究所	Institute of Electrical Engineering	Beijing	None
工程热物理研究所	Institute of Engineering Thermophysics	Beijing	None

国家空间科学中心	National Space Science Center	Beijing	None
自然科学史研究所	Institute for the History of Natural Sciences	Beijing	None
科技战略咨询研究院	Institutes of Science and Development	Beijing	None
信息工程研究所	Institute of Information Engineering	Beijing	None
数据与通信保护研究教育中心	Data Assurance & Communications Security Center[102]	Beijing	None
空间应用工程与技术中心	Technology and Engineering Center for Space Utilization	Beijing	None
天津工业生物技术研究所	Tianjin Institute of Industrial Biotechnology	Tianjin	None
大连化学物理研究所	Dalian Institute of Chemical Physics	Dalian	None
金属研究所	Institute of Metal Research	Shenyang	None
沈阳应用生态研究所	Institute of Applied Ecology	Shenyang	None
沈阳自动化研究所	Shenyang Institute of Automation	Shenyang	Entity List[103]
海洋研究所	Institute of Oceanology	Qingdao	None
青岛生物能源与过程研究所	Qingdao Institute of Bioenergy and Bioprocess Technology	Qingdao	None
烟台海岸带研究所	Yantai Institute of Coastal Zone Research	Yantai	None
长春光学精密机械与物理研究所	Changchun Institute of Optics, Fine Mechanics, and Physics	Changchun	None
长春应用化学研究所	Changchun Institute of Applied Chemistry	Changchun	None
东北地理与农业生态研究所	Northeast Institute of Geography and Agroecology	Changchun	None
农业技术中心	Center for Agricultural Technology[104]	Changchun	None

上海微系统与信息技术研究所	Shanghai Institute of Microsystem and Information Technology	Shanghai	Entity List[105]
上海技术物理研究所	Shanghai Institute of Technical Physics	Shanghai	None
上海光学精密机械研究所	Shanghai Institute of Optics and Fine Mechanics	Shanghai	None
上海硅酸盐研究所	Shanghai Institute of Ceramics	Shanghai	None
上海有机化学研究所	Shanghai Institute of Organic Chemistry	Shanghai	None
上海应用物理研究所	Shanghai Institute of Applied Physics	Shanghai	Unverified List[106]
上海天文台	Shanghai Astronomical Observatory	Shanghai	None
分子细胞科学卓越创新中心 (生物化学与细胞生物学研究所)	Center for Excellence in Molecular Cell Science (Shanghai Institute of Biochemistry and Cell Biology)	Shanghai	None
脑科学与智能技术卓越创新中心 (神经科学研究所)	Center for Excellence in Brain Science and Intelligence Technology (Institute of Neuroscience)	Shanghai	None
分子植物科学卓越创新中心 (植物生理生态研究所)	Center for Excellence in Molecular Plant Sciences (Institute of Plant Physiology and Ecology)	Shanghai	None
上海营养与健康研究所	Shanghai Institute of Nutrition and Health	Shanghai	None
上海药物研究所	Shanghai Institute of Materia Medica	Shanghai	None
上海免疫与感染研究所	Shanghai Institute of Immunity and Infection	Shanghai	None
上海高等研究院	Shanghai Advanced Research Institute	Shanghai	None

微小卫星创新研究院	Innovation Academy for Microsatellites	Shanghai	None
福建物质结构研究所 (海西研究院)	Fujian Institute of Research on the Structure of Matter (Haixi Institutes)	Fuzhou	None
宁波材料技术与工程研究所	Ningbo Institute of Materials Technology & Engineering	Ningbo	None
城市环境研究所	Institute of Urban Environment	Xiamen	None
杭州医学研究所	Hangzhou Institute of Medicine	Hangzhou	None
南京地质古生物研究所	Nanjing Institute of Geology and Palaeontology	Nanjing	None
南京土壤研究所	Institute of Soil Science	Nanjing	None
南京地理与湖泊研究所	Nanjing Institute of Geography & Limnology	Nanjing	None
紫金山天文台	Purple Mountain Observatory	Nanjing	None
苏州纳米技术与纳米仿生研究所	Suzhou Institute of Nano-tech and Nano-bionics	Suzhou	None
苏州生物医学工程技术研究所	Suzhou Institute of Biomedical Engineering and Technology	Suzhou	None
赣江创新研究院	Ganjiang Innovation Academy	Ganzhou	None
合肥物质科学研究院	Hefei Institutes of Physical Science	Hefei	None
武汉岩土力学研究所	Institute of Rock and Soil Mechanics	Wuhan	None
精密测量科学与技术创新研究院	Innovation Academy for Precision Measurement Science and Technology	Wuhan	None
武汉病毒研究所 (生物安全大科学研究中心)	Wuhan Institute of Virology (Center for Biosafety Mega-science)	Wuhan	None
水生生物研究所	Institute of Hydrobiology	Wuhan	None

