CHAPTER 3

POTENTIAL RISKS TO CHINA'S FUTURE ECONOMIC COMPETITIVENESS

SECTION 1: CHINA EDUCATING AND TRAINING ITS NEXT GENERATION WORKFORCE

Abstract

Stark contrasts define China's education system, which contains some of the world's most highly rated universities within a broader landscape beset by widespread, systemic weaknesses. These contrasts contribute to and reflect a more general divergence between China's increasing ability to compete with the United States in cutting-edge innovation and its deteriorating productivity growth. Unequal access to quality education, particularly noticeable between urban and rural areas, undermines the country's capacity to cultivate a nationwide skilled workforce. The implications for the United States are mixed: Party-state-led initiatives that funnel resources into strategic sectors such as artificial intelligence (AI) and semiconductors may generate near-term challenges for the United States, while China's broader educational deficiencies may hamper its long-term economic and technological competitiveness.

Key Findings

- China's continued economic growth depends on the country's ability to cultivate talent, but its education system faces acute challenges. China's primary, secondary, vocational, and higher education suffer from weak curricula and instruction that leave some graduates poorly trained to enter the workforce, particularly in rural areas.
- The quantitative expansion in China's education system has not been matched by qualitative improvement. Large swaths of high school and vocational students receive low-quality education, leaving them unprepared to join an increasingly knowledge-intensive economy; at the same time, colleges outside of a top few fail to develop students' cognitive or technical skills. These structural issues are one factor that has contributed to China's soaring official youth unemployment rate, which was above 21 percent in June 2023 before the Party-state abruptly stopped reporting it.
- Despite major challenges facing China's education system, a relatively small number of universities have emerged as world-class institutions that drive global innovation, posing a critical

challenge to U.S. security. Research centers at these universities often serve as platforms to advance industrial policy objectives and further China's development of dual-use technologies, such as AI and semiconductors.

- Concentration of resources in a few of China's top universities and select schools in the wealthiest metropolitan areas has come at the expense of broad-based investments in the country's educational system. Even if top universities train scientists and engineers who can develop world-leading technologies, the workforce may lack the technical proficiency to adapt and deploy these innovations.
- The national college entrance exam, the *gaokao*, is the centerpiece of China's education system and is both a key to success for some and a source of mounting challenges. Its focus on intensive memorization inhibits development of critical thinking skills. Despite drawbacks, the Chinese public views the exam as the primary route to upward mobility and a great equalizer in a system that otherwise privileges wealth and connections, making it a bulwark of social stability. Still, this social contract is under stress. University graduates confront a difficult job market in a decelerating economy. Fewer opportunities have led some students to question the system's meritocracy, challenging an idea central to the Chinese Communist Party's (CCP) legitimacy.

Recommendations

The Commission recommends:

- Congress request a Government Accountability Office report assessing the reciprocal nature of information sharing, including access to databases, and scientific collaboration between the United States and the People's Republic of China. Such a report shall include information on access by U.S. academics and experts to ongoing research activities, projects, symposia, and other scientific and technology activities in China. It should also assess whether such collaboration and activities provide comparable information and value to that which is available to researchers from China at international conferences and venues or in the United States.

Introduction

According to General Secretary of the CCP Xi Jinping, competition in today's world is essentially competition in talent and education. An assessment of China's education system, its curriculum, instruction, and achievements is compromised by a lack of qualitative research. Nevertheless, there are indicators that call into question China's ability to engage in breakthrough technological innovation and at the same time sustain training and skills to serve economic productivity and growth. This section explores key features of China's education system. The context, however, is as important as the quantitative measures of students, teachers, programs, and government investment and guidance. While China has increased the number of students attending college, evidence suggests many graduates face limited success and opportunities. Moreover, there is an ongoing tension in the system characterized by education experts as involution, where it is harder and harder to succeed in China. The rural population endures educational disadvantages described as learning little at a lower level. In contrast, a select few universities are driving China's AI chip and quantum research, although these centers are largely staffed by researchers returning from abroad. Education in China continues to be affected by a tension between the CCP's interests and the nation's educational needs. The creative thinking skills key to technological breakthroughs are seen by the Party as a threat to ideological rigor. Years of rote memorization to pass the national college entrance exam stands in tension to the need for technological innovation. Even as these weaknesses remain unaddressed, China's government is focusing its educational system on securing a lead in emerging technology areas, and the potential of breakthrough success in China's science and technology (S&T) research may pose a significant threat to the United States and its allies.

This section begins with an overview of the key features of China's education system. It then examines the critical role the education system plays in supporting Party-state ambitions in indigenous technological development. Augmenting quantitative measures with qualitative analysis, the section then delves into the mounting challenges in labor market outcomes and their interconnection with educational quality in China. Finally, the section identifies implications for the United States. The section draws on the Commission's 2023 hearing on "China's Challenges and Capabilities in Educating and Training the Next Generation Workforce," the Commission's staff and contracted research, consultations with policy experts, and open source research and analysis.

Education and China's Economic, Technological, and Military Objectives

The Party-state sees China's education system as an essential tool for its economic growth, technological development, and military modernization ambitions. At the most basic level, the CCP leverages this system to develop its workforce and enable both economic development and industrial upgrading. China's education system is also a core component of its S&T ecosystem as it builds a knowledgeable workforce and facilitates translation of research into commercial and military technology. But as China's economic activity shifts toward knowledge and skill-intensive work, sustained economic growth is at risk of being undermined by the large portion of China's workforce that still lacks sufficient cognitive skills. Foundational skills in math and creative thinking, increasingly critical for adapting to technology-induced changes in the economy, are not broadly supported. In testimony before the Commission, Stanford education economist Scott Rozelle estimated that roughly "500 million people, almost all poor, rural individuals, have no skills that allow them to participate in the high-skill, high-wage economy."[1]

Though China has committed immense resources into growing and training its talent base, government expenditure as a share of gross domestic product (GDP)—3.3 percent in 2021—is less than the average of 5.2 percent among high-income countries and the 4.3 percent expended by the United States for the same year.* [2] This spending even lags behind the middle-income country average of 4.1 percent of GDP.[3] China's relative underinvestment in education partially reflects a highly unequal distribution of resources between rural and urban education systems, with local governments bearing over 90 percent of these funding responsibilities.[4] Evidence shows that wealthier cities can allocate more funding to support students and attract talented teachers, which exacerbates a rural-urban divide in education outcomes.[5]

Education is a key pillar of China's military-civil fusion strategy, particularly leveraging civilian innovation to drive military modernization (for more on China's strategy to align its commercial and military industries into an integrated system, see Chapter 4, Section 2, "Weapons, Technology, and Export Controls").† In practice, the Party-state implements this component of the strategy by mobilizing nonstate actors to support military development objectives through a thick web of linkages between state and nonstate entities that blurs the lines between civilian and military realms. Universities are key actors within this military-industrial ecosystem: the CCP controls funding and administrative levers across all universities to direct research activities toward advancing the national S&T agenda. According to the Australian Strategic Policy Institute, over 60 public universities are explicitly involved in defense-related research and training in defense technology.[6] This number includes the group of schools known as the Seven Sons of National Defense, which have historic roots in China's defense industry.‡ This poses a challenge for U.S.-China research collaboration, as ostensibly civilian universities seek to establish partnerships aiming to acquire specific capabilities.[7] A 2020 report by the Hoover Institution identified 254 scientific publications coauthored by researchers at U.S. institutions with researchers affiliated with the Seven Sons universities between January 2013 and March 2019.[8] Numerous universities and affiliated research institutes have been added to the Entity List for their role in military-civil fusion and acquiring technology and knowhow for the People's Liberation Army (PLA).[9] China's publicly declared commitment to promote transnational cooperation in

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*In 2021, China's Ministry of Finance reported that government expenditure across all levels of education totaled $591 billion (renminbi [RMB] 3.8 trillion). However, China's educational expenditure data quality are poor and inconsistent, as most funding occurs at local levels. The Ministry of Education, in contrast, suggests that China spent $902 billion (RMB 5.8 trillion) on education in 2021, or 5 percent of GDP. China Ministry of Education, *Statistical Report on the Implementation of National Education Funding in 2021* [2021年全国教育经费执行情况统计快报], December 30, 2022. Translation; China Ministry of Finance, *Fiscal Revenue and Expenditure in 2021* [2021年财政收支情况], January 29, 2022. Translation.

†As articulated in many speeches, General Secretary Xi's vision for military-civil fusion aims to facilitate transfers between the defense and civilian sectors to improve the sophistication of China's military, creating cohesion in Chinese industry and academia working with and in support of military objectives so that the entire system can be effectively mobilized to support the military in the future and to drive technological innovation and economic growth. Greg Levesque, written testimony for the U.S.-China Economic and Security Review Commission, *Hearing on What Keeps Xi Up at Night: Beijing's Internal and External Challenges*, February 7, 2019, 10–16.

‡The Seven Sons of National Defense is a group of universities deeply integrated with China's defense industry that are subordinate to the Ministry of Industry and Information Technology. The universities include Beijing Institute of Technology, Beihang University (previously named Beijing University of Aeronautics and Astronautics), Harbin Engineering University, Harbin Institute of Technology, Nanjing University of Aeronautics and Astronautics, Nanjing University of Science and Technology, and Northwestern Polytechnical University. Alex Joske, "The China Defense Universities Tracker," *Australian Strategic Policy Institute*, November 25, 2019.

S&T may instead be aimed at accelerating these actors' technology acquisition efforts, meaning the research output of such collaboration primarily benefits China, with little reciprocated to the United States. The U.S.-China Agreement on Cooperation in Science and Technology, a bilateral agreement to facilitate scientific interaction that was renewed for six months in August 2023, has limitations in safeguarding against the transfer of critical capabilities to China's defense research ecosystem.* [10]

Education System and the Pursuit of Technological Development

Evaluating the ability of China's education system to contribute to economic development and innovation requires a holistic assessment. While universities are widely recognized as ecosystems that drive an economy's innovation output, all tiers of an education system factor into an economy's capacity to develop and adapt new technology. Educational outcomes support technological development and economic growth in three key ways: supporting breakthrough innovation, diffusing knowledge and technological knowhow to industry, and training a workforce that can promote production, manufacturing, and technological upgrading. China's education system is relatively strong in the first area but struggling in the latter two.

- *Innovation:* Education systems train scientists and engineers while providing them access to facilities and resources, supporting both foundational research and applied research and development (R&D). Universities draw in funding from various sources to advance promising frontier research areas with limited commercial viability (e.g., for many applications of quantum physics at present).
- *Diffusion to industry:* Linkages between university research hubs, government agencies, and industry facilitate economic upgrading via knowledge and technological diffusion. University-industry linkages include commercialization via licensing and academic startups as well as conferences and consulting.
- *Training and development:* Robust technical education supports the development of cognitive skills within and upstream from the leading technology sectors, creating a workforce capable of adapting and adopting innovations throughout the economy. Since a trained workforce promotes technology diffusion by adapting innovations, spillover benefits accrue as industry builds on developments across adjacent fields (e.g., biotech researchers using AI to identify cancer in X-rays), increasing labor productivity and stimulating market demand.

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*The U.S.-China Agreement on Cooperation in Science and Technology was originally signed in 1979 and last extended for five years in 2018. The agreement promotes bilateral science and technology exchanges and has fostered cooperative research across a range of fields, including between government agencies. Some argue that the agreement contains outdated and insufficient provisions. Director and distinguished senior fellow at the Berkeley Center for Law and Technology Mark Cohen noted that the agreement's provisions on intellectual property date back to 1967. Professor Emeritus at the University of Oregon Richard P. Suttmeier argued that the agreement was first negotiated at a time when the United States vastly outmatched China in S&T capabilities, although the gap has since narrowed. Mark Cohen, "Renewing the U.S.-China STA Is Not the Question," *ChinaIPR*, August 13, 2023; Richard P. Suttmeier, "Trends in U.S.-China Science and Technological Cooperation: Collaborative Knowledge Production for the Twenty-First Century?" (prepared for the U.S.-China Economic and Security Review Commission), September 11, 2014, 4.

Key Features of China's Education System

China's education system is defined by sharp contrasts between high-quality schools and universities in China's most populous and prosperous cities and generally mediocre institutions everywhere else, substantial reliance on foreign-trained faculty, and a high degree of CCP control throughout. Despite a massive quantitative expansion over the last several decades and pointed areas of success, the vast majority of China's education system still suffers from major deficiencies. Weak vocational education, deep inequalities in educational outcomes for rural versus urban students, poor teacher quality, and limited integration with industry outside of the most elite institutions compromise China's ability to cultivate a workforce capable of sustaining productivity-based economic growth. Moreover, underinvestment and insufficient support for early childhood development inhibits the cognitive development of millions of rural Chinese infants, planting the seeds of a rural human capital crisis even before children reach school age. Despite these challenges, roughly two dozen of China's top universities rival peer institutions in the United States in terms of research and education quality, particularly in science, technology, mathematics, and engineering (STEM) fields. Their research output, steered by China's government toward meeting national technology development goals, facilitates challenges to U.S. security and economic competitiveness. A pattern of select pockets of excellence amid broader weakness replicates at each level of China's education system.

China's education system has expanded rapidly since the 1986 passage of the Compulsory Education Law, which requires all children to receive nine years of basic education.[11] Continued education after junior high school is optional for students. Nationwide exams at the end of junior high school filter those that complete nine years of school into either academic or vocational schools (see Figure 1). Another nationwide exam in the final year of senior high school determines students' qualification for university. As there are few other avenues to attend elite universities outside of a high score, students and families view the college entrance exam, or *gaokao*, as the pivotal opportunity for upward mobility (see textbox "The *Gaokao*: China's All-Consuming Exam" below). Students consequently devote tremendous effort toward this goal, and many students begin preparing for the *gaokao* as early as primary school.*[12] Actual learning outcomes are difficult to measure, a challenge compounded by China's manipulation of standardized international test score data (see textbox "China's Problematic Participation in the Program for International Student Assessment (PISA)" below).

Quantity Outpaces Quality across China's Primary, Secondary, and University Education

Compulsory Education

In 2021, there were 158 million students in the compulsory education system (grades 1–9), with 107.8 million in elementary

*Teachers' evaluations, as well as school administrator bonuses, are based in large part on students' *gaokao* scores. Zachary Howlett, *Meritocracy and Its Discontents*, Cornell University Press, 2021, 93–94.

school and another 50.2 million in junior high school.*[13] China's government deploys considerable resources to support this student population, with 154,279 elementary schools across the country employing 6.2 million teachers in 2021.[14] As of 2020, 93.8 percent of the compulsory school-age population completed all nine years; however, this is a recent development.†[15] School attainment grew rapidly over the past three decades, meaning older generations received fewer years of education.‡ As a result, nearly one in five adults aged 25–64 years old have completed fewer than nine years of schooling as of 2020.[16] Educational attainment is even lower within China's rural resident population, where over two in five adults aged 25 and over have never completed junior high school.[17] This rural-urban gap in education is a substantial threat to China's economic development.

China's Problematic Participation in the Program for International Student Assessment (PISA)

The performance of China's education system garnered international attention after a select number of schools ranked at the top of the Organization for Economic Cooperation and Development's (OECD) Program for International Student Assessment (PISA) despite the controversial administration of the assessment in China.[18] PISA aims to provide comparable data about the relative performance of education systems across countries by assessing the knowledge and cognitive abilities of 15-year-old students in reading, mathematics, and science.[19] The program is administered by the OECD every three years across more than 80 economies. PISA scores have become a widely recognized and influential metric in the field of education assessment. Because China has controlled how PISA tests are administered and limited the availability of results, it is

* In 2020, China's government claimed that 99.96 percent of all school-aged children were actually enrolled in schools (i.e., the net enrollment rate was nearly 100 percent). Emily Hannum, "Educational Development in China: Progress, Challenges, and Outlook" (prepared for the U.S.-China Economic and Security Review Commission), February 23, 2023, 9; China Ministry of Education, *Major Educational Achievements in China in 2020*, February 28, 2021.

† In 2021, China's Ministry of Education stated that the completion rate for compulsory education—calculated as the ratio of graduates from ninth grade to the number of students enrolled in that cohort during first grade—was 95.4 percent. However, this methodology overstates the number of students who graduate "on-time," as it includes over-age students who did not graduate at the intended age. In 2020, 9.8 percent of all junior high students were aged 16 years or above, compared to an intended graduation age of 14. Under the definition of junior high school completion used for the UN Sustainable Development Goals—the education attainment rate among all people aged three to five years above the intended age for the last grade of junior high school (in China's case, the reference age group is 17 to 19 years old)—China's compulsory completion rate was 93.8 percent. UN Children's Fund, China National Bureau of Statistics, UN Population Fund, "What the 2020 Census Can Tell Us about Children in China: Facts and Figures," April 2023, 16–17; China Ministry of Education, *Statistical Report on China's Educational Achievements in 2021*, September 23, 2022.

‡ Gross enrollment in junior high education grew from 66.7 percent in 1990 to near-universal enrollment in 2020. The gross enrollment ratio is calculated by dividing the total enrollment in schooling by the population of school-aged children. This can lead to gross enrollment overstating the size of the cohort in grades appropriate for their age, as it reflects both overage and underage students. UN Children's Fund, China National Bureau of Statistics, and UN Population Fund, "What the 2020 Census Can Tell Us about Children in China: Facts and Figures," April 2023, 16; Emily Hannum, "Educational Development in China: Progress, Challenges, and Outlook" (prepared for the U.S.-China Economic and Security Review Commission), February 23, 2023, 9; Organization for Economic Cooperation and Development, "Benchmarking the Performance of China's Education System," October 2020, 40.

China's Problematic Participation in the Program for International Student Assessment (PISA)—*Continued*

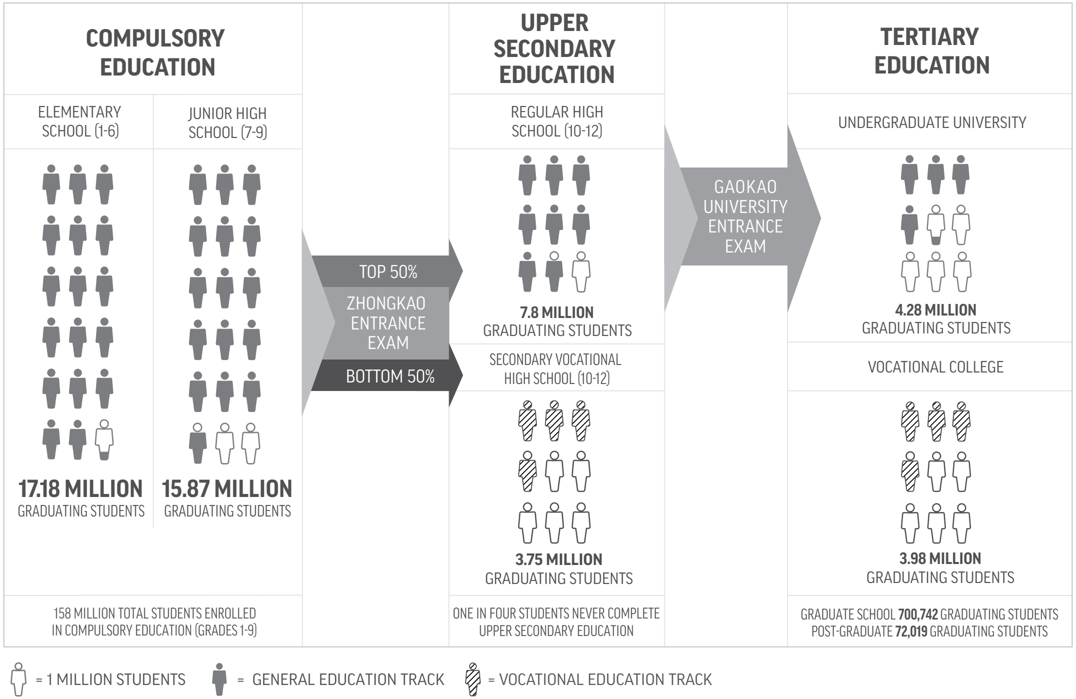
impossible to use PISA as a representation of the country's educational quality.

Major problems with China's participation in 2009 and 2012: China has participated in PISA testing four times, the first two in 2009 and 2012, respectively, under the heading "Shanghai-China." By restricting participation to its wealthiest metropolitan area, the country managed to rank first in the world across reading, mathematics, and science. Notably, in 2009, PISA tests were actually administered in 12 Chinese provinces, including several rural areas, but only scores from Shanghai were released and "the Chinese government has so far not allowed the OECD to publish the actual data," which remains the case to this day.[20] Close analysis of the number of 15-year-old test takers in Shanghai, moreover, revealed systematic exclusion of approximately two-thirds of the testing age population.* Less-privileged children of migrant workers with rural household registration, or *hukou,* were excluded from PISA assessments, along with students with special needs, leaving only the most privileged to take the test.[21] Furthermore, unlike most other participating economies, the Shanghai municipal government explicitly prioritized PISA performance for schools, influencing results.[22] Despite the systematic manipulation on multiple fronts, Shanghai's results were credulously celebrated internationally.

Problems with China's participation in 2015 and 2018: In 2015, China allowed four of its wealthiest provincial-level territories—Beijing, Shanghai, Jiangsu, and Guangdong—to participate in the assessment. China's ranking slipped to the sixth spot in math, tenth spot in science, and 27th spot in reading.[23] Realizing that Guangdong, a province of over 100 million people with a substantial rural population, was dragging down the results, the Party decided to substitute in the smaller, richer, and more urbanized province of Zhejiang in the 2018 assessment. The country's rankings duly skyrocketed back to first across all subjects.[24] China will likely include Zhejiang in lieu of Guangdong again in the 2022 assessment, which will be released in late 2023.

* Based on other population figures in other countries, "one would expect about 300,000 15-year-olds in Shanghai" to have participated. "Instead, only about one-third of that amount, 108,056, is reported by PISA." Sean Coughlan, "China: The World's Cleverest Country?" *BBC News*, May 12, 2012.

Figure 1: Overview of China's Education System and 2021 Graduation Statistics



Note: The number of students graduating from each level and education track reflects the number of students completing their final year in each tier in 2021. The proportion of students who never complete upper secondary education is calculated using the rate of upper secondary school completion among adults aged 20–22 in China's 2020 census, the closest available year. The majority of university entrants come from regular high schools, although secondary vocational graduates can also take the *gaokao*.

Source: Various.[25]

Secondary and Vocational Education

After completing the mandatory nine years of basic education, around age 15, students are tested and filtered into either an academic or vocational educational track based on their performance on the senior high school entrance exam. Those students who score in roughly the top 50 percent, the vast majority of whom are urban *hukou* holders, enter general high schools and will study core, transferable skills in math, science, computers, and language.[26] As with China's primary schools, general high schools are massively stratified in quality. Students in China's wealthiest urban areas undergo rigorous coursework to prepare for testing into an elite university.[27] The quality of senior high school education, however, drops off precipitously outside of these urban centers.[28] Most students at China's first-tier universities come from urban school districts, while less than 1 percent of students from underperforming urban high schools or the countryside test into a top university.[29]

Students who score in the bottom half of the high school entrance exam can attend vocational high school, though many choose to stop schooling instead.* China's vocational education system has largely been neglected over the past three decades, and recent efforts to shore up technical training have delivered poor results. As Dr. Rozelle summarizes, "Studies have shown that vocational schooling has failed to instill either general learning or even specific vocational skills, and even induces drop out."[30] Many students end up in the low-wage factory workforce, and in some cases vocational schools explicitly act as labor dispatch agencies to provide cheap labor for the manufacturing sector.[31] In turn, vocational education is widely stigmatized, with many considering attendance of vocational school a personal and academic failure.† [32]

The *Gaokao:* China's All-Consuming Exam

A record 12.9 million students took the *gaokao* in 2023.‡ [33] Buttressed by "the cultural importance attached to educational credentials," the *gaokao* serves as "the conducting baton of the Chinese education system," according to Zachary Howlett, sociologist at the Yale-National University of Singapore.[34] The *gaokao* is effectively the sole determinant of the caliber of university high school students can attend, which in turn has outsized bearing

* In 2021, 15.9 million students graduated from junior high school, whereas general high schools and vocational high schools admitted just 9 million and 4.9 million students, respectively. While China's Ministry of Education does not provide data on the percentage of students that fail to complete 12 years of school, these figures suggest more than 10 percent drop out after junior high school. China National Bureau of Statistics, "21–2 Number of Students of Formal Education by Type and Level," *2022 Statistical Yearbook*.

† In 2022, the Chinese government revised the Vocational Education Law for the first time in 26 years, formally declaring vocational and general education of equal importance in an attempt to dispel the stigma, in addition to other measures aimed at increasing overall vocational education. The extent to which the changes will be effective remains to be seen. Li Yulan, "The First Revision after 26 Years—Where Is the "New" in the New Vocational Education Law" (时隔26年首次修订一新职业教育法"新"在哪儿), *Guangming Daily*, April 28, 2022.

‡ In 2019, China allowed secondary vocational students to take the exam and have a pathway into a nonvocational college. This change undergirds the record *gaokao* participation in 2023. Zhao Yusha, "Record 12.91 Million Sit amid Popularization of Higher Education," *Global Times*, June 7, 2023.

The *Gaokao:* China's All-Consuming Exam—*Continued*

on career prospects.* [35] Studying for the exam is consequently an all-consuming undertaking, with students across China spending up to 14 hours a day of their senior high school years becoming "test-taking machines" at the expense of other pursuits, passions, and extracurriculars.[36] As an indicator of how seriously the exam is taken, police in one city during the 2023 exam even deployed a magnetic pulse gun to prevent drones from potentially facilitating cheating.[37] The gravity of the exam exacts a heavy toll on China's youth. As one student laments: "Our final purpose, our whole life before 18, is for the *gaokao*. Every teacher says, 'If you don't pass the *gaokao*, and you don't go to college, your life is ruined.'"† [38] Many worry that the intensive, memorization-heavy nature of test-taking in China stifles development of skills needed for innovative and critical thinking.[39]

The exam is nonetheless a cornerstone of the Party-state's legitimacy, giving many in China hope that they can improve their life circumstances.‡ [40] The *gaokao*, as Dr. Howlett notes, takes on special gravity because it is widely perceived as China's "only relatively fair competition" within a broader "system rife with corruption and backroom dealing."[41] As one rural high school principal put it to Dr. Howlett, "Without the *gaokao*, there would be a social revolution."[42] The all-out scramble to succeed in China's high-stakes examination system can also serve the Party-state's pursuit of political stability in an indirect way. As author Peter Hessler wrote of his experience teaching in China's Sichuan Province in 2022: "There's a point at which competition becomes a highly effective distraction. For most of my students, the greatest worry didn't seem to be classroom security cameras or other instruments of state control—it was the thought of all those talented young people around them."[43]

Unequal Access to Education Undermines China's Talent Base

Learning inequities and barriers confronting rural students cascade throughout the education system, leaving many without the necessary skills to contribute to China's modernizing economy. Rural schools have historically been underfunded, under-resourced, and understaffed rela-

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* Each year, the Ministry of Education determines two cutoff scores for the *gaokao* based on the number of university spots available, one being a minimum score for entry into any university and the second for entry to elite universities. Emily Hannum, Xuehui An, and Hua-Yu Sebastian Cherng, "Examinations and Educational Opportunity in China: Mobility and Bottlenecks for the Rural Poor," *Oxford Review of Education* 37:2 (2011): 270–275.

† Students routinely characterized their experience finishing the *gaokao* as one of "breaking out of prison" or "ending captivity." Shuyi Guo, "Gaokao Examination Influences Senior High School Education to Some Extent, Resulting in the Senior High School Education Bringing Many Negative Effects to Its Students," *Atlantis Press*, December 30, 2022, 1980.

‡ Dr. Howlett argues that China watchers' understanding of Chinese political legitimacy is wrong. Rather than resting on a tacit performance of legitimacy wherein "people acquiesce to Party-state rule in exchange for wealth," people instead "expect to have opportunities to improve their [own] lives. In other words, people expect the state to guarantee the conditions for the meritorious to advance. At minimum, it must ensure the perception that such conditions exist. Like the imperial exams of old, the *gaokao* reinforces this perception because it forms a national fateful rite of passage that is open, anonymous, and competitive." Zachary Howlett, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Challenges and Capabilities in Educating and Training the Next Generation Workforce*, February 24, 2023, 8–9.

tive to urban areas.* [44] China's government enforces an internal passport system that limits individuals' access to public services, including education, outside of their place of "household registration," or *hukou*.[45] Over 60 percent of students hold rural *hukou* and are restricted from accessing urban schools, even though their parents often move to cities as migrant workers.† [46] The consequence is that rural students are often shut out of superior urban schools. While rural children complete the mandatory nine years of education at approximately the same rate as urban residents, they are much less prepared to succeed in senior high school. In 2020, just 56.7 percent of rural residents completed senior high school by the time they turned 20, compared to 82.3 percent among urban residents.‡ [47]

Relative to urban students, rural students are falling short on assessments of math and language achievement, which are significant correlates with a worker's ability to acquire new skills and competitiveness in the job market.[48] Many rural families lack the resources to support further education after junior high school. Although China's Compulsory Education Law provides tuition-free education for the first nine years of school, students must pay tuition to attend senior secondary school, with fees ranging from $138 (RMB 1,000)§ to $690 (RMB 5,000) per year—a sizeable burden relative to a rural household's meager wages.¶ [49] As a result, a rural *hukou* is a barrier to higher educational attainment, and only a small fraction of rural residents ever attend university.**

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*Over the past decade, government investment and programs have targeted some of the most consequential barriers to learning in rural areas, including problems common to developing economy contexts that were widespread in China's countryside. As Dr. Rozelle and author Natalie Hell detail in their 2020 book *Invisible China*, basic, untreated health issues hindered students' ability to learn, despite the availability of low-cost treatments. Through field work conducted between 2013 and 2016, they found that around 60 percent of rural children suffered from anemia, uncorrected poor vision, and/or intestinal worm infection. More recent statistics suggest that government programs have begun to have a positive impact in improving widespread health problems among rural children. Education scholars visiting rural schools over the past decade also found that basic education infrastructure remained lacking, finding inadequate facilities, equipment, and materials, including insufficient numbers of desks and textbooks. Dr. Rozelle nonetheless indicates this situation is also starting to improve, writing, "China has invested enormously into improving school infrastructure; teachers are now paid by the central government on a timely basis; most schools have computer rooms and libraries and good quality equipment for teaching." Despite China's progress, the low rate of rural students who continue to high school and university reflects the systemic challenges that persist. Scott Rozelle, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Challenges and Capabilities in Educating and Training the Next Generation Workforce*, February 24, 2023, 4; Scott Rozelle and Natalie Hell, *Invisible China: How the Urban-Rural Divide Threatens China's Rise*, University of Chicago Press, 2020, 109.