武汉植物园	Wuhan Botanical Garden	Wuhan	None
南海海洋研究所	South China Sea Institute of Oceanology	Guangzhou	None
华南植物园	South China Botanical Garden	Guangzhou	None
广州能源研究所	Guangzhou Institute of Energy Conversion	Guangzhou	None
广州地球化学研究所	Guangzhou Institute of Geochemistry	Guangzhou	None
长沙矿产资源勘查中心	Changsha Center for Mineral Resource Exploration[107]	Changsha	None
广州生物医药与健康研究院	Guangzhou Institutes of Biomedicine and Health	Guangzhou	None
深圳先进技术研究院	Shenzhen Institute of Advanced Technology	Shenzhen	None
亚热带农业生态研究所	Institute of Subtropical Agriculture	Changsha	None
深海科学与工程研究所	Institute of Deep-Sea Science and Engineering	Wuhan	None
成都生物研究所	Chengdu Institute of Biology	Chengdu	None
成都山地灾害与环境研究所	Institute of Mountain Hazards and Environment	Chengdu	None
光电技术研究所	Institute of Optics and Electronics	Chengdu	None
重庆绿色智能技术研究院	Chongqing Institute of Green and Intelligent Technology	Chongqing	None
昆明动物研究所	Kunming Institute of Zoology	Kunming	None
昆明植物研究所	Kunming Institute of Botany	Kunming	None
西双版纳热带植物园	Xishuangbanna Tropical Botanical Garden	Xishuangbanna	None
广州地球化学研究所	Guangzhou Institute of Geochemistry	Guangzhou	None

西安光学精密机械研究所	Xi'an Institute of Optics and Precision Mechanics	Xi'an	None
国家授时中心	National Time Service Center	Xi'an	None
地球环境研究所	Institute of Earth Environment	Xi'an	None
山西煤炭化学研究所	Institute of Coal Chemistry	Taiyuan	None
近代物理研究所	Institute of Modern Physics	Lanzhou	None
兰州化学物理研究所	Lanzhou Institute of Chemical Physics	Lanzhou	None
西北生态环境资源研究院	Northwest Institute of Eco-environment and Resources	Lanzhou	None
青海盐湖研究所	Qinghai Institute of Salt Lakes	Xining	None
西北高原生物研究所 (三江源国家公园研究院)	Northwest Institute of Plateau Biology (Institute of Sanjiangyuan National Park)	Xining	None
新疆理化技术研究所	Xinjiang Technical Institute of Physics and Chemistry	Urumqi	None
新疆生态与地理研究所	Xinjiang Institute of Ecology and Geography	Urumqi	None

Source: Chinese Academy of Sciences.

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This report was updated on October 25, 2024, to clarify the relationship between CAS, Legend Holdings, and Lenovo.

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Endnotes

[1] The State Council (国务院), also known as the Central People's Government of the People's Republic of China, is the top executive organ of the Chinese government. See: William Hannas, James Mulvenon, and Anna Puglisi, *Chinese Industrial Espionage: Technology Acquisition and Military Modernisation* (New York: Routledge, 2013).

[2] "2023 Tables: Institutions," Nature Index, www.nature.com/nature-index/annual-tables/2023/institution/all/all/global.

[3] For more, see: Autumn Toney and James Dunham, "Multi-label Classification of Scientific Research Documents Across Domains and Languages," *Association for Computational Linguistics Proceedings of the Third Workshop on Scholarly Document Processing* (October 2022): 105–114.

[4] For more on how we classify AI-related research, see: Daniel Chou, "Counting AI Research" (CSET, July 2022), https://cset.georgetown.edu/wp-content/uploads/CSET-Counting-AI-Research.pdf.

[5] Hannas, Mulvenon, and Puglisi, *Chinese Industrial Espionage*.

[6] Paul H. B. Godwin, "Strategic Forces," in *Development of the Chinese Armed Forces* (Montgomery, AL: Air University Press, 1988), https://irp.fas.org/dia/product/prc_ch-11.htm.

[7] Godwin, "Strategic Forces."

[8] Liu Yanqiong, "Chinese Academy of Sciences and the 'Two Bombs and One Satellite' Project," *Proceedings of the Chinese Academy of Sciences* 34, no. 9 (2019): 1003–1013. The Chinese term here, 两弹一星, literally means "two bombs and one satellite." It refers to China's Mao Zedong–era accomplishments of building its own nuclear bombs (原子弹), ballistic missiles (导弹), and earth satellites (卫星). The "two bombs" (两弹) part is often misconstrued as "atomic and hydrogen bombs." See William Hannas and Huey-Meei Chang, "China's STI Operations: Monitoring Foreign Science and Technology Through Open Sources" (CSET, January 2021), 27, https://cset.georgetown.edu/publication/chinas-sti-operations.

[9] "Computer 156 [156 计算机]," *CCF China Computer Historical Memory*, 2018, https://perma.cc/2Y3Q-VWQ3.

[10] The six institutes were the Institute of Computing Technology, Institute of Electronics, Institute of Physics, Northeast Institute of Physics, Northwest Institute of Computing Technology, and Institute of Applied Chemistry. Today, as part of the China Aerospace Science and Technology Corporation (CASC), the Xi'an Microelectronics Technology Institute remains a key People's Liberation Army supplier and manages two military-standard integrated circuit foundries. CASC is a state-owned defense and aerospace conglomerate. For more, see Eric Lee and Seamus Boyle, "Chinese Nuclear Missile Guidance Systems: Spotlight on the Xian Institute of Microelectronics Technology" (Project 2049 Institute, September 18, 2020), https://project2049.net/2020/09/18/chinese-nuclear-missile-guidance-systems-spotlight-on-the-xian-institute-of-microelectronics-technology/.