†Parents in China's nearly 300-million-strong migrant workforce who bring their children with them to cities face limited access to public services and a near-absent social support network, meaning babies receive little to no individualized care while their parents work ten- to 12-hour days. *China Labor Bulletin*, "Migrant Workers and Their Children," May 26, 2022; McKinsey Global Institute, "Reskilling China: Transforming the World's Largest Workforce into Lifelong Learners," 2021, 62.

‡The completion rate for urban residents includes both urban *hukou* holders and internal migrant students with rural *hukou*, but the completion rate for urban *hukou* holders alone is likely higher. Children in China's migrant floating population have limited access to urban public schools, gated by onerous application requirements. Private schools provide another option for migrant families that are willing to pay the relatively modest tuition; however, these schools are frequently overcrowded and provide an inferior education. *China Labor Bulletin*, "Migrant Workers and Their Children," May 26, 2022.

§Unless noted otherwise, this section uses the following exchange rate throughout: $1 = RMB 7.25.

¶In 2021, the average disposable income of rural households was $2,994 (RMB 18,931), just under 40 percent of the $7,374 (RMB 47,412) earned by the average urban *hukou* holder. China National Bureau of Statistics, "6–6 Per Capital Income and Consumption Expenditure of Urban Households," *2022 Statistical Yearbook*; China National Bureau of Statistics, "6–11 Per Capital Income and Consumption Expenditure of Rural Households," *2022 Statistical Yearbook*.

**For example, in Central and Western China, where much of the rural population resides, only 10 percent of rural students attend university. Scott Rozelle, written testimony for U.S.-China

These learning challenges are exacerbated by widespread delays in infants' basic cognitive development across rural China. Tens of millions of rural children are behind before they even start school, as many rural areas face an "invisible crisis" in early childhood development. As many as 45 percent of rural babies are at risk of delayed cognitive development in the first three years of childhood.[50] Dr. Rozelle notes that a primary cause of delayed cognitive development is insufficient stimulation from caregivers.* Widespread separation of rural children from parents working in cities is a major contributor to this challenge.[51]

The rural human capital crisis threatens to undermine China's productivity growth, and barriers to rural education may contribute to the economy becoming stuck in a middle-income trap.† As Dr. Rozelle states, "An educated labor force can more easily shift into higher value-added (or "white collar") jobs, facilitating the national transition from a low-skill, low-wage economy to a high-skill, high-wage economy."[52] Workers who are unable to make the transition face being marginalized in the labor market. Already, less-educated workers face declining wages as China's manufacturing sector becomes less labor-intensive and more automated, with low-skill workers being forced to find work in China's informal services sector.[53] As Dr. Rozelle argues, "There has never been a nation in past decades that has moved from middle income to high income (and stayed at high income) when their labor force has had such low levels of human capital" as China has today.[54] A stagnant economy and hundreds of millions of low-skilled workers harbor the potential for immense costs to China's economic and social landscape. Structurally unemployable workers may view the prospect of upward mobility as increasingly remote, and broad malaise may lead to declining welfare and social unrest.[55]

University Education

The Party-state views higher education as crucial to China's competitiveness and has invested in a quantitatively astounding expansion of China's higher education system over the last three decades. Enrollment has expanded 22 times over from roughly two million enrolled students in higher education in 1990 to 44 million in 2021.[56] China's postgraduate enrollment (masters and PhDs) is even more impressive, ballooning 36 times from 93,100 in 1990 to 3.33 million in 2021.‡[57] In 2010, only 3 percent of China's adult

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Economic and Security Review Commission, *Hearing on China's Challenges and Capabilities in Educating and Training the Next Generation Workforce*, February 24, 2023, 3.

*As Dr. Rozelle explains, "The main problem is rooted in insufficient stimulation of infants from caregivers. Studies in China show that close to half of rural caregivers rarely read, sing, or talk to their babies, either because they are out of the village working (as a migrant and have left their children behind with grandparents) or do not realize how important such engagement is." Scott Rozelle, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Challenges and Capabilities in Educating and Training the Next Generation Workforce*, February 24, 2023, 4.

†Many economies that have achieved middle-income status faced a stagnation in growth and productivity—often due to an aging population and rising labor costs for labor-intensive industries—before they could "graduate" to high-income status. By "growing old before growing rich," this "trapped" group of economies is unable to establish sustainable drivers of economic growth, and such economic distress generates political and social unrest. Pierre-Richard Agénor, "Caught in the Middle? The Economics of Middle-Income Traps," *Journal of Economic Surveys* 31:3 (2017): 771–791.

‡Over the past two decades, the number of degree-granting higher education institutions has also grown rapidly from 1,041 universities in 2000 to 2,738 in 2020. China's tertiary education

population (ages 25–64) held at least an undergraduate degree. As of 2020, 9 percent of China's adult population held at least an undergraduate degree.[58] By comparison, 39 percent of U.S. adults held a bachelor's degree or higher in 2020.[59]

In strictly quantitative terms, China's higher education system is now larger than that of the United States. In 2021, China matriculated 4.3 million undergraduates (equivalent to 0.3 percent of China's population) compared to the United States' 2.1 million (equivalent to 0.63 percent of the United States' population).*[60] Similarly, China appears to be catching up quickly to the United States in human capital in STEM disciplines. In 2020, over 1.7 million students completed bachelor's degrees at Chinese universities in science and engineering,† compared to 437,000 STEM bachelor's degree graduates in the United States (including approximately 15,870 Chinese nationals enrolled at U.S. institutions).‡[61] By 2025, Chinese universities are projected to graduate over 77,000 STEM PhDs, twice as many as the United States.[62]

The quantitative expansion of higher education institutions has not been met with equal qualitative improvements in faculty or learning outcomes. In a 2021 study comparing the U.S. and Chinese education systems' cultivation of cognitive abilities and workforce skills, Stanford associate education professor Prashant Loyalka and a team of researchers found that high school graduates from both countries entered undergraduate programs with nearly equivalent critical thinking skills. Chinese students, however, left university having regressed drastically in academic and critical thinking skills, not only relative to peers in the United States (who, in contrast, made significant gains) but also in absolute terms over the course of college education.§[63] In a separate

system includes higher vocational or technical education institutions as well, and there were 1,468 of these schools in 2020. China National Bureau of Statistics, "21–6 Number of Schools by Type and Level," *2022 Statistical Yearbook*.

*In 2021, 4.43 million students graduated from tertiary (or college) institutions in the United States, with 24.6 percent receiving associate's degrees and 49.9 percent receiving bachelor's degrees. China, meanwhile, graduated 9.09 million college graduates overall, with 47.2 percent receiving bachelor's degrees. Meanwhile, in 2021 in China, there were 1,238 bachelor's degree-granting institutions, with a combined enrollment of 18.9 million undergraduates. Melanie Hanson, "College Enrollment & Student Demographic Statistics," *Education Data Initiative*, July 26, 2022; *Guangming Daily*, "The Employment Situation of 9.09 Million College Graduates Is Generally Stable" (909万高校毕业生就业局势总体稳定), December 29, 2021. Translation; China National Bureau of Statistics, "21–1 Number of Schools and Educational Personnel by Type and Level (2021)," *2022 Statistical Yearbook*; China National Bureau of Statistics, "21–2 Number of Students of Formal Education by Type and Level (2021)," *2022 Statistical Yearbook*.

†China's STEM graduates are concentrated in the engineering field, and 1.4 million students graduated in 2020 with an undergraduate degree in engineering, which also includes computer science under the Ministry of Education's classification of degrees. In the United States, 148,000 students graduated in engineering and 97,000 in computer science. China Ministry of Education, *Number of Regular Students for Normal Courses in HEIs by Discipline*, 2020; China Ministry of Education, *Catalogue of Undergraduate Majors for Regular Higher Education Institutions* (普通高等雪娇本科专业目录), 2020; National Center for Education Statistics, *Degrees in Engineering and Engineering Technologies Conferred by Postsecondary Institutions, by Level of Degree and Sex of Student: Selected Years, 1949–50 through 2019–20.*

‡In the closest comparable year for which there are data, 2018, the National Science Foundation estimated 63,480 Chinese nationals were enrolled in science and engineering undergraduate programs. A quarter of that number, 15,870, is the graduating class. This number is roughly consistent with research from Georgetown's Center for Security and Emerging Technology, which estimated that roughly 2 percent of all U.S. STEM undergraduates are Chinese nationals. Jacob Feldgoise and Remco Zwetsloot, "Estimating the Number of Chinese STEM Students in the United States," *Center for Security and Emerging Technology*, October 2020, 3; Josh Trapani and Katherine Hale, "Higher Education in Science and Engineering," *U.S. National Science Foundation*, September 4, 2019.

§These results are based on math and physics exams as well as a critical thinking exam given to the same students at multiple points. The critical thinking exam "reflects the ability to develop sound and valid arguments, evaluate evidence and its use, understand implications and

2019 study, Dr. Loyalka found that computer science students in their senior year at Chinese universities significantly underperformed compared to their U.S. counterparts.[64] Computer science graduates from China's top-tier institutions had skill levels more akin to those of U.S. students graduating from nonelite institutions, with the average U.S. computer science major even outperforming the average elite computer science major in China.[65] Dr. Loyalka attributes the regression in critical thinking among Chinese students to a lack of incentive to study hard, as they are all but guaranteed to graduate in four years.[66] In most universities across China, professors are not allowed to fail students, grades count for little, and there are few incentives for teachers to teach well.[67]

Dr. Howlett attributes Chinese students' lagging performance to weak curricula and poor instruction and evaluation.[68] "Many college majors and programs in China, particularly at elite universities, provide excellent training," Dr. Howlett wrote in testimony for the Commission, "but students in ordinary universities often say that the knowledge their professors teach is out of date and disconnected with the realities of the employment market."[69] Many students, especially at lower-tier universities, spend their time at university preparing for examinations to attain a higher degree from a more prestigious university, which has increasingly become a prerequisite for competitiveness in the job market.[70]

As Denis Simon, former vice chancellor of Duke Kunshan University, noted during testimony before the Commission, "[Y]ou have to ask yourself if the enrollments in universities are increasing so rapidly, who is teaching these kids? That's a really big question."[71] China's own assessments of weaknesses in the education system routinely point to teacher quality as among the biggest challenges, and evidence strongly suggests that the country has not trained qualified faculty at a pace equivalent to the expansion in enrollment.[72] In 2018, China's Ministry of Education (MOE) reported that only 38.2 percent of university professors held doctoral degrees.[73] While the ratio is much higher at China's top universities—a survey of 731 STEM faculty at China's top 25 universities found that 96 percent held a PhD—the MOE's statistics overstate the number of high-caliber educators due to variation in the quality of Chinese PhD programs.[74] Additionally, professors are disproportionately recruited from their alma maters; in 2009, some 57 percent of faculty worked at the institution where they studied.[75] In testimony, Dr. Simon suggested the "incestuousness in the system" remains a major issue, with universities facing a shallow labor pool and forced to retain low-performing teachers due to a lack of suitable candidates.[76]

Foreign Talent and Resources Fill Shortfalls in China's Education System

Because the expansion of China's university enrollment has outpaced the country's ability to train faculty, China has sought to rely

consequences, and differentiate between causation and explanation.... The exam was designed to be culturally neutral, so that it could be given to students in different national contexts. The same critical thinking exam was given to first- and third-year students in the baseline. It was also given, almost two years later, to the same students in the follow-up." Prashant Loyalka et al., "Skill Levels and Gains in University STEM Education in China, India, Russia and the United States," *Nature Human Behavior* 5 (2021): 11.

on overseas training and foreign talent to fill the vacuum. Many of China's most internationally cited professors and researchers hold degrees from foreign institutions.[77] In research tracking the top-cited authors in 44 critical technology areas by their country of residence, the Australian Strategic Policy Institute estimated that roughly one-third of all authors in China who rank at the top of citation indices completed their graduate studies at an overseas university.[78] The trend is set to continue with foreign-trained Chinese scholars returning at higher rates. According to one estimate, over 1,400 Chinese scientists and researchers left posts at U.S. universities and joined universities in China in 2021 alone.[79] Nonetheless, hundreds of thousands of Chinese students still aspire to study outside of China, with a large proportion intending to remain overseas after graduation (for more, see textbox below).

Foreign Universities Attract Promising Chinese Students

Because of the intense competition for spots in China's top universities and because foreign universities are perceived as higher quality and more prestigious, many talented Chinese students aspire to study overseas, particularly in the United States.[80] In the 2021 academic year, 290,086 Chinese students were enrolled at U.S. universities.[*] [81] A large proportion of these students seek to remain in the United States after graduation. In one survey of Chinese nationals at 50 U.S. four-year universities, roughly 40 percent indicated intent to remain permanently in the United States after graduation, with many more planning to stay in the United States for another one to five years.[82] The stay rates are even higher among Chinese nationals who earned a STEM PhD at a U.S. institution. According to a study by the Center for Security and Emerging Technology, over 90 percent of students who earned their doctoral degree between 2000 and 2015 remained in the United States as of 2017, reflecting the demand for STEM talent within the United States.[83] Though there has not been as systematic a study on stay rates of Chinese graduates after 2015, the stay rates of Chinese students may have started to decline amid growing U.S.-China tensions, particularly since 2018.[84] Similar factors may be driving an uptick in Chinese studying overseas in other countries, particularly the United Kingdom (UK). In a survey by a Chinese education company, the proportion of Chinese students wanting to study in the United States declined from roughly 50 percent in 2015 to 30 percent in 2022, while the share wishing to study in the UK rose from 32 percent to 41 percent.[85]

To shore up its faculty and researcher pool, reverse a brain drain from top Chinese students staying abroad after completing their degrees, and attract leading foreign researchers, China has launched a number of recruitment initiatives, most famously the Thousand Talents program (for a catalogue of China's recruitment initiatives, see Appen-

*The student body has declined during the course of the pandemic. In 2019, 372,532 students were enrolled at U.S. universities.

dix I, "List of China's Talent Programs").* These initiatives have pulled a large cohort of well-qualified academics into China's S&T ecosystem, rewarding over 16,000 scientists for working in China through 2018.[86] Talent recruitment initiatives have nonetheless had clear limitations. Many recruited under such programs are only willing to work part of the year in China, splitting their affiliation between their overseas and Chinese institutions.[87] Returnee researchers employed fulltime in China are generally less accomplished.[88] Moreover, one study found that young Chinese academics who rejected China's talent recruitment rewards were more productive researchers, while those who accepted the offer won fewer and smaller research grants and were unlikely to hold a faculty appointment outside of China.[89] In spite of these limitations to date, academics may yet be drawn to China by increased funding opportunities and state-of-the-art facilities offered by China's extensive state-led research programs.[90] Other factors cited by academics returning to China from the United States include U.S. scrutiny of Chinese researchers and increased violence targeting Asian-Americans.[91]

China's Education System Is a Policy Tool

China's leadership views education as both a primary means to attain the Party's great power aspirations and a tool that must be strictly controlled. To steer curricula and research, particularly in higher education, the Party oversees a centralized state administrative structure (see Appendix II, "Major Agencies Involved in the State Direction of Research"). National education objectives are predominantly defined by the MOE, which guides China's education system via five- to 15-year policy roadmaps and closely manages China's top 75 universities.[92] Established in 2018 and housed within the MOE, the CCP Central Education Work Leading Small Group coordinates across education policy and ensures implementation follows the Party's objectives.[93] The minister of education also runs the Small Group's day-to-day management, reflecting the politicization of education in China.[94]

The Party-state exerts tremendous operational control and influence within the university system in particular. As a Center for Strategic and Emerging Technology (CSET) study notes, "Universities in China differ significantly from those in the United States, with the most glaring difference being that the CCP exercises extensive control over university administration, staffing, and research priorities. University presidents, for example, are typically not se-

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*China's overseas talent recruitment ecosystem rests on three mutually reinforcing pillars. First, the government operates scholarship programs to fund Chinese students to study STEM fields at foreign universities in exchange for an obligation to return home immediately and complete a national service work requirement lasting several years. In the second pillar, programs offer robust incentives to Chinese students who are studying or working abroad to return to China at some point in the future. These incentives include perks associated with talent programs, like the opportunity to conduct research at prestigious institutions, employment in specialized entrepreneurship parks, and special government subsidies to start their own businesses. Third, networks of transnational technology transfer organizations target Chinese students and scholars who have permanently settled in other countries. These transnational organizations are part of the CCP's united front system, which is tasked with mobilizing Chinese citizens and ethnic Chinese in pursuit of the Party's goals. Such transnational organizations incentivize Chinese students and scholars to contribute to China's national rejuvenation through appeals to national pride, ethnic identity, or desire for financial reward. Despite the considerable resources deployed to attract high-performing researchers, the programs are still only attracting second-tier researchers. For more on these programs, see Anastasya Lloyd-Damnjanovic and Alexander Bowe, "Overseas Chinese Students and Scholars in China's Drive for Innovation," *U.S.-China Economic and Security Review Commission*, October 7, 2020.

lected by search committees comprised of senior faculty, but by the Organization Department of the university's CCP committee."[95] More broadly, the university governance structure is characterized by a dual control system, with a formal university administration shadowed at every level by the Party's own structures: a Party secretary at the top who outranks the president; Party groups and cells within university departments; and Communist Youth League organizations that recruit, train, and mobilize young people on campus. Furthermore, CCP control within universities can be especially granular, with professors even given quotas for the number of graduate students they may supervise.[96] In a series of interviews with Chinese academics published in 2021, the Institute for Defense Analysis Science and Technology Policy Institute, a U.S. federally funded research and development center, found that the most common complaint was bureaucratic control over China's academic S&T research ecosystem.*[97]

Higher Education Is a Tool in China's Quest for National Security

The CCP's emphasis on education facilitating technological advancement is further driven by the Party's vision of a world increasingly hostile to its great power aspirations.† Concerned that access to overseas research, training, and talent may be cut off, the CCP sees improving domestic foundational research capabilities as a vital component of economic and national security, enabling China to achieve self-sufficiency in critical domains, move up value chains, and shore up identified supply chain vulnerabilities. Urgent calls to overcome "chokepoints" over key technologies and avoid what General Secretary Xi has referred to as "technological vassaldom" animate China's quest to foster innovative universities.[98] At the same time, China's S&T education goals are driven by Xi's belief that the global power dynamics are undergoing "great changes unseen in a century," and China must take advantage of the strategic moment to build prowess in emerging

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* In 2015 and 2016, Science and Technology Policy Institute researchers interviewed 40 academics in China. Of those, 21 commented on political control and 18 agreed the control was excessive and harmful. Sixteen also commented on the rigidly bureaucratic graduate student quota, explaining that "the quota on the number of graduate students is first dictated by MOE, providing a quota to each university; universities then dictate quotas for each department; and department leaders then dictate quotas for each professor." Xueying Han et al., "Challenges to China's Academic STEM Research Ecosystem," *Institute for Defense Analysis' Science and Technology Policy Institute*, July 2021.

† In his 20th Party Congress report, General Secretary Xi starkly described the world as undergoing a "new period of turmoil and change" wherein "external suppression and containment may escalate at any time." In a speech in March 2023, Xi made a rare and uniquely direct move by explicitly calling out the United States, saying: "Western countries led by the United States have implemented all-around containment, encirclement and suppression of China, which has brought unprecedented severe challenges to our country's development" and went on to emphasize that "in the coming period, the risks and challenges we face will only increase and become more severe." *Xinhua*, "Xi Jinping: Hold High the Great Banner of Socialism with Chinese Characteristics and Work Together to Build a Modern Socialist Country in an All-Round Way—Report at the Twentieth National Congress of the Communist Party of China" (习近平:高举中国特色社会主义伟大旗帜 为全面建设社会主义现代化国家而团结奋斗——在中国共产党第二十次全国代表大会上的报告), October 25, 2022. Translation; *Xinhua*, "(Published under the authority of the Two Sessions) When Xi Jinping Visited the Members of the Civil Construction Industry and Commerce Federation Who Participated in the CPPCC Meeting, He Emphasized Correct Guidance for the Healthy and High-Quality Development of the Private Economy, Wang Huning Cai Qi, and Ding Xuexiang Participated in the Visit and Discussion" ((两会受权发布)习近平在看望参加政协会议的民建工商联界委员时强调　正确引导民营经济健康发展高质量发展　王沪宁蔡奇丁薛祥参加看望和讨论), March 6, 2023. Translation.

fields and disruptive technologies like AI to overtake the United States.[99] China's domestic innovation system with universities as the linchpin will be called upon to fulfill the CCP's technological aspirations. China's military-civil fusion initiative will in turn leverage the technological prowess nurtured in Chinese universities to rapidly advance its military capabilities, potentially posing significant challenges to U.S. interests and security.

The CCP's Political Indoctrination and Control Now Permeates Chinese Education

China's surge in university enrollment in the 1980s produced a tension between two competing objectives: promoting education for greater economic growth and increasing political control of the population.[100] Following the 1989 Tiananmen Square massacre, the Party executed a draconian crackdown on the education system in the 1990s, labeling its efforts a "patriotic education campaign." While this indoctrination campaign saw a brief period of laxity in the 2000s, an inflection point occurred in 2013 when the MOE initiated a new patriotic education campaign it referred to as "My Chinese Dream," altering textbooks to "guide young students to feel the superiority of the road and system of socialism with Chinese characteristics."[101] This trend has intensified since Xi came to power, with the ministry releasing a guiding opinion in 2016 to "integrate patriotic education into all aspects of education and teaching."[102] In 2019, the Central Committee and State Council issued a lengthy notice explicitly placing Xi Jinping Thought at the core of patriotic education at all levels.[103] Textbooks introduced at the start of the 2021 school year were fully inundated with these references.[104] CCP indoctrination today now extends even to preschool students.[105] Additionally, the *gaokao* has begun incorporating elements of Xi Jinping Thought into essay questions.[106] Suisheng Zhao, a political scientist at Denver University, argues this has "created a new generation of nationalists who are more fiercely patriotic and loyal to the party than those of the older generations."[107]

Education and Cultural Genocide in Tibet and Xinjiang

In its darkest guises, education in China goes beyond indoctrination to serve as a tool for the Party's campaign of cultural genocide against ethnic minorities in Tibet and Xinjiang that has seen hundreds of thousands of students removed from their families and forced into boarding schools.[108] While roughly 20 percent of children study at boarding schools in China, in areas populated by Tibetans the share approaches 100 percent, according to the UN High Commissioner for Human Rights.[109] Nearly one million Tibetan children are forced into "residential schools" wherein they receive education solely in Mandarin as part of an intentional program to separate them from their roots and eradicate their culture.[110] In Xinjiang, up to half a million young children have been placed in boarding schools, while many parents have been sent to concentration camps, which the Party refers to as "educational facilities," where they undergo so-called "transformation through education."[111] The Education Bureau in Xinjiang's

Education and Cultural Genocide in Tibet and Xinjiang—*Continued*

capital Urumqi, in an open announcement calling forth a cadre of local teachers to implement the Party's indoctrination, paraphrased Stalin by reminding would-be recruits that "teachers are the engineers of the human soul."[112]

China's Education System in Technological Competition

China's education system is facilitating breakthrough innovations that contribute to both economic and national security challenges for the United States. Many of these innovations are in dual-use technologies, such as AI and semiconductors—fields in which a small number of highly trained scientists and engineers can make major strides in advancing the technological frontier. Understanding this, the Party has concentrated resources in its elite institutions and is building a network of dedicated national laboratories with deep connections to government agencies leading industrial policy initiatives and developing defense technology. China's strategy, while posing acute risks to the United States, also comes at a cost to its long-term material development: fewer resources are directed toward fostering broad increases in workforce productivity.

China's Higher Education System Focuses on Improving Domestic Innovation

Beijing has intentionally concentrated resources into a select number of elite institutions, enacting a series of initiatives aimed at developing globally competitive universities over the past three decades. Most recently, the Party-state's 2015 "Double First-Class University" initiative seeks to develop "first-class" universities and "first-class" academic disciplines, aiming to elevate 147 higher education institutions to world-class status (see Table 1 for an overview of China's efforts to develop world-class universities).[113] Within this cohort of Double First-Class institutions, as noted previously, the MOE directly oversees 75 of the most elite universities, providing them the bulk of centrally allocated funding for higher education. Direct funding of these universities is the single largest publicly known line item provided for by the State Council, at $50.9 billion (RMB 327.1 billion) in 2021.* [114] In large part due to this concentration of resources at the top, several of China's universities have climbed global ranking tables of higher education institutions, with a few now arguably among the best in the world. The 2023 edition of the *Times Higher Education* World University Rankings has seven Chinese universities among the top 100 institutions worldwide and

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*This number, derived from CSET's recent report on Chinese universities, is recalculated here using a market exchange rate of 6.76 rather than via the Purchasing Power Parity (PPP) methodology used in CSET's report. The MOE's budget is the largest of any ministry with publicly disclosed figures, and direct funding of these universities takes up 85 percent of its budget. Ryan Fedasiuk, Alam Omar Loera Martinez, and Anna Puglisi, "A Competitive Era for China's Universities," *Center for Security and Emerging Technology*, March 2022, 1; Dahlia Peterson, Kayla Goode, and Diana Gehlhaus, "Education in China and the United States: A Comparative System Overview," *Center for Strategic and Emerging Technology*, September 2021, 17–18.

27 among the top 500, with Tsinghua and Peking ranking highest at 16th and 17th, respectively.* [115] The United States, according to the same rankings, has seven of the top ten universities globally, 34 in the top 100, and 105 in the top 500.[116] Thirty percent of the *Times Higher Education* ranking is citations by faculty and researchers, likely skewing results in Chinese universities' favor, as the Chinese academic system has long incentivized high citation rates in academic promotion.† [117]

Table 1: Comparison of China's Universities of Excellence Initiatives

Program	Timeline	Description
Project 211	1995–2017	Project 211 provided funding to around 100 top universities to foster the development of elite institutions that can compete in the 21st century. Universities applied for inclusion in the program by outlining their plans to become high-quality research institutions and centers of teaching excellence, and they were selected for inclusion by an interministerial working group. In addition to billions of dollars in funding directly associated with the program, inclusion in Project 211 also catalyzed investment from provincial and local governments where the university was located.
Project 985	1998–2017	Project 985, named after the year and month it launched in May 1998, initially provided a large pool of funds to nine universities chosen by the central government as flagship institutions. These universities would become known as the C9 group, China's Ivy League equivalent. The initiative formalized the goal of developing world-class universities. It was later expanded to fund 30 additional universities.
Double First-Class	2015–present	The Double First-Class initiative replaced the 211 and 985 projects between 2015 and 2017. It initially provided funding to a core group of 42 universities, which were deemed to have potential as world-class institutions and leading centers of science-based innovation. Another 95 high-performing universities were selected to excel in specific disciplines. The second phase of the initiative, launched in 2022, expanded the number of member universities to 147 and removed the distinction between core and discipline-focused universities. These universities are granted access to additional funding based on the government's evaluation of its performance in particular disciplines as well as overall international ranking.

Source: Various.[118]

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*The other universities are all members of the so-called C9 League in China, an association established in 2009 that receives lavish government funding. The C9 universities ranked in the top 100 consist of Tsinghua University, Peking University, Fudan University, Shanghai Jiao Tong University, Zhejiang University, University of Science and Technology of China, and Nanjing University. The two other C9 universities are Harbin Institute of Technology and Xi'an Jiaotong University. Emily Hannum, "Educational Development in China: Progress, Challenges, and Outlook" (prepared for the U.S.-China Economic and Security Review Commission), February 23, 2023, 18.