[11] Xi'an Microelectronics Technology Institute still holds 34 percent ownership of ZTE, and financial filings show that ZTE maintains close ties to the institute. The institute is the second largest shareholder of ZTE. The company and institute are also tied through shared personnel. The institute in 2022 nominated three of the nine directors on the company's board, and the current chairman and executive director of ZTE previously held numerous leadership positions at the institute, including deputy head of from 2015 to 2019. In August 2022, the U.S. Department of Commerce's Bureau of Industry and Security (BIS) added Xi'an Microelectronics Technology Institute to the Entity List "for acquiring and attempting to acquire US-origin items in support of China's military modernization efforts." Lee and Boyle, "Chinese Nuclear Missile Guidance Systems"; "2022 Annual Report" (ZTE Corporation, March 2023), https://perma.cc/7ZN8-X42W; BIS, "Additions of Entities to the Entity List," *Federal Register* 87 FR 51876 (August 24, 2022), www.federalregister.gov/documents/2022/08/24/2022-18268/additions-of-entities-to-the-entity-list.

[12] Richard P. Suttmeier, Cong Cao, and Denis Fred Simon, "China's Innovation Challenge and the Remaking of the Chinese Academy of Sciences," *Innovations: Technology, Governance, Globalization* 1, no. 3 (Summer 2006): 78–97, https://doi.org/10.1162/itgg.2006.1.3.78.

[13] Suttmeier, Cao, and Simon, "China's Innovation Challenge."

[14] Suttmeier, Cao, and Simon, "China's Innovation Challenge."

[15] Richard P. Suttmeier, Cong Cao, and Denis Fred Simon, "'Knowledge Innovation' and the Chinese Academy of Sciences," *Science* 312, no. 5770 (April 7, 2006): 58–59.

[16] Suttmeier, Cao, and Simon, "Knowledge Innovation." For example, in 2001, the Institute of Genetics and Developmental Biology was formed by merging the Institute of Genetics and the Institute of Developmental Biology. In 2003, the Beijing Genomics Institute—now BGI Group—was separated from the Institute of Genetics and Developmental Biology and established as a CAS research institute. "Institute Overview" [研究所概况], Institute of Genetics and Developmental Biology, accessed May 9, 2024, https://perma.cc/PMC3-SPX6.

[17] Suttmeier, Cao, and Simon, "Knowledge Innovation"; Federal Bureau of Investigation Strategic Partnership Unit, *Chinese Talent Programs*, Counterintelligence Strategic Partnership Intelligence Note (Washington, DC: FBI, September 2015), https://info.publicintelligence.net/FBI-ChineseTalentPrograms.pdf.

[18] The seven new institutes established were the Guangzhou Institutes of Biomedicine and Health, Institute of Urban Environment (in Xiamen), Yantai Institute of Coastal Zone Research, Suzhou Institute of Nano-tech and Nano-bionics, Qingdao Institute of Bioenergy and Bioprocess Technology, Ningbo Institute of Materials Technology & Engineering, and the Shenzhen Institute of Advanced Technology. Micah Springut, Stephen Schlaikjer, and David Chen, *China's Program for Science and Technology Modernization: Implications for American Competitiveness* (Washington, DC: U.S.-China Economic and Security Review Commission, April 20, 2011), www.uscc.gov/sites/default/files/Research/USCC_REPORT_China%27s_Program_forScience_and_Technology_Modernization.pdf.

[19] Springut, Schlaikjer, and Chen, *China's Program for Science and Technology Modernization*.

[20] Jane Qiu, "China Sets 2020 Vision for Science," *Science* 470, no. 15 (February 1, 2011), https://doi.org/10.1038/470015a.

[21] Yuehui Wu, "Chinese Academy of Sciences Contributes to Belt and Road Construction through Science Cooperation," *People's Daily*, April 23, 2019, https://perma.cc/7LYW-J93M.

[22] CAS, "Outline of the Chinese Academy of Sciences 13th Five-Year Development Plan" [中国科学院'十三五'发展规划纲要], trans. CSET (CSET, October 20, 2022), https://cset.georgetown.edu/publication/outline-of-the-chinese-academy-of-sciences-13th-five-year-development-plan/.

[23] Jane Qiu, "Chinese Academy of Sciences Has Big Plans for Nation's Research," *Nature*, March 24, 2011, www.nature.com/articles/news.2011.180.

[24] CAS, "Chinese Academy of Sciences 2022 Budget" [中国科学院 2022 年部门预算], trans. CSET (CSET, June 30, 2022), https://cset.georgetown.edu/publication/chinese-academy-of-sciences-2022-budget/.

[25] USTC (中国科学技术大学) was founded in 1958 to support China's "Nuclear Bombs, Ballistic Missiles, and Earth Satellites" program. USTC houses 32 colleges focusing on cutting-edge science and technology, medicine, and humanities subjects. USTC also has five research institutes: the Suzhou Institute for Advanced Research, the Shanghai Institute for Advanced Studies, Beijing Research Institute, the Institute of Advanced Technology, and the International Institute of Finance. On May 9, 2024, USTC was added to the BIS's Entity List for acquiring and attempting to acquire U.S.-origin items in support of advancing China's quantum technology capabilities and for being involved in advancing China's nuclear program development.

UCAS (中国科学院大学)—as it is known today—was established in 2012, but the school has existed since 1978. Formerly known as the Graduate School of the University of Science and Technology of China, it was the first graduate school in China. Since 2014, however, UCAS has enrolled both undergraduate and graduate students.