†Chinese universities offer substantial cash rewards for publication in prestigious journals. A review of such awards offered by 40 Chinese universities between 2008 and 2016 found that authors published in *Nature* or *Science* received an average of $43,783 in 2016. Wei Quan, Bikun

In first-tier cities,* China's elite universities anchor the technology ecosystem and play a fundamental role in China's efforts to dominate every part of what it calls "the innovation chain."[119] While focusing on basic research, such universities are also integrated closely with China's many state-managed laboratories, research institutes, and funded research projects.[120] As CSET researchers note in a study on China's state key labs,† they are "evolving to be one of the most important building blocks in China's innovation base," are at the forefront of China's efforts to reduce dependence on foreign technology, and are key contributors to military-civil fusion.[121] These 533 laboratories are overseen by the MOE as well as China's Ministry of Science and Technology (MOST) and tend to be organized around a specific discipline.[122] The labs are often co-located with elite universities (those counted in the Double First-Class program), and university faculty are frequently the investigators on research grants awarded to the state key labs.[123] MOST also oversees thousands of national-level R&D projects, known as National Key Projects (5,262 launched between 2016 and 2021), as well as the National Natural Science Foundation, with the majority of funding going to elite universities and research labs.[124]

Specific Disciplines at the Frontier

Resource concentration is also directed into specific disciplines selected by the central government. Currently, 465 disciplines from 147 universities are being targeted and supported under the premise that they have "the potential to become world class."[125] Notably, whereas universities such as Peking and Tsinghua have roughly 30 disciplines that will qualify for promotion, lesser institutions tend to have only a few and are disproportionately concentrated in "hard" technology and science areas, such as the Wuhan University of Technology, whose only supported discipline will be materials science and engineering.[126] As Emily Hannum, professor of sociology and education at the University of Pennsylvania, notes in a report prepared for the Commission, "unlike the earlier projects, the Double First Class project supported not only 'the already established universities' but also universities 'with urgent needs, distinctive features, and new disciplines.'"[127] In spite of this, as Dr. Hannum notes, the "majority of disciplines to be developed are still clustered

Chen, and Fei Shu, "Publish or Impoverish: An Investigation of the Monetary Reward System of Science in China (1999–2016)," *arXiv*, July 2017.

*Chinese cities are unofficially but widely grouped into four "tiers" based on population, affluence, and whether they are governed at a provincial level (e.g., Shanghai, Chongqing, Beijing, and Tianjin are provincial-level municipalities), as provincial capitals, or at lower echelons of administrative hierarchy. For example, Shanghai is a first-tier city; Chengdu, the populous capital of Sichuan and a regional hub in the southwest, is a second-tier city; Wenzhou, a prefecture-level port city and tourist destination on the coast of Zhejiang Province, is a third-tier city; and Xiangcheng, a county-level city in Henan Province famous foremost as the birthplace of the first president of the Republic of China, Yuan Shikai, is a fourth-tier city. Dorcas Wong, "China's City-Tier Classification: How Does It Work?" *China Briefing*, February 27, 2019.

†State key labs are subordinate to—but far more numerous than—the 20 national-level labs. The Party-state also operates 191 National Engineering Research Centers, differing from state-key labs in being more focused on commercialization of technology. Previously, these research centers were far greater in number but have been scaled back due to the current widespread quality issues, failing to actually promote commercialization while building up debt and wasting resources. Jeroen Groenewegen-Lau and Michael Laha, "Controlling the Innovation Chain: China's Strategy to Become a Science and Technology Superpower," *Mercator Institute for China Studies*, February 2, 2022; Michael Laha, "How China Plans to Engineer Its Way Out of Technology 'Strangleholds,'" *Australian Strategic Policy Institute*, September 26, 2022.

in major cosmopolitan areas in the eastern region of China," and for most of China's provinces, the only institution selected into the Double First-Class project is the strongest university in the provincial capital.[128]

Promoting Semiconductor and AI Development in Higher Education

Promoted areas of study are disproportionately in the Party's priority S&T areas, including semiconductors and AI. Since 2015, the Party-state has selected 28 schools to build out microelectronics colleges. In 2020, China separated integrated circuit science and engineering from the broader category of electronic S&T and made it a first-level discipline.[129] Also in 2020, the National Development and Reform Commission and the MOE moved forward on implementing "national integrated circuit industry-education integrated innovation platforms" at specific universities to increase university-industry collaboration. According to Dr. Simon, each "has a specialized mandate, e.g. Tsinghua is focused on CMOS* logic devices and circuits, memory, and sensors," and each receives hundreds of millions of RMB from the government in support.[130] In 2021, 18 universities were selected to begin offering doctoral programs in integrated circuit science and engineering, nearly all of them elite universities on China's coast.[131] Efforts in AI mirror these trends in semiconductors, according to Dahlia Peterson, a research analyst at CSET.[132] More elite locales have established AI institutes, which by Ms. Peterson's calculations currently include at least 36 AI colleges and 18 AI research institutes.[133] More broadly, in 2019 the MOE standardized an AI major that has now been taken up by 440 universities. Initial uptake was strongest at elite institutions but has now spread to lower-tier universities, raising concerns about quality.[134] These initiatives are a clear response to Beijing's calls to the higher education system to target "stranglehold" technology areas as well as areas critical to the Party-state's industrial policy ambitions.

Concentration of Resources at the Top Is Growing China's Innovation Capacity

A wide array of organizations and analysts find that China's overall innovation capacity has expanded sizably over the last several decades, in line with China's massive expenditure on its leading universities. The World Intellectual Property Organization's Global Innovation Index, one of the most frequently cited metrics, found that from 2010 to 2022 China advanced from the 43rd to the 11th ranked country in terms of innovation capacity.[135] Two recent reports buttress this finding with a broad set of quantitative indicators. In late 2022, the Information Technology and Innovation Foundation (ITIF), a U.S. nonprofit public policy think tank, created a proprietary index summing together a range of innovation inputs, outputs,

* CMOS stands for Complementary Metal-Oxide-Semiconductor and refers to the physical layering of a semiconductor: a metal (used for the transistor gate) is deposited on top of a layer of silicon dioxide (the "oxide"), which in turn is on top of a silicon semiconductor substrate. CMOS is the most common method for constructing integrated circuits.

and outcomes (e.g., R&D spending, science and engineering articles, and value added in advanced industries) to calculate China's overall innovation capacity, finding that it has ballooned from 77.8 percent of the United States' capacity in 2010 to exceed the United States at 139.2 percent as of 2020.[136] In early 2023, meanwhile, the Australian Strategic Policy Institute (ASPI), based on research that looked at academic publications related to specific technologies, concluded that "China has built the foundations to position itself as the world's leading science and technology superpower, by establishing a sometimes stunning lead in high-impact research across the majority of critical and emerging technology domains."[137] The authors note that "China's global lead extends to 37 out of 44 technologies that ASPI is now tracking, covering a range of crucial technology fields spanning defense, space, robotics, energy, the environment, biotechnology, AI, advanced materials and key quantum technology areas" (see Table 2).[138] As portrayed in the figure below, the technology monopoly risk score developed by ASPI is derived by considering two factors: (1) the top country's share of the world's top ten institutions in the specific technology and (2) the top country's research lead over the closest competitor, based on the ratio of publications in the top 10 percent most cited for that technology. "High risk" means eight or more of the top ten institutions are in the top country, and that country also commands at least three times the share of publications in the top 10 percent relative to the next closest country.* [139] Publications, however, are a second order measure and may not necessarily be indicative of underlying technological deployment. Chinese policy incentives, which reward metrics like patenting and citations, may also lead the study to overstate the actual progress of Chinese scientific research.[140]

Table 2: Research Areas China Appears to Lead

Selected Technologies	Lead Country	Technology Monopoly Risk
Advanced materials and manufacturing		
Nanoscale materials and manufacturing	China	high
Coatings	China	high
Smart materials	China	medium
Advanced composite materials	China	medium
Novel metamaterials	China	medium
High-specification machining processes	China	medium
Advanced explosives and energetic materials	China	medium
AI, computing, and communications		
Advanced radiofrequency communications (incl. 5G and 6G)	China	high

*Medium risk in turn means five out of the top institutions are in the first-ranked country, which also commands at least two times the share of publications in the top 10 percent relative to the next-closest country. Low risk simply means the medium-risk criteria were not met. Jamie Gaida et al., "ASPI's Critical Technology Tracker: The Global Race for Future Power," *Australian Strategic Policy Institute*, February 2023, 13.

Table 2: Research Areas China Appears to Lead—*Continued*

Selected Technologies	Lead Country	Technology Monopoly Risk
Advanced optical communications	China	medium
AI algorithms and hardware accelerators	China	medium
Distributed ledgers	China	medium
Advanced data analytics	China	medium
Energy and environment		
Hydrogen and ammonia for power	China	high
Supercapacitors	China	high
Electric batteries	China	high
Photovoltaics	China	medium
Nuclear waste management and recycling	China	medium
Directed energy technologies	China	medium
Biotechnology, gene technology, and vaccines		
Synthetic biology	China	high
Biological manufacturing	China	medium
Sensing, timing, and navigation		
Photonic sensors	China	high
Defense, space, robotics, and transportation		
Advanced aircraft engineers (incl. hypersonics)	China	medium
Drones, swarming, and collaborative robots	China	medium

Source: Jamie Gaida et al., "ASPI's Critical Technology Tracker: The Global Race for Future Power," *Australian Strategic Policy Institute*, February 2023, 8.

China Limits Academic Sharing of Research and Data

As China expands its presence in academic research in biotechnology and other cutting-edge domains, the Party-state is also increasingly enforcing restrictions on data sharing and research transparency. According to Anna Puglisi, director for biotechnology at Georgetown's Center for Security and Emerging Technology, "China has amassed the largest genomic holdings of anywhere in the world."[141] Beijing views these resources as a strategic advantage and is increasingly protective of them. In July 2023, the Party-state issued new regulations on foreign access that add onto 2019 laws already restricting foreign entities' ability to collect genetic material in China or disseminate it abroad.[142] The new regulations further increase scrutiny of collaboration in clinical studies and restrict outflows of information, creating an environment so stringently controlled that one specialist described it as "basically grant[ing] exclusive access to Chinese nationals based in China to conduct this research."[143] Chinese publications in Western journals have begun omitting data on genomic sequences, including a disclaimer stating that—due to restrictions im-

China Limits Academic Sharing of Research and Data—*Continued*

posed by the Chinese government on the export of genomic data and certain sequencing information—they are unable to share the complete data, instead providing a mere summary of the underlying data.[144] Such practices deviate from the global norms of research collaboration and create a slippery slope with regard to data transparency in the scientific community.[145] The greater scrutiny over academic information sharing comes after several databases were restricted on CNKI, the top portal for academic papers in China, reflecting the tightening grip over information as the Party-state prioritizes national security and control.[146]

China's Innovation Emphasis May Fuel a Technology "Diffusion Deficit"

As demonstrated above, assessments of China's science, technology, and education capacity often rely heavily on quantitative metrics such as research publications, R&D expenditures, and patents. Such traditional innovation metrics, however, often overlook the issue of "technology diffusion," or the process by which innovations, technological knowledge, and new production processes spread across an economy.* Scholars have emphasized the importance of technological diffusion in economic and technological development for decades.† [147] Particularly important is the potential relationship between diffusion capacity and a country's growth in productivity, or the amount of output that can be produced from a given amount of inputs, such as labor and capital. China's declining productivity growth since at least 2007‡ may owe in part to barriers to diffusing technology and knowhow throughout its economy, particularly educational barriers.[148] George Washington University political scientist Jeffrey Ding disaggregated the 2020 Global Innovation Index into subindices that align with innovation and diffusion, respectively, in order to highlight an apparent differential between the two. Where China registers an impressive performance on the former subindex, ranking on average 13.8, Dr. Ding describes China's relatively poor performance on the latter, ranking on average 47.2, as a "diffusion deficit" (see Table 3).[149]

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*This is partly because diffusion is much harder to measure at a national level. Aggregate data for innovation inputs (e.g., R&D) and outputs (e.g., patents) are readily available. By contrast, data on the extent and intensity of diffusion, or for instance how many firms adopt a new technology and how frequently they use it, tend to only be available in small, firm-level datasets and are often not readily comparable between sectors or technologies. Jeffrey Ding, "The U.S. May Be Overstating China's Technological Prowess," *China File*, June 7, 2023; Diego A. Comin and Martí Mestieri, "Technology Diffusion: Measurement, Causes and Consequences," *National Bureau of Economic Research*, May 8, 2013.

†The most widely referenced study on diffusion of innovations—with over 150,000 citations, according to Google Scholar—was first written in 1962. That study was itself a synthesis of research across hundreds of studies on diffusion undertaken in the decades prior, building in particular on studies looking at technology adoption among farmers in the American Midwest. Everett Rogers, "Diffusion of Innovations," *Free Press of Glencoe*, 1962.

‡Since 2007, China's GDP growth has mostly been driven by state-directed investment in infrastructure and housing projects, where for the prior three decades it was driven upward of 70 percent of GDP growth due to reallocation of resources from low- to high-efficiency sectors and firms. For more background on the decrease in China's productivity, see Loren Brandt, written testimony for the U.S.-China Economic and Security Review Commission, *Hearing on An Assessment of the CCP's Economic Ambitions, Plans, and Metrics of Success,* April 15, 2021.

Table 3: China's Innovation vs. Diffusion Capacity, 2020

Innovation Capacity Subindex		*Diffusion Capacity Subindex*	
Indicator	**China's Global Rank**	**Indicator**	**China's Global Rank**
QS University Rankings	3	ICT Access	71
Gross Expenditures on R&D	13	ICT Use	53
Global R&D Companies	3	University/Industry Research Collaboration	29
Researchers, Fulltime Equiv/mn pop	48	State of Cluster Development	25
R&D Performed by Business	12	Gross Domestic Expenditure on Research and Development Financed by Abroad	81
R&D Finance by Business	4	JV Strategic Alliance Deals/Bn	76
Patents by Origin	1	Patent Families 2+ Offices/Bn PPP% GDP	27
Patent Cooperation, Treaty Patents by Origin	15	Intellectual Property Receipts, % Total Trade	44
Utility Models by Origin/Bn PPP$ GDP	1	High-tech Net Exports, % Total Trade	5
Scientific and Technical Articles	39	Information and communications technology (ICT) Services Exports, % Total Trade	61
Citable Documents H-Index	13		
Average Ranking	**13.8**	**Average Ranking**	**47.2**

Source: Adapted from Jeffrey Ding, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Challenges and Capabilities in Educating and Training the Next Generation Workforce*, February 24, 2023, 7.