ShanghaiTech University (上海科技大学) was founded in 2013 as a collaboration between the Shanghai Municipal People's Government and CAS. The university consists of five schools and three research institutes. ShanghaiTech claims to be an internationally focused university that aims to cultivate innovative scientists, investors, and entrepreneurs. The majority of classes are taught in both Chinese and English, and the university heavily emphasizes study abroad opportunities at prestigious universities, including Harvard University, the Massachusetts Institute of Technology, and Yale University. According to its website, 14 percent of faculty are foreign nationals and almost 25 percent of its graduates pursue postgraduate programs overseas.

"School Profile" [学校简介], USTC, January 2024, https://perma.cc/E643-UF2N; BIS, "Additions of Entities to the Entity List," *Federal Register* 89 FR 41886 (May 09, 2024), www.federalregister.gov/public-inspection/2024-10485/additions-of-entities-to-the-entity-list; "School

Profile" [学校简介], UCAS, accessed April 10, 2024, https://perma.cc/P8BX-Q6ZV; "School Profile" [学校简介], ShanghaiTech University, accessed April 10, 2024, https://perma.cc/QVD4-FJTL.

[26] Emily Weinstein, Channing Lee, Ryan Fedasiuk, and Anna Puglisi, "China's State Key Laboratory System: A View into China's Innovation System" (CSET, June 2022), https://doi.org/10.51593/20210019.

[27] Weinstein et al., "China's State Key Laboratory System."

[28] "About Us," CAS, accessed May 9, 2024, https://perma.cc/D3MV-GLFX; "Publications," CAS, accessed May 9, 2024, https://perma.cc/3K5Q-2DKD; "Machine Intelligence Research," Springer Link, accessed May 9, 2024, https://link.springer.com/journal/11633; "Journal of Plant Ecology," Oxford University Press, accessed May 9, 2024, https://academic.oup.com/jpe.

[29] For example, as of 2020, USTC had signed cooperation agreements with 39 CAS institutes and more than 30 CAS academicians and institute directors serve as part-time department leaders at the university. See "Introduction to 'All of CAS Helps Run the School and Its Departments Are Combined with CAS Institutes'" ['全院办校、所系结合'简介], USTC, August 2020, https://archive.ph/xYYBd.

[30] "Introduction to the Chinese Academy of Sciences" [中国科学院简介], CAS, August 2022, https://perma.cc/UJ86-KP9Q; "Who We Are," CAS, accessed April 10, 2024, https://perma.cc/CQV5-NZK6.

[31] The NSFC is a government-run body that oversees and audits Chinese scientific research funds, principally those that support basic research. CAS, "About Us"; "Overview" [概况], NSFC, accessed August 19, 2024, https://perma.cc/LGG9-QD2T.

[32] CAS, "The Chinese Academy of Sciences (CAS)," International Research Collaboration Information Platform, May 27, 2016, https://perma.cc/3RSV-K9U6; David Cyranoski, "China Fires Up Next-Generation Neutron-Science Facility," *Nature* 551, no. 284 (November 16, 2017), https://doi.org/10.1038/nature.2017.22976; "Another World Record for China's EAST Tokamak," *Nuclear Engineering International*, April 18, 2023, www.neimagazine.com/news/newsanother-world-record-for-chinas-east-tokamak-10768385; Institute of Plasma Physics, "Experimental Advanced Superconducting Tokamak (EAST)," CAS Large Research Infrastructures User Service Platform, accessed April 16, 2024, https://perma.cc/55SU-NANM.

[33] USD conversions used average exchange rates for years 2021 and 2023. Currency exchange rates retrieved from "Chinese Yuan to US Dollar Spot Exchange Rates for 2021," Exchange Rates UK, accessed April 10, 2024, www.exchangerates.org.uk/CNY-USD-spot-exchange-rates-history-2021.html; "Chinese Yuan to US Dollar Spot Exchange Rates for 2023," Exchange Rates UK, accessed April 10, 2024, www.exchangerates.org.uk/CNY-USD-spot-exchange-rates-history-2023.html.

[34] Figure 1 was created using data collected from the CAS budgets, which are published annually, and national basic R&D expenditure data published by the National Bureau of Statistics of China. Chinese organizations refer to the *Frascati Manual* of the Organization for Economic Cooperation and Development to define basic R&D activities. National Bureau of Statistics of China, "Notice on Issuing the 'Standards for the Statistics of Research and Experimental Development (R&D) Investment (Trial)'"

[国家统计局关于印发《研究与试验发展（R&D）投入统计规范（试行）》的通知], *National Bureau of Statistics*, no. 47 (April 19, 2019), https://perma.cc/9J4S-Q76H.

[35] As of 2023, according to the National Bureau of Statistics of China, Chinese basic R&D expenditure had risen to 6.6 percent of total R&D spending. "Cross-National Comparisons of R&D Performance," in *Science & Engineering Indicators 2018* (Washington, DC: National Science Board, January 2018), www.nsf.gov/statistics/2018/nsb20181/report/sections/research-and-development-u-s-trends-and-international-comparisons/cross-national-comparisons-of-r-d-performance.

[36] "U.S. R&D Expenditures," in *National Patterns of R&D Resources 2021–2022* (Arlington, VA: National Center for Science and Engineering Statistics, January 2024), https://ncses.nsf.gov/data-collections/national-patterns/2021-2022#data. Both the United States and China use OECD's definitions for basic R&D activities. "Wan Donghua, the Main Responsible Person of the Department of Social, Science, Culture and Health Statistics of the National Bureau of Statistics, Answers Reporters' Questions Regarding the Release of the 'Standards for Statistics on Research and Experimental Development (R&D) Input (Trial)'" [国家统计局社科文司主要负责人万东华就发布《研究与试验发展（R&D）投入统计规范（试行）》答记者问], Xinjiang Survey Corps of the National Bureau of Statistics, May 20, 2019, https://perma.cc/BB24-9384; OECD, "Concepts and Definitions for Identifying R&D," in *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development* (Paris: OECD Publishing, October 8, 2015), 47–70, https://doi.org/10.1787/9789264239012-4-en.

[37] Nature Index, "2023 Tables: Institutions."

[38] Nature Index, "2023 Tables: Institutions."

[39] See, for example, Dag W. Aksnes, Liv Langfeldt, and Paul Wouters, "Citations, Citation Indicators, and Research Quality: An Overview of Basic Concepts and Theories," *Sage Open* 9, no. 1 (2019), https://doi.org/10.1177/2158244019829575.

[40] Ken Hyland, "Enter the Dragon: China and Global Academic Publishing," *Learned Publishing* 36, no. 3 (May 18, 2023), https://doi.org/10.1002/leap.1545.

[41] Hyland, "Enter the Dragon."

[42] "Highly Cited Researchers 2023," Clarivate, accessed April 10, 2024, https://clarivate.com/highly-cited-researchers/.

[43] Clarivate, "Highly Cited Researchers 2023."

[44] Anderson, "U.S. R&D Increased by $72 Billion in 2021 to $789 Billion"; "Chinese Academy of Sciences 2022 Department Budget" [中国科学院 2022 年部门预算] (Beijing: CAS), https://perma.cc/UFQ5-KWJP.

[45] National Center for Science and Engineering Statistics, "Harvard U: Headcount of R&D Personnel: 2022–16," National Science Foundation, accessed August 19, 2024, https://ncsesdata.nsf.gov/profiles/site?method=report&tin=U1300001&id=h4.

[46] University of California, "The University of California at a Glance," March 2024, https://ucop.edu/institutional-research-academic-planning/_files/uc-facts-at-a-glance.pdf.

[47] CAS, "Outline of the Chinese Academy of Sciences 13th Five-Year Development Plan."

[48] Fang Xu and Xiaoxuan Li, "The Changing Role of Metrics in Research Institute Evaluations Undertaken by the Chinese Academy of Sciences (CAS)," *Palgrave Communications*, no. 2 (October 25, 2016), https://doi.org/10.1057/palcomms.2016.78.

[49] "Yang Chunli" [杨春莉], UCAS, accessed June 18, 2024, https://perma.cc/K4XL-9GYU .

[50] "Introduction to University of Chinese Academy of Sciences (UCAS)," UCAS, accessed June 18, 2024, https://perma.cc/2SZY-CGGN.

[51] See, for example, Institute of Automation, "Admission Brochure for the Institute of Automation, Chinese Academy of Sciences, to Recruit Master's Degree Students in 2024" [中国科学院自动化研究所 2024 年招收攻读硕士学位研究生招生简章], CAS, September 22, 2023, https://perma.cc/YE2N-R9CW.

[52] Liu Gang et al., *China's New Generation Artificial Intelligence Technology Industry Development Report 2022* [中国新一代人工智能科技产业发展报告 2022] (Chinese Institute of New Generation Artificial Intelligence Development Strategies [中国新一代人工智能发展战略研究院], June 24, 2022), https://perma.cc/3259-XU3J.

[53] CAS, "Outline of the Chinese Academy of Sciences 13th Five-Year Development Plan." "Hidden Champion" (隐形冠军) enterprises prioritize R&D and focus on developing cutting-edge products in niche markets. Source: https://perma.cc/T4MH-4CN2.

[54] Cong Cao and Richard P. Suttmeier, "Challenges of S&T System Reform in China," *Science* 355, no. 6329 (April 10, 2017): 1019–2021, https://doi.org/10.1126/science.aal2515; "Notice of the State Council on Issuing and Implementing Certain Provisions of the 'Law of the People's Republic of China on Promoting the Transformation of Scientific and Technological Achievements'" [国务院关于印发实施《中华人民共和国促进科技成果转化法》若干规定的通知], State Council, no. 16 (March 2, 2016), https://cset.georgetown.edu/publication/state-council-notice-on-the-publication-of-certain-regulations-on-implementing-the-law-of-the-peoples-republic-of-china-on-promoting-the-conversion-of-scientific-and-technological-achievements/.