The stark decline in quality outside China's top universities may contribute to China's apparent diffusion deficit. Beyond the select universities directly managed by the MOE and other state agencies, most institutions are funded by cash-strapped city and provincial governments.* Dr. Simon explains that for higher education institutions, "after you go beyond the first 25, 30, at least on the civilian universities, the drop-off [in quality] is very, very sharp."[150] Cross-country comparisons focused on number of graduates and

*Although Chinese universities charge tuition, fees are maintained at low levels by the MOE and provincial governments in order to promote universal access to education. As a consequence, universities rely on government appropriations to finance operations. Increasingly, universities have diversified their funding sources by soliciting donations from the nonstate sector, but these remain a small portion of their revenue sources. An expanding number of private colleges operate outside the government funding structure, charging tuition fees many times higher than public universities. William B. Kirby, *Empire of Ideas: Creating the Modern University from Germany to America to China*, Harvard University Press and Belknap Press, 2022, 254, 261; Gerard A. Postiglione, "Expanding Higher Education: China's Precarious Balance," *China Quarterly* 244 (2020): 922–923; *Guangming Daily*, "How Universities Can Make Up for Fundraising" (中国大学如何补上"募款"课), January 13, 2016. Translation.

publications often do not capture this drop-off. If, as most research on the issue suggests, a crucial aspect of effective diffusion of innovations is absorptive capability, then diffusion in China is likely hampered by the extent of the drop-off in educational provision outside of China's well-off urban areas.[151] Additionally, even among firms that do ostensibly adopt new innovations, the ability to fully utilize and assimilate such technologies and processes is constrained by internal competencies, such as skilled and knowledgeable managers and employees.[152] With severe constraints on talent development outside well-off urban areas, firms in poorer regions will struggle to effectively benefit from innovations. Despite China's rapid development over the last several years, across information and communications technology broadly, "China lags behind the U.S. in penetration rates of many digital technologies across industrial applications, including digital factories, industrial robots, smart sensors, key industrial software, and cloud computing."[153]

China's innovation and technological diffusion capacities each pose unique challenges. On the one hand, China's intensive concentration of resources into innovations in critical and emerging technology sectors could lead to asymmetrical payoffs, giving the Party-state power, challenging U.S. technology leadership in new domains, and creating potential threats. China's evolving strategies for concentrating resources to solve key technology challenges is improving and should not be underestimated, as Dr. Puglisi assessed in testimony before the Commission.[154] Development of dual-use technologies in domains like biotechnology and AI may possess "first mover" advantages that could confer impactful and lasting benefits, particularly relevant to the Party-state's military-civil fusion strategy.[155] Beijing-based venture capitalist Kai Fu Lee argues that critics of China's resource concentration strategy fail to appreciate the asymmetrical upside potential:

> *What these critics miss is that this process can be both highly inefficient and extraordinarily effective. When the long-term upside is so monumental, overpaying in the short term can be the right thing to do. The Chinese government wanted to engineer a fundamental shift in the Chinese economy, from manufacturing-led growth to innovation led growth, and it wanted to do that in a hurry and the process of pure force was often locally inefficient—incubators that went unoccupied and innovation avenues that never paid off—but on a national scale, the impact was tremendous.*[156]

At the same time, a number of analysts believe that China's inefficient allocation will be a severe constraint on the country's further development. As Loren Brandt and Thomas Rawski wrote in a 2020 research paper published by the IZA Institute of Labor Economics,

> *Assigning vast resources to a talented and highly motivated corps of domestic researchers will surely deliver successes.... When measured against the enormity of the world's largest economy, however, even considerable numbers of isolated breakthroughs may fail to deliver economy-wide productivity increases, leading to a Soviet-style outcome in which the occasional Sputnik illuminates galaxies of mediocrity.*[157]

Similarly, Doug Fuller, associate professor at Copenhagen Business School and an expert on China's S&T ecosystem, argues that for "the needs of a developing country like China ... knowledge diffusion should take precedence over knowledge generation."* [158]

China's Education System Struggles to Promote Diffusion via Industry Linkages

While universities in China's wealthy coastal cities have strong ties to industry, producing startups from research labs and licensing technology to businesses, most of China has weak university-industry linkages. Richer locales such as Shenzhen and Kunshan (where Duke University's China campus is located) have benefited from attracting national and international elite universities to set up satellite campuses, often covering large portions of their costs. By contrast, most areas in China have had to create and fund their own institutions.† [159] Since 2000, nearly 700 universities were created by local governments with a primary aim of fostering cooperation between academia and local industry, with 196 out of China's 339 cities, or 57.8 percent, establishing their own university.[160] Hundreds of so-called "university towns" in turn were brought forth by government investment around these universities.[161] The results have been poor, with most institutions low in quality and failing to spur technological diffusion. As of 2021, 802 colleges and universities had established an in-house technology transfer institution, yet only 12 had technology development, consulting, and service contracts valued at more than $138 million (RMB 1 billion).[162] Further, research from Qiang Zha, associate professor of education at York University, has shown that local institutions have been plagued by bad incentives and limited expertise, fatally undermining integration with industry.‡ China's local universities face major "constraints in the strength and availability of their teaching staff" and operate under top-down incentives that encourage engaging in publication and metric chasing.[163] Dr. Zha notes that rather than work closely with local industry, they "mimic elite universities through increasing research activities and adding graduate programs."[164] Industry, in turn, has had little incentive to collaborate substantively with China's nonelite universities.

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*Dr. Ding also noted a historical parallel between China today and the former Soviet Union, when innovation-oriented assessments overstated that nation's prowess. Dr. Ding, for example, writes that "the notion of a 'scientific manpower gap' — specifically, that the Soviet Union was graduating two to three times as many scientists and engineers than the U.S. — took hold in U.S. discourse" and that "[t]hroughout the 1950s, this figure was 'repeated ad infinitum' by analysts and politicians." Jeffrey Ding, "The Diffusion Deficit in Scientific and Technological Power: Re-assessing China's Rise," *Review of International Political Economy* (2023): 12.

†Duke's deal with Kunshan, a wealthy city in coastal Jiangsu, for example, entailed the Municipality of Kunshan providing and leasing 200 acres of land to Duke for ten years at no cost as well as paying for construction. Operational costs were split between Kunshan and Duke for the first six years. Duke's Kunshan campus is one of 16 U.S. branch campuses in China, according to March 2023 data from the Cross-Border Education Research Team. Ian Wilhem, "Duke's China Plan Sparks Doubts on Campus," *Chronicle of Higher Education,* May 25, 2011; Cross-Border Education Research Team, "List of International Branch Campuses."

‡Dr. Zha also notes that local universities are driven by an overwhelming imperative to raise funds, and thus "they tend to offer more 'soft' programs; those do not require expensive resource inputs, such as business administration, foreign languages, economics, management, Chinese language and literature, and media studies. Such programs do not cost much, while the enrollment pool is relatively large and steady, which in turn helps secure government appropriations and student fee revenues. After all, local governments' appropriations and students' contributions constitute almost the entire revenue stream of those universities." Qiang Zha, "Newly Founded Local Universities: 'Land-Grant Colleges' on Chinese Soil?" in Ceren Ergenc and David S.G. Goodman, eds., *Handbook on Local Governance in China: Structures, Variations, and Innovations*, Edward Elgar Publishing, 2023, 4.

Limited Industry-Education Linkages Threaten Beijing's Industrial Policy Aims

The disconnect between education and industry is hindering Beijing's progress in the competitive race for the industries of the future. China's research landscape has become dotted with many government-created "science parks" and "development zones" that focus in part on promoting education-industry collaboration on specific technologies.[165] Outside of a few high-performing zones, such as Beijing's Zhongguancun, local governments have accumulated an extensive amount of debt to promote such university-industry collaboration with little to show.* While a coordination body exists in the semiconductor industry to promote industry-education linkages (known as the Semiconductor Industry & Education Integration Development Alliance),† substantive collaboration is rare and partnerships are largely limited to naming and donations, serving as a form of corporate brand promotion and a method to acquire tax breaks and subsidies.[166] The central government has effectively acknowledged the overextension and waste set off by "zone fever," reducing the number of existing zones and dramatically slowing approval of new ones such that only five new high-technology zones were approved between 2018 and 2023.‡[167] The Party-state's own 2023 assessment of China's innovation ecosystem, produced by the Chinese Academy of Sciences, warned of the continuing lack of education and industry collaboration:

> *In comparison to the world's S&T superpowers, China's innovation and development in S&T has no shortage of issues, such as deficiencies in foundational and critical technologies, a lack of interaction between the educational and technical industries, and a shortage of industry*

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*There are 140 national-level science parks as of 2021 and, per China's most recent audit in 2018, there were 552 national-level development zones, which included 219 "economic and technology development zones" and 156 "high-technology industrial development zones." Below the national level, zones have proliferated to 1,991 at the provincial level and, though not tabulated by the audit, tens of thousands more below the provincial level. The results are a select few zones of excellence, such as Beijing's Zhongguancun, but many more have failed to develop or diffuse technology while incurring massive debt. Creating these zones is the primary undertaking of local government financing vehicles, involving major expenditure on infrastructure and accounting for a large portion of China's recent debt accumulation. China Ministry of Science and Technology, *The Ministry of Science and Technology and the Ministry of Education Identified the Eleventh Batch of National University Science and Technology Parks* (科技部 教育部认定第十一批国家大学科技园), June 3, 2021. Translation; National Development and Reform Commission et al., *Catalogue of China Development Zone Audit Announcements (2018 edition)* (中国开发区审核公告目录(2018年版)), February 26, 2018. Translation.

†The alliance was jointly initiated and established by 73 leading education and industry organizations, including Tsinghua Unigroup, SMIC, Huahong Group, Tsinghua University, Peking University, Xidian University, and Institute of Microelectronics, and Chinese Academy of Sciences. Industrial Culture Development Center of the Ministry of Industry and Information Technology, "Wang Zhijun Attended the Founding Meeting of the Integrated Circuit Industry-Education Integration Development Alliance and the 2nd Semiconductor Wisdom Conference in 2019" (王志军出席集成电路产教融合发展联盟成立大会暨2019第二届半导体才智大会), December 23, 2019. Translation.

‡According to analysis by the Mercator Institute for China Studies (MERICS), this led MOST, which at the time managed high-technology zones under its Torch Program, to miss its target of 240 high-technology zones by 2020. Following Party-state restructuring in 2023, however, MOST's management of these zones has now been moved to Ministry of Industry and Information Technology. Similar trends hold for the Economic and Technological Development Zones, which are overseen by the Ministry of Commerce. Jeroen Groenewegen-Lau and Michael Laha, "Controlling the Innovation Chain: China's Strategy to Become a Science and Technology Superpower," *Mercator Institute for China Studies*, February 2, 2022, 13.

Limited Industry-Education Linkages Threaten Beijing's Industrial Policy Aims—*Continued*

members in the community for S&T innovation. These issues have severely restricted the overall effectiveness of the innovation system. In the face of deep and complex changes occurring both within China and abroad, the national innovation system urgently needs to undergo a systematic transformation.[168]

Labor Market Outcomes and Educational Quality

Despite its growing strengths in fostering innovation, China's education system is failing to meet the economy's demand for skilled workers, posing an immense challenge to China's continued economic growth.[169] Analyses of China's labor force indicate major skills gaps and shortfalls of workers with needed skills. The education system's challenges in developing a nationwide skilled workforce could slow the development of knowledge-intensive sectors and deepen China's "diffusion deficit." A recent spike in the youth unemployment rate has put a spotlight on the limited training and development provided by China's education system. The high youth unemployment situation is also attributable to the Party-state's missteps in Zero-COVID and its regulatory crackdown on nonstate businesses. At the same time, despite efforts to reform and promote vocational education, vocational schools almost uniformly fail to instill work-relevant skills let alone develop students' broader cognitive abilities, hindering the development of a technically skilled workforce and fostering a societal bias against such schooling.

China's Education System Struggles to Meet Labor Market Demand

China's government is grappling with looming talent shortages as it struggles to expand training capacity and guide students to pursue careers in sectors targeted by government industrial policies. In 2016, China's MOE, Ministry of Human Resources and Social Security, and Ministry of Industry and Information Technology forecasted that ten key industrial sectors will face a shortfall of nearly 30 million skilled workers by 2025, with huge gaps in new-generation information technology (IT), power equipment, and new materials.[170] McKinsey Global Institute similarly projects that by 2030, up to 220 million Chinese workers will lack the skills needed to contribute to the economy, meaning 30 percent of the workforce will be forced to reskill, retrain, or languish in unemployment.[171] In reporting by independent Chinese economic media outlet Caixin, a senior executive of a leading Chinese recruitment service provider stated that the driving factor in China's unemployment is a mismatch between the skills of graduates and the demands of the labor market. The current unemployment situation "doesn't reflect insufficient job offerings so much as a structural mismatch between supply and demand," the executive said.[172] The prospects of a high-paying career weigh heavily in students' decision on what discipline to study.* [173] This dynamic has led to an oversupply of graduates in the information and communications technology sector, with 43 percent of job applicants pursuing IT positions.[174] With roughly one-third of university graduates failing to find work in a field related to what they studied at school, there is some evidence for this structural mismatch hypothesis, as companies are forced to compete over a sparse pool of individuals with appropriate experience.[175]

Evidence from AI and semiconductors suggests Chinese industry faces challenges in filling vacant roles due to inadequately trained talent, in spite of the Party-state's efforts to train microelectronics and AI specialists. Multiple AI subsectors suffer from "critical shortages," with fewer than four workers for every ten open positions, calculated as a labor supply-demand ratio below 0.4. The ratios range from 0.37 for AI chip engineers to 0.23 for machine learning engineers, 0.20 for natural language engineers, and 0.09 for computer vision engineers, among other shortages.[176] Meanwhile, according to a major mainland research report on China's semiconductor talent ecosystem covering 2020–2021, the semiconductor industry is expecting a shortfall in talent of 200,000–300,000 trained personnel, with 541,000 estimated to be employed in the industry in 2021 (about double the U.S. number) compared to an estimated need for 740,000–760,000 by the end of 2023.† [177] While China's top microelectronics colleges graduate roughly 180,000 people, nearly enough to fill the gap, only 13.8 percent funnel into the industry.‡ [178] The underlying reason for this, Dr. Simon explained in his testimony, is that a large portion of graduates from these programs "simply do not possess the right sets of skills and experience needed by the industry."[179] This deficit reflects the fact that faculty often lack engagement with industry, institutions lack pilot research equipment or production lines for students to train on, and many schools do not even possess up-to-date textbooks.[180]

Demographic Decline Increases China's Need for Skilled Workers to Sustain Growth

China's workforce is shrinking as the population ages, deepening the necessity for human capital improvement to sustain economic growth. According to UN modeling, China's working-age population (those aged 15–64) is projected to decline from 986 million in 2021 to 767 million by 2050.§ [181] This shrinking workforce will be forced

* Universities and their provincial education authorities negotiate each year on the number of students to admit by major. This grants the MOE a degree of control over the allocation of majors across the higher education system; however, student applicants retain discretion over what major they study. After receiving their score on the *gaokao*, students rank their top choice schools as well as the specific majors they wish to apply to, with the highest-scoring students generally able to self-select into their preferred programs. Ruixue Jia and Hongbin Li, "Just Above the Exam Cutoff Score: Elite College Admission and Wages in China," *Journal of Public Economics* 196 (2021): 3; Organization for Economic Cooperation and Development, "Education in China: A Snapshot," 2016, 12.

† Across the semiconductor ecosystem's three segments of design, manufacturing, and packaging and testing, there are— respectively—199,600, 181,200, and 160,200 employees in China as of 2021. Li Pei, "[Chip Vision] Discussion on Semiconductor Talent Shortage, Vocational Education Should Not Be Absent" ([芯视野]半导体人才荒的讨论，职业教育不应缺席), *Aijiwei*, April 18, 2022.

‡ These data reflect graduates from 20 of the 28 microelectronic colleges in China that had available data.

§ In 2021, out of the total working-age population of 986 million, China's workforce had 780 million workers based on data from the International Labor Organization and the UN Popula-

Demographic Decline Increases China's Need for Skilled Workers to Sustain Growth—*Continued*

to support a massive dependent population. By 2050, the UN projects that there will be one old-age dependent (over 65) for every two working-age individuals, an increase from one senior for every five workers in 2021.[182] Continued growth in per capita income will require each worker to become more productive.

High Youth Unemployment Creates Potential for Unrest

After averaging 17.5 percent in 2022, China's unemployment rate for 16- to 24-year-old urbanites had climbed to an all-time high of 21.3 percent by June 2023, a stark contrast with the highly stable and managed unemployment rate for 25- to 59-year-old urbanites (see Figure 2).[183] China's national statistics agency subsequently ceased releasing the youth unemployment data series, a decision likely made due to increasingly dismal data.[184] The sharp rise in unemployment coincided with the largest ever cohort of graduates from China's higher education system—11.58 million—who entered a slowing job market in the summer of 2023.[185] While these unemployment figures comprise more than just college graduates, new graduates appear to face the weakest job prospects. In 2022, unemployment for college graduates in 2022 was estimated at 24.5 percent* in what was then characterized as the "hardest employment season in history."[186] The climbing youth unemployment rate in 2023 likely reflects even dimmer job prospects for university degree holders.[187]

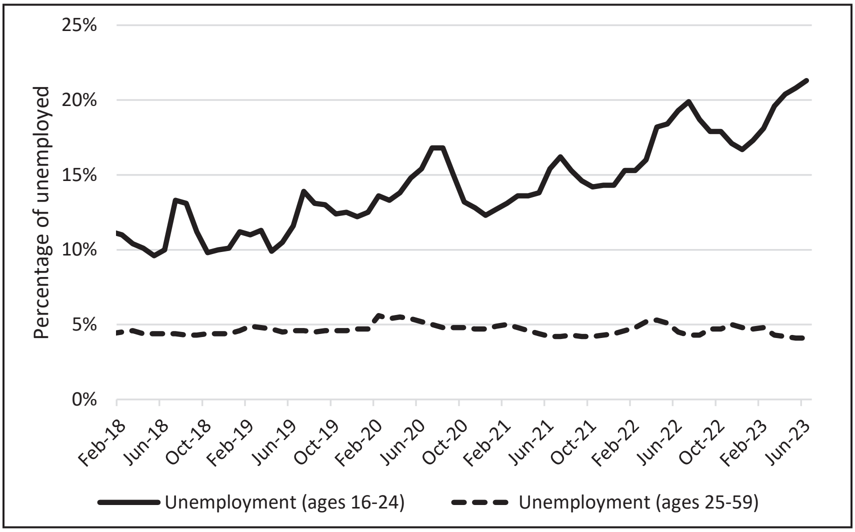
Analysts disagree on the extent to which shortcomings in China's education system are to blame for high youth unemployment, with some citing a weak economy, interventionist government policies, and even underlying statistical issues as primary factors.[188] The foremost cause may be lingering economic weakness from China's drastic Zero-COVID campaign. Labor-intensive jobs in the services industries are disproportionately filled by young people, especially those without an undergraduate degree, and the fall in retail spending under strict lockdowns in 2022 contributed to significant job losses.† [189] Job creation in the services sector remained weak in 2023 due to a sluggish recovery in household consumption.[190] Meanwhile, in addition to Zero-COVID, the Chinese Party-state's efforts to engineer the economy have contributed to labor market problems for new graduates. The tutoring, real estate, and commercial internet industries, which absorbed a substantial and growing share of new graduates up until 2020, each experienced a Party-state-led "rectification" campaign that severely depressed new hiring.[191] Finally, China uses a looser definition of unemployment that

tion Division. World Bank, "Labor Force, Total—China," 2022; UN Department of Economic and Social Affairs, Population Division, "World Population Prospects 2022: Population by Select Age Groups—Both Sexes," 2022.

*According to Caixin and Nikkei Asia, Zhuo Xian, vice department director at the State Council's Development Research Center, stated that the unemployment rate was estimated at 1.4 times that of youth as a whole, which would put the number at 24.5 percent in 2022. Huang Huizhao et al., "Solving China's Soaring Youth Unemployment," *Nikkei Asia*, March 16, 2023.

†Employment in the services sector fell by 12.9 million workers between 2021 and 2022, a decline of 3.6 percent. China Ministry of Human Resources and Social Security via CEIC database.

Figure 2: China's Increasing Urban Youth Unemployment, January 2018–June 2023



Note: Like China's official overall unemployment indicator, the officially reported youth unemployment rate tracks registered unemployment in China's urban areas.
Source: China National Bureau of Statistics via CEIC database.

may inflate numbers, especially in the youth category with the highest labor market frictions.* In contrast to these explanations, meanwhile, the Party-state has used its propaganda channels to play up the less credible notion that unemployment owes to students being unwilling to take certain jobs because of their "expectations getting higher." [192]

China's Tutoring Crackdown May Worsen Inequality

As part of a sweeping regulatory clampdown across several sectors dubbed the "common prosperity" campaign in 2021,† the Chinese government introduced a series of tightening measures on the once booming for-profit tutoring industry. Among other changes, the new regulations require all companies offering tutoring services in the compulsory education (grades 1–9) curricula to become nonprofits, prohibit them from going public, and force

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*In China, unemployment data include jobless individuals in urban areas who have sought employment in the preceding three months and are able to start work within two weeks. The primary unemployment metric in the United States, by contrast, only includes those who have pursued employment within the most recent four weeks and are capable of starting immediately. Adam Wolfe, "China counts anyone living in an urban area without a job that has looked for work in the past 3 months and can start work within 2 weeks as unemployed. The US only counts as unemployed those that have looked for work in the past 4 weeks and can start immediately," X, formerly known as Twitter, June 6, 2023.

†The campaign also included a prominent crackdown on consumer-facing internet firms and fintech firms as well as high-level rhetoric about expanding the middle class, with General Secretary Xi suggesting that China create an "olive-shaped [income] distribution, where the middle is large and the two ends are small" in an August 2021 speech at Central Commission for Financial and Economic Affairs, one of China's top economic deliberation bodies. For more on the campaign, see Chapter 2, Section 1, "Year in Review: Economics and Trade," in U.S.-China Economic and Security Review Commission, *2021 Annual Report to Congress*, November 2021, 119–164; Trivium China, "Soaking the Rich," *China Markets Dispatch*, August 18, 2021.

China's Tutoring Crackdown May Worsen Inequality—*Continued*

all online tutoring companies to register with regulators for approval to operate.[193] The move devastated the industry overnight. The largest private tutoring company, New Oriental, which once enrolled some ten million students, lost 80 percent of its revenue and 90 percent of its market value and laid off more than half of its roughly 110,000 employees.[194] Prior to the crackdown, total employment estimates for the industry were in the millions, with hundreds of private companies operating in the space.[195] The Party's regulations were ostensibly intended to reduce inequality in educational access generally as a part of General Secretary Xi's so-called common prosperity campaign as well as—analysts believe—Party-state efforts to counteract China's demographic decline by making it less expensive for families to raise children.[196] Many, however, view the afterschool tutoring crackdown as off the mark and counterproductive, attacking a mere symptom of the underlying problem, which is the hypercompetitive college entrance system.[197]

Ironically, the crackdown may even be exacerbating the inequality it set out to ameliorate. Middle class Chinese parents complain that in order to secure a future for their child, they must now surreptitiously hire private tutors that are 50 percent more expensive—an expense wealthier families can much more easily afford.[198] Worse, underserved rural areas have seen shutdowns of crucial learning centers that provided online access to learning opportunities that otherwise are not available.[199] The Party-state's intervention has contributed to China's rising youth unemployment while creating unintended side effects that may have made the original problem of inequity in the education system worse.

Economic uncertainty and limited job prospects are nonetheless leading students into suboptimal pathways as the Party-state responds to ward off any potential social unrest. Record numbers of Chinese graduates are opting to either take the civil service exam for a government job or try to pursue additional education.[200] Others, meanwhile, are looking to the safety net of state-owned enterprises (SOEs), with 39 percent of students from China's top-ranked universities stating in 2021 that they most prefer employment at SOEs.[201] In April 2023, Beijing announced an employment promotion campaign that will see central and local levels mobilize SOEs and government offices to hire additional graduates as well as subsidize various firms to hire fresh graduates to limit youth unemployment.[202] In the short run, such efforts threaten to exacerbate inefficient resource allocation issues, when only a consumer-led economic recovery is likely to stimulate aggregate demand and promote employment. Over the long term, the Party-state continues to indicate that it is focused on remediating quality issues, issuing directives, and working with higher education institutions to reform curriculum, improve teacher quality, and promote better integration with industry needs (see Appendix III, "Selected Education System

Guidance Documents since 2019"). Major funding shortfalls at local levels, pervasive incentive problems, ongoing discrimination against rural migrant populations, and increasing resources directed at political indoctrination call into question the efficacy of these long-term reforms.

Vocational Training in China Does Not Teach Transferrable Skills

Central planners intend for China's vocational education system to meet labor market demand for technical skills, but poor learning outcomes prevail across vocational schools, potentially endangering China's advantages in manufacturing. As a result of a lack of coordination between industry and vocational schools, course content is often outdated and out of step with modern production techniques. As wages rise in China, factories are turning to automation and pivoting to higher-value-added stages of production to stay competitive.[203] Without robust technical skills training, however, highly automated factories are struggling to find workers capable of operating advanced equipment.[204] According to a 2020 Peking University study, only 35 percent of students found a job upon graduating from a vocational high school, reflecting the extent of a mismatch between skills and job requirements.[205]

Chinese policymakers are attempting to reform the underdeveloped vocational education system to meet the needs of China's changing economy; however, the problems lie beyond vocational school campuses. In 2020, nine ministries jointly released an action plan to reform the apprenticeship system, which imitates the German apprenticeship system where schools and enterprises have co-equal responsibilities for developing training programs.[206] While some vocational schools have partnered with domestic and foreign multinational enterprises* to improve the quality of their curricula and provide apprenticeships, these partnerships tend to overemphasize techniques specific to those firms; furthermore, these firms seek to deemphasize skills that are potentially transferable to other businesses.[207] As Dr. Rozelle and author Natalie Hell document in their book *Invisible China*, 56 percent of vocational education students spent their internships doing manufacturing work that required no specialized skillset, such as graphic design students who spent their internships assembling smartphones on a factory line.[208]

Even with local governments providing substantial monetary incentives for firms to shift part of their internal training to vocational schools, firms report that establishing these partnerships is highly costly while still generating suboptimal outcomes.[209] Chinese policymakers are nonetheless doubling down on facilitating firm-school linkages to overcome the market failure in training technical skills.

*Foreign multinational companies have participated extensively in developing local apprenticeship and training programs to support their operations in China, often in return for substantial government subsidies. These companies include major carmakers—Germany's VW, the UK's Jaguar-Land Rover, and Japan's Toyota—as well as South Korea's Samsung and the German machine tooling giant Bosch. In total, over 200 companies have developed partnerships with leading vocational schools across China. Asian Development Bank, "Crossing the River by Touching the Stones: Alternative Approaches in Technical and Vocational Education and Training in the People's Republic of China and the Republic of Korea," 2022, 65; Hao Zhang, "An Institutional Dilemma in China's Skills-Development System: Evidence from Two Apprenticeship Reforms," *China Quarterly* 248:1 (2021): 1116–1117, 1120–1121; McKinsey Global Institute, "Reskilling China: Transforming the World's Largest Workforce into Lifelong Learners," 2021, 11.

In pursuing this avenue, China risks a miss-skilled workforce if future technological disruptions render some skillsets obsolete. Further elevating this risk is the fact that schools are not simultaneously emphasizing foundational skills such as math, science, English, and computers, which enable workers to learn new things over a lifetime of employment.[210]

Vocational Education in Semiconductors and AI

China faces talent shortages at every level of the semiconductor and AI industries, but challenges at the vocational level may be as acute as those at the top.[211] When it comes to running semiconductor fabrication facilities, operating manufacturing equipment lines, and undertaking packaging and testing, for instance, higher education qualifications are often unnecessary and some of the largest limitations are in technical and vocational-level talent.[212] In 2016, China's Party-state established the China Vocational Education and Microelectronics Industry Alliance to attempt to resolve shortcomings.[213] The 2020 State Council notice on promoting the integrated circuit and software industry further incentivized a number of vocational and technical schools to set up majors in integrated circuit production to train technicians; it also strove to get buy-in from industry via tax breaks.[214] In AI, meanwhile, as competition shifts toward identifying industrial-level applications, China is trying to shift toward an education approach that blends technical expertise with fluency in AI.[215] In 2017, China's State Council launched the New Generation AI Development Plan, which called for implementing AI training at every level of education.[216] Hundreds of higher vocational colleges responded to the directive by establishing professional AI courses that include training in coding, machine learning, computer vision, and natural language processing.[217] China's AI industry giants have established partnerships with vocational colleges and deployed online training courses.[218] A core issue remains the shortage of qualified teachers. As Ms. Peterson assessed in testimony before the Commission, the massive expansion of AI education "runs the risk that China's centralized push could lead to widespread integration of AI education, but with poorly designed curricula and insufficient instructional resources."[219]

Implications for the United States

The strengths and weaknesses in China's education system have significant implications for China's economic and technological competitiveness with the United States. Overall, the uneven distribution of educational excellence in China, predominantly concentrated in select urban regions, calls into question China's ability to escape the middle-income trap in the medium- to long-term future. Despite China's vast size, the prevailing weaknesses in its education system are inhibiting the development of a skilled labor force necessary for sustained economic advancement. The associated diffusion deficit leaves China's education system struggling to upgrade its economy and cultivate an environment of innovation outside of its metropolitan areas, thus constraining the country's ability to translate technological advancements into employment and broad, productivity-based growth. This systemic weakness could impede China's ability to establish a comprehensive, nationwide knowledge economy and sustain robust economic competition with the United States into the future.

Despite overall systemic limitations, localized pockets of excellence in China have the potential to pose significant challenges for the United States. These can emanate from strategic industries that compete with their counterparts in the U.S. economy or through the creation and application of advanced technologies and weaponry systems. Even a small proportion of high-performing institutions and individuals in China's large population can have a significant global impact. China's government is strategically employing education policies to bolster its industrial policy ambitions in areas like AI and semiconductors, and with sufficient resources such policies may facilitate breakthroughs in targeted domains. Despite overall educational limitations, China's state-led research system could promote integration of research breakthroughs into defense applications, threatening U.S. national security.

Ultimately, there are clear strengths to the U.S. model that China is far from matching. Foremost, these include the education system's ability to train a workforce that can widely and quickly adopt technology, as well as strong ties between education institutions and industry. Challenges from China present opportunities for the United States to maintain and potentially strengthen its competitive position. Despite China's advancements over the past several decades, the United States' broad-based educational capabilities remain far superior.*

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*Such a conclusion is confirmed by the MOE's own think tank, the Chinese Academy of Educational Science. The think tank created an index ranking each country's "educational power," which concluded that the United States ranks first at 0.89, way ahead of second-place UK at 0.76 and 23rd-ranked China at 0.62. Xi specifically cited this ranking during a collective study session in May 2023. *CCTV*, "[Video] During the Fifth Collective Study of the Political Bureau of the Central Committee of the Communist Party of China, Xi Jinping Emphasized Accelerating the Construction of an Educational Powerhouse to Provide Strong Support for the Great Rejuvenation of the Chinese Nation" ([视频]习近平在中共中央政治局第五次集体学习时强调 加快建设教育强国 为中华民族伟大复兴提供有力支撑), May 29, 2023. Translation; China National Academy of Educational Science, *Building an Educational Power by the Research Group of the Chinese Academy of Education: China in the World* (中国教科院课题组 建设教育强国：世界中的中国), May 12, 2023. Translation.