[55] Suttmeier, Cao, and Simon, "'Knowledge Innovation"; "Notice of the Chinese Academy of Sciences on the Issuance of the 'Measures for the Openness and Sharing of Large-Scale Scientific Research Instruments of the Chinese Academy of Sciences'" [中国科学院关于印发《中国科学院大型科研仪器开放共享管理办法》的通知], CAS, March 25, 2022, https://perma.cc/J2GC-MQZS; State Council, "Opinions of the State Council on the Opening of Major National Scientific Research Infrastructure and Large-Scale Scientific Research Instruments to the Public" [国务院关于国家重大科研基础设施和大型科研仪器向社会开放的意见], Science and Technology Innovation and Development Center, December 31, 2014, https://perma.cc/TUW2-85XR; 科技部, 发展改革委, and 财政部, "Notice of the Development and Reform Commission of the Ministry of Science and Technology and the Ministry of Finance on the Issuance of

the ‘Measures for the Openness and Sharing of National Major Scientific Research Infrastructure and Large Scientific Research Instruments” [科技部 发展改革委 财政部关于印发《国家重大科研基础设施和大型科研仪器开放共享管理办法》的通知], 中国科学院条件保障与财务局, September 20, 2017, 国科发基〔2017〕289 号 edition, https://perma.cc/S87C-C88W.

[56] “Corporate Bond Annual Report (2022)” [公司债券年度报告 (2022 年)] (Chinese Academy of Sciences Holdings Co., Ltd., April 2023), https://perma.cc/EG53-K8WD.

[57] “Who Are We?” [我们是谁?], CAS Investment Management Co., Ltd, accessed April 16, 2024, https://perma.cc/3MV3-SQ2B.

[58] “Company Introduction” [公司简介], USTC Holdings Company Limited, accessed April 15, 2024, https://perma.cc/R32R-GVEM.

[59] “We Are Very Proud That iFLYTEK Originated from the University of Science and Technology of China” [我们很自豪，讯飞源于中科大!], National Engineering Research Center of Speech and Language Information Processing, February 28, 2022, https://perma.cc/3L6X-2XQT.

[60] “2021 Annual Report” (iFLYTEK Co., Ltd., 2021), https://perma.cc/RD9E-PEQT.

[61] National Engineering Research Center of Speech and Language Information Processing, “We Are Very Proud.”

[62] iFLYTEK, “2021 Annual Report.”

[63] BIS, “Additions of Entities to the Entity List,” *Federal Register* 87 FR 51876 (October 9, 2019), www.federalregister.gov/documents/2022/08/24/2022-18268/additions-of-entities-to-the-entity-list.

[64] BIS, “Additions and Revisions to the Entity List and Conforming Removal from the Unverified List,” *Federal Register* 87 FR 77505 (December 16, 2022), www.federalregister.gov/documents/2022/12/19/2022-27151/additions-and-revisions-to-the-entity-list-and-conforming-removal-from-the-unverified-list.

[65] “Business Incubation” [企业孵化], Institute of Computing Technology, accessed April 15, 2024, https://perma.cc/UZS4-VCL7.

[66] For example, Lenovo Venture Capital was a seed investor in chip designer Jeejio (中科物栖) in 2018 and Sugon is a 50 percent shareholder in data intelligence firm Golaxy (中科天玑). “Jeejio” [中科物栖], 36Krypton Venture Capital Platform, accessed April 16, 2024, https://perma.cc/7928-EWLM; “Golaxy” [中科天玑], 36Krypton Venture Capital Platform, accessed April 16, 2024, https://perma.cc/QYL3-EKQP.

[67] “History” [历史沿革], Institute of Computing Technology, accessed April 15, 2024, https://perma.cc/3MSH-86F4; “Development Path” [发展历程], Legend Holdings, accessed June 18, 2024, https://perma.cc/GT56-KXRD.

[68] Nathaniel Ahrens and Yu Zhou, "China's Competitiveness: Myths, Realities, and Lessons for the United States and Japan—Case Study: Lenovo" (Center Strategic & International Studies, January 2013), https://www.csis.org/programs/japan-chair/japan-chair-archives/chinas-competitiveness-myths-realities-and-lessons-united.

[69] While we have not found unambiguous documentation regarding the origins of Legend Holdings, we do know that in 1994 Legend Holdings was the owner of the company producing "Legend" branded computers and in that year transferred 65 percent of its own shares to CAS. Ahrens and Zhou, "China's Competitiveness."

[70]Ahrens and Zhou, "China's Competitiveness"; Institute of Computing Technology, "History" [历史沿革].

[71] Ahrens and Zhou, "China's Competitiveness."

[72] "Lenovo - Statistics and Facts," Statista, accessed October 24, 2024, https://perma.cc/YWL2-FLAR.

[73] "2023 Annual Report," (Legend Holdings), https://perma.cc/3UVU-6RBE; "Lenovo Group Limited 2023/24 Annual Report," (Lenovo Group), https://perma.cc/T9LS-493G.

[74] Xiaoxuan Li, Kejia Yang, and Xiaoxi Xiao, "Scientific Advice in China: The Changing Role of the Chinese Academy of Sciences," *Nature*, July 12, 2016, www.nature.com/articles/palcomms201645; CAS, "About Us"; "About CASAD," Academic Divisions of the Chinese Academy of Sciences, accessed April 15, 2024, https://archive.ph/8Ze5l.

[75] CAS, "About Us."

[76] Jane Qiu, "Chinese Academies Promise Cleaner Elections," *Nature*, August 10, 2011, www.nature.com/articles/476139a; Hao Xin, "The True Cost of Becoming an Academician in China?," *Science*, September 17, 2013, www.science.org/content/article/true-cost-becoming-academician-china.

[77] "Yin Hejun" [阴和俊], Ministry of Science and Technology, accessed April 15, 2024, https://perma.cc/P3AQ-UXUT; Jiang Chenglong, "Yin Hejun Appointed as Minister of Science and Technology," *China Daily*, October 24, 2023, https://perma.cc/UP3C-A2SG.