Appendix I: List of China's Talent Programs

Table 4: Programs Related to Talent Attraction, Retention, and Utilization as of 2018

Program	Agency in Charge	Target of the Program	Year Initiated	Number of Researchers Involved
Hundred Talents Program	Chinese Academy of Sciences	Scientists under 45 years old	1994	n.a.
National Science Fund for Distinguished Young Scholars	National Natural Sciences Foundation of China	Academic leaders under 45 years old; frontier sciences and technology	1994	3,454
Chunhui Program	MOE	Chinese expatriates for short-term services	1996	n.a.
Cheung Kong/Changjiang Scholar Program	MOE	Endowed professorships for under 45 years old; extended to 55 years old in social sciences and humanities	1998	2,948
111 Program	MOE and State Administration of Foreign Expert Affairs	1,000 foreign scholars from the top 100 universities and research institutions	2005	n.a.
Thousand Talents Program	Central Leading Group for the Coordination of Talent Work	1,000 academics, corporate executives, and entrepreneurs under 55 years old to return from overseas	2008	n.a.
Young Thousand Talents Program	Central Leading Group for the Coordination of Talent Work	Academics under 40 years old with three plus years of postdoctoral research	2010	3,535
Science Fund for Emerging Distinguished Young Scholars	National Natural Sciences Foundation of China	Researchers under 38 years old to work in academia	2011	2,398
Ten Thousand Talents Program	Central Leading Group for the Coordination of Talent Work	To support high-end talent residing in China	2012	3,454

Table 4: Programs Related to Talent Attraction, Retention, and Utilization as of 2018—*Continued*

Program	Agency in Charge	Target of the Program	Year Initiated	Number of Researchers Involved
New Hundred Talents Program	Chinese Academy of Sciences	Renewal of Hundred Talents Program	2014	n.a.
Young Cheung Kong Scholar Program	MOE	Endowed professorships for young scholars at Chinese universities	2015	440

Source: Cong Cao, “Returning Scientists and the Emergence of China’s Science System,” *Science and Public Policy* 47:2 (2020): 176.

Appendix II: Major Agencies Involved in the State Direction of Research

This appendix looks at the ministries and policy instruments within the Party-state that steer research and teaching activities at China's higher education institutions. Although only a select number of universities are directly administered by the central government, multiple agencies within the Party-state control powerful levers to influence the research decisions of academics and administrators. These mechanisms include conducting grant approvals and research funding, administering the state key laboratories system, and setting high-level guidelines. Aside from the MOE, three organizations, namely China's Ministry of Science and Technology (MOST), the Ministry of Industry and Information Technology (MIIT), and the Chinese Academy of Sciences (CAS), have critical equities and roles in China's higher education ecosystem. MOST is responsible for overseeing basic R&D and has become more focused on this central task following the 2023 Party-state restructuring wherein it became a "leaner but more powerful R&D-focused institution" (see textbox below for more information).[220] Most significantly, MOST is the largest government funder of R&D and also oversees the National Natural Sciences Foundation, which is the major funding agent for research projects in the natural sciences in China.[221] Universities and faculty thus look not only to the MOE but also to MOST to guide and coordinate their research capacities. MIIT, meanwhile, oversees industrial policy implementation and high-technology development zones, which often draw in and facilitate university-industry research collaboration, diffusion, and interconnection with fundamental research and the education ecosystem. MIIT also manages China's most important defense-focused universities, known as the Seven Sons of National Defense. CAS, the largest research institution in China, is responsible for a substantial portion of China's broader innovation and education ecosystem, including running hundreds of research institutes and state key laboratories, which are often co-located with universities, as well as directly overseeing two of China's most prestigious research universities.

Ministry of Science and Technology (MOST)	MOST sets the top-level goals and long-term plans for the entire civilian-focused S&T research system.[222] It also manages China's state-run system of basic and applied science laboratories, and it is responsible for designating laboratories as state key laboratories, which gives a laboratory access to consistent annual funding rather than having to compete for grants.[223] MOST operates the Torch Center, the government agency that creates the infrastructure for China's 173 high-tech industrial development zones and oversees their operation.[224] Over 80 percent of the state key labs are located in these industrial clusters.[225] MOST has shifted its approach to funding science, increasingly focusing on the quality of research over the quantity of research centers. In particular, MOST announced in August 2022 that it will focus support into state key laboratories that are producing research "deemed useful" for the nation and will restructure or withdraw support from those that are not directly supporting its techno-industrial plans.[226]

Ministry of Science and Technology (MOST)—*Continued*	MOST also absorbed the National Natural Science Foundation of China (see below) and the State Administration of Foreign Experts Affairs, giving it direct control over much of the funding for science research and China's talent recruitment policies, respectively.* [227]
National Natural Sciences Foundation of China (NSFC)	The NSFC is the major funding agent for research projects in natural sciences.[228] It evaluates research proposals and awards grant money to researchers at universities and research institutes.[229] In 2021, the NSFC provided $4.8 billion (RMB 30.8 billion) in funding to around 20,000 research projects in basic science, accounting for 16.9 percent of China's total basic research expenditure.[230] In 2017, 64.5 percent of papers published by Chinese researches in journals included in the Science Citations Index noted the NSFC as a funding provider.[231] In 2018, the NSFC was placed directly under MOST, which gives MOST control over 45 percent of the government's funding for R&D.[232]
National Social Science Fund (NSSF)	The NSSF is the main source of funding for social sciences research at Chinese universities.[233] The NSSF is a research funding body under the CCP's Leading Group for Philosophy and Social Sciences that provides grants to research projects in the social sciences.† [234] Through the NSSF, the CCP uses grant funding to control the direction of social science research. Since 2012, NSSF funding has increasingly skewed toward proposals tied to Xi Jinping's ideology or the development of Marxism.[235] In 2022, the NSSF had a budget of $433 million (RMB 2.9 billion) for funding research.[236]
State Administration for Science, Technology, and Industry for National Defense (SASTIND)	SASTIND is an agency under MIIT that sets top-level policies for China's defense-focused innovation ecosystem. SASTIND oversees China's 56 defense S&T key laboratories, which focus on defense R&D.‡ [237] SASTIND also directly administers the Seven Sons of National Defense, a group of universities tied to China's defense industry.§ The agency has also reached agreements with other state agencies, including the Ministry of Education, to jointly supervise 61 additional universities and boost defense-related research activity at those institutions.[238]

*As part of a major restructuring of MOST announced in March 2023, the State Administration of Foreign Expert Affairs will be transferred to China's Ministry of Human Resources and Social Security. For more on MOST's changing role in managing China's industrial policy, see Chapter 3, Section 2, "Fiscal, Financial, and Debt Problems Weigh Down Beijing's Ambitions."

†The NSSF is directly run by the National Office for Philosophy and Social Sciences under the State Council, which handles the daily work of the CCP leading group of the same name. National Office for Philosophy and Social Sciences, *Departmental Budget 2022*, March 2022, 3. Translation.

‡These laboratories are likely comanaged by the CCP's Central Military Commission Equipment Development Department. Alex Stone and Ma Xiu, "The PRC State & Defense Laboratory System: An Overview," *China Aerospace Studies Institute*, April 2022, 1.

§These universities are Beijing Institute of Technology, Beihang University, Harbin Engineering University, Nanjing University of Aeronautics and Astronautics, Nanjing University of Science and Technology, and Northwestern Polytechnical University.

Ministry of Education (MOE)	The MOE oversees the entire higher education system. Its main responsibilities include: • Managing and funding the 75 universities under its direct administration • Administering the *gaokao* • Jointly managing the Double First-Class University program alongside the Ministry of Finance and National Development and Reform Commission • Accrediting degree-granting programs and assessing quality of universities • Publishing guidelines on teaching academic subjects • Approving Sino-foreign joint universities and education programs [239] In addition, the MOE manages 450 MOE key laboratories, 149 of which are also designated as state key laboratories, making it the largest administrator of these laboratories in China.[240]
Chinese Academy of Sciences (CAS)	CAS is the largest research institution in China and is directly under the State Council.[241] In addition to research conducted at its more than 100 institutes, CAS also operates the University of Science and Technology and the University of Chinese Academy of Sciences, two of China's leading research universities.[242] CAS runs 153 key laboratories, many of which are designated state key labs.[243]

Geopolitical Impetus behind 2023 Party-State Restructuring of the Research Ecosystem

China's Party-state is proactively implementing reforms in its S&T institutions to surmount technological limitations and bolster domestic innovation capabilities amid intensifying geopolitical rivalry. As part of the most recent Party and state reorganization in March 2023, the Party-led Central Science and Technology Commission was established, becoming the highest-ranked authority over the entire S&T research ecosystem, surpassing the State Council's National Science and Technology Leading Group, which previously held the top position. The office for this new S&T commission will be housed within MOST, greatly increasing the ministry's bureaucratic sway. At the same time, however, MOST had substantial responsibilities removed from it and distributed to other agencies. This is apparently intended to increase the ministries' role in macro-level direction rather than micro-level implementation. State Councilor Xiao Jie said that restructuring MOST was specifically motivated by the "severe situation" of "international technology competition, containment, and suppression."[244] There also appears to be a comprehensive effort underway to distinguish basic science and research from applied industrial policy and commercialization. The most notable bureaucratic change involves transferring MOST's responsibilities for high-tech development zones to MIIT.[245] Likewise, while then Vice Premier Liu He previously oversaw both industrial policy and S&T, these responsibilities have now been divided between Premier Li Qiang and a vice premier. Premier Li will be responsible for a basic research portfolio that includes education, science, and technology issues, while the vice premier will be responsible for industrial policy, market reform, and state-owned enterprises.[246]

Appendix III: Selected Education System Guidance Documents since 2019

These top-level documents provide guidance to the rest of the Party-state system. These documents are akin to "wish lists" that are aspirational and broad. Nonetheless, they point to areas wherein the Party-state perceives weaknesses in its educational system.

State Council and Central Committee (2019): "China's Educational Modernization 2035."[247] This is the highest-level guidance document on China's education system produced by the Party-state. The document emphasizes being both "red and expert,"* but overall it evinces an understanding of the key challenges facing China's education system.

Overarching Priorities:

- (1) Thoroughly study and implement Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era, (2) develop high-quality education with Chinese characteristics to the world's leading edge, (3) promote the popularization of high-level and high-quality education at all levels (e.g., provide quality preschool, compulsory, high school; improve vocational capabilities), (4) realize the equalization of basic public education services, (5) build a lifelong learning system for all, (6) enhance the cultivation and innovation capabilities of first-class talents (e.g., significantly improve the competitiveness of higher education), (7) build a team of high-quality professional and innovative teachers, (8) accelerate the reform of education in the information age, (9) create a new pattern of opening up education internationally, and (10) promote the modernization and enhance the capabilities of the education governance system.

14th Five-Year Plan Outline (2020):[248] This document provides shorter-term overarching guidance based on the Party's recognition of ambitions and challenges, per the 2035 outline above.

Overarching Priorities:

- "Construct a high-quality education system": (1) promote equitable basic public education, (2) enhance the adaptability of vocational and technical education, (3) increase the quality of higher education, (4) build teams of high-quality professional teachers, and (5) deepen education reform (i.e., focus on quality and create evaluation systems).
- "Advancing socialist culture": (1) promote Xi Jinping Thought and (2) develop philosophy and social sciences with Chinese characteristics.

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* In 1963, the CCP introduced the "red and expert" policy to control access to higher education, requiring that applicants excel in both technocratic and ideological elements. "Red and expert" has reemerged in higher education in recent years as universities incorporate Xi Jinping Thought into their curricula. University Heidelberg, "Red and Expert—Negotiating Academic Freedom in China," October 28, 2022.

Selected Specific Goals (these goals speak to the increasing recognition, at the highest levels of the Party, of vocational education's importance):

- Enhance the adaptability of vocational and technical education ... deepen the integration of production and education and school-enterprise cooperation, encourage enterprises to conduct high-quality vocational and technical education, and explore an apprenticeship system with Chinese characteristics ... build a number of high-level vocational technical colleges and majors, and steadily develop vocational undergraduate education ... support high-level engineering universities in organizing vocational and technical teaching majors and establish a mechanism for the joint training of "double-qualified" (i.e., academic and business qualifications) teachers by colleges and universities, vocational schools, and industry enterprises.
- Accelerate the training of talents in higher education that are in short supply: science, engineering, agriculture, and medical majors.
- Increase the gross enrollment rate of higher education to 60 percent ... increase the gross enrollment rate in high school education to 92 percent or higher ... increase the gross enrollment rate in preschool education to over 90 percent.

Ministry of Education 14th Five-Year Plan (2021): "Implementation Plan for Promoting an Educational Powerhouse during the 14th Five-Year Plan Period."[249] This document was produced following the outline of the 14th Five-Year Plan document.

Overarching Priorities:

- (1) Consolidate the achievements of basic education in poverty alleviation, (2) integrate production and education in vocational education, and (3) develop well-rounded higher education.

Selected Specific Goals:

- Accelerate the construction of "double first-class" universities and majors and vigorously strengthen disciplines and majors in urgently needed fields ... significantly improve the ability to cultivate talents, and speed up the cracking of the "stranglehold" over key core technologies. In key fields such as integrated circuit and energy storage technology, a number of national industry-education integration innovation platforms will be constructed; build a joint training base for graduate students with industry-education integration.
- In terms of specific project planning and arrangement, priority should be given to the construction of teaching and scientific research facilities for integrated circuits, AI, energy storage technology, quantum technology, high-end equipment, smart manufacturing, biotechnology, medical research, digital economy (including blockchain), and other related disciplines.

General Office of the CCP's Central Committee (2021): Opinions on Promoting the High-Quality Development of Modern Vocational Education.[250] This document further outlines the growing recognition the Party places on vocational education.

Overarching Priorities:

- By 2025, establish a "modern vocational education system"; by 2035, ensure the overall level of vocational education is at the forefront of the world.
- Enhance the adaptability of vocational education; build a skill-based society; cultivate more high-quality technical and skilled personnel to "comprehensively construct a modern socialist country."

Selected Specific Goals:

- Better integrate production and education, giving priority to the development of strategic emerging industries such as advanced manufacturing, new energy, new materials, modern agriculture, modern information technology, biotechnology, and AI.
- For vocational schools, work with leading enterprises to participate deeply in vocational education professional planning, curriculum setting, teaching material development, teaching