[78] CSET analysis of the Central Committee; Xinhua, "List of Members of 20th CPC Central Committee," State Council Information Office, October 22, 2022, https://perma.cc/XSV2-3LTU.

[79] The Chinese Academy of Engineering, often referred to with CAS as the "two academies," is a parallel organization to CAS focused on engineering sciences. Although smaller than CAS, CAE's structure and functions are similar, except focused in engineering sciences. "About Us," CAE, accessed June 17, 2024, https://en.cae.cn/cae/html/en/col2014/column_2014_1.html.

[80] The CASAD claims it is comparable to the U.S. National Academy of Sciences. CASAD, "About CASAD."

[81] Alex Stone, “China’s Model of Science: Rationale, Players, Issues” (China Aerospace Studies Institute, 2022), www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Infrastructure/2022-02-07%20Model%20of%20Science.pdf.

[82] “An Overview of China’s 2035 Development Strategy for Academic Disciplines and Frontier Fields” [中国学科及前沿领域 2035 发展战略总论] (NSFC and CAS, March 2023), https://perma.cc/T9L8-C3KS.

[83] “‘2035 Development Strategy Series of Chinese Disciplines and Frontier Fields’ Published” [“中国学科及前沿领域 2035 发展战略丛书”出版] (CASAD, May, 26, 2023, https://perma.cc/753W-4VDV; “An Overview of China’s 2035 Development Strategy.”

[84] “National High-End Think Tank Construction Pilot Project” [国家高端智库建设试点], China Development Institute, accessed April 15, 2024, https://perma.cc/JA9N-NUXU; “Review and Research on the First Anniversary of the National High-End Think Tank Construction Pilot Work” [国家高端智库建设试点工作一周年回顾与研究], *Chinese Communist Party News Network, People’s Daily*, December 1, 2016, https://perma.cc/K3JS-HRJY.

[85] China Development Institute, “National High-End Think Tank Construction Pilot Project.”

[86] Science and Technology Daily, “The First Phase of the ‘Take the Lead Initiative’ Plan Has Yielded Fruitful Results” [【科技日报】“率先行动”计划第一阶段硕果累累], CAS, accessed April 15, 2024, https://archive.ph/VcXb9; “Introduction to the Institute of Science and Technology Strategy Consulting, Chinese Academy of Sciences” [中国科学院科技战略咨询研究院简介], Institutes of Science and Development, accessed April 15, 2024, https://perma.cc/9EBR-VMJT.

[87] CAS, “Outline of the Chinese Academy of Sciences 13th Five-Year Development Plan.”

[88] Every five years, CAS publishes a development plan that sets the organization’s goals for the period. See, for example, CAS, “Outline of the Chinese Academy of Sciences 13th Five-Year Development Plan.”

[89] Lokman Meho identified one hundred of the world’s most prestigious scientific awards. Just 11 of the 3,445 awards in Meho’s dataset featured a researcher with a CAS affiliation. Lokman I. Meho, “Highly Prestigious International Academic Awards and Their Impact on University Rankings,” *Quantitative Science Studies* 1, no. 2 (2020): 824–848, https://doi.org/10.1162/qss_a_00045. Data accessible from: Lokman I. Meho, “Highly Prestigious International Academic Awards and Their Impact on University Rankings (Article and Supporting Data),” American University in Beirut, February 12, 2020, https://scholarworks.aub.edu.lb/handle/10938/21535.

[90] Barry Naughton, Tai Ming Cheung, Siwen Xiao, Yaosheng Xu, and Yujing Yang, “Reorganization of China’s Science and Technology System” (UC Institute on Global Conflict and Cooperation, July 2023), https://ucigcc.org/wp-content/uploads/2023/08/Naughton-et-al-Working-Paper-Reorg-v1-8.22.23.pdf.

[91] We used the International Trade Administration’s Consolidated Screening List to determine whether a CAS institute faces U.S. government restrictions. This tool checks against BIS’s Denied Persons List, Unverified List, Entity List, and Military End User List; the Department of State Bureau of International Security and Nonproliferation’s Nonproliferation Sanctions; the Department of State Directorate of

Defense Trade Controls' Arms Export Control Act Debarred List; and the Department of Treasury Office of Foreign Assets Control's Specially Designated Nationals (SDN) List, Foreign Sanctions Evaders List, Sectoral Sanctions Identification List, Correspondent Account or Payable-Through Account Sanctions List, Non-SDN Menu-Based Sanctions List, Non-SDN Chinese Military-Industrial Complex Companies, and Palestinian Legislative Council List.

[92] The Institute of Physics was added to the Entity List on May 9, 2024, for acquiring and attempting to acquire U.S.-origin items in support of advancing China's quantum technology capabilities. BIS, "Additions of Entities to the Entity List," *Federal Register* 89 FR 41886 (May 9, 2024), www.federalregister.gov/public-inspection/2024-10485/additions-of-entities-to-the-entity-list.

[93] The Yunnan Observatories are affiliates of the Beijing-based National Astronomical Observatories (国家天文台), but they are located in Kunming, Yunnan. "Introduction" [单位简介], National Astronomical Observatories, accessed May 9, 2024, https://archive.ph/JEOpB.

[94] The Nanjing Institute of Astronomical Optics and Technology is an affiliate of the Beijing-based National Astronomical Observatories (国家天文台), but it is located in Nanjing, Jiangsu. National Astronomical Observatories, "Introduction" [单位简介].

[95] The Nanjing Institute of Astronomical Optics & Technology was added to the Entity List on September 27, 2023, for procuring U.S.-origin items in likely furtherance of Chinese military research. BIS, "Addition of Entities and Revision to Existing Entities on the Entity List; Removal of Existing Entity from the Military End User List," *Federal Register* 88 FR 66271 (September 27, 2023), www.federalregister.gov/documents/2023/09/27/2023-21080/addition-of-entities-and-revision-to-existing-entities-on-the-entity-list-removal-of-existing-entity.

[96] The Xinjiang Astronomical Observatory is an affiliate of the Beijing-based National Astronomical Observatories (国家天文台), but it is located in Urumqi, Xinjiang. National Astronomical Observatories, "Introduction" [单位简介].

[97] The Changchun Observatory (literally, "Changchun Artificial Satellite Observation Station") is an affiliate of the Beijing-based National Astronomical Observatories (国家天文台), but it is located in Changchun, Jilin. National Astronomical Observatories, "Introduction" [单位简介].

[98] The Beijing Genomics Institute—now BGI Group—was part of the Institute of Genetics and Developmental Biology until 2003, when it was separated into a separate institute. Institute of Genetics and Developmental Biology, "Institute Overview" [研究所概况].

[99] The Center for Agriculture Resources Research is nominally a component of the Beijing-based CAS Institute of Genetics and Developmental Biology (遗传与发育生物学研究所), but it is located in a different city (Shijiazhuang, Hebei) and is legally a separate entity. "Introduction to the Center" [中心简介], Center for Agricultural Resources Research, accessed May 7, 2024, https://perma.cc/LR9C-LKVW.

[100] The Institute of Computing Technology was added to the Entity List on December 16, 2022, for acquiring and attempting to acquire U.S.-origin items in support of China's military modernization. BIS identifies this entity as a major AI-chip R&D, manufacturing, and sales entity. They also identify this

entity for being, or having close ties to, government organizations that support the Chinese military and the defense industry. BIS, "Additions and Revisions to the Entity List and Conforming Removal from the Unverified List," *Federal Register* 87 FR 77505 (December 16, 2022), www.federalregister.gov/documents/2022/12/19/2022-27151/additions-and-revisions-to-the-entity-list-and-conforming-removal-from-the-unverified-list.

[101] The predecessor of the Institute of Microelectronics was the CAS 109 Factory (中科院 109 工厂). In 1958, it established China's first transistor production factory. In 1965, the CAS 109 Factory built the 109B computer, which contributed to the development of the hydrogen bomb. In 1986, the CAS 109 Factory merged with the Institute of Semiconductors and the Institute of Computing Technology to form the Institute of Microelectronics. Liu "Chinese Academy of Sciences and the 'Two Bombs and One Satellite' Project"; "Institute Overview" [研究所概况], Institute of Microelectronics, accessed May 9, 2024, https://perma.cc/9A52-7EX8.

[102] The Data Assurance & Communications Security Center is one part of the State Key Laboratory of Information Security (信息安全国家重点实验室). Both the DCS Center and its parent laboratory are components of the CAS Institute of Information Engineering (中国科学院信息工程研究所). "Introduction to the DCS Center" [DCS 中心介绍], Data Assurance & Communications Security Center, accessed May 7, 2024, https://perma.cc/JV6V-LGD6.

[103] The Shenyang Institute of Automation was added to the Entity List on June 8, 2022, for acquiring and/or attempting to acquire U.S.-origin items in support of military applications, contrary to the national security or foreign policy interests of the United States. BIS, "Addition of Entities, Revision and Correction of Entries, and Removal of Entities from the Entity List," *Federal Register* 87 FR 38920 (June 28, 2022), www.federalregister.gov/documents/2022/06/30/2022-14069/addition-of-entities-revision-and-correction-of-entries-and-removal-of-entities-from-the-entity-list.

[104] The Center for Agricultural Technology is a component of the CAS Northeast Institute of Geography and Agroecology (中国科学院东北地理与农业生态研究所). "Homepage" [首页], Center for Agricultural Technology, accessed May 7, 2024, https://perma.cc/NGA6-XWMK.

[105] The Shanghai Institute of Microsystem and Information Technology was added to the Entity List on May 9, 2024, for acquiring and attempting to acquire U.S.-origin items in support of advancing China's quantum technology capabilities. BIS, "Additions of Entities to the Entity List," *Federal Register* 89 FR 41886 (May 9, 2024), www.federalregister.gov/public-inspection/2024-10485/additions-of-entities-to-the-entity-list.

[106] The Shanghai Institute of Applied Physics was added to the Unverified List on April 11, 2019, because BIS was unable to verify their bona fides through an end-use check. BIS, "Revisions to the Unverified List (UVL)," *Federal Register* 84 FR 14608 (April 11, 2019), www.federalregister.gov/documents/2019/04/11/2019-07211/revisions-to-the-unverified-list-uvl.

[107] The Changsha Center for Mineral Resource Exploration is a component of the CAS Guangzhou Institute of Geochemistry (广州地球化学研究所). "Changsha Center for Mineral Resource Exploration" [长沙矿产资源中心], Guangzhou Institute of Geochemistry, accessed May 9, 2024, https://perma.cc/ABD8-JMF5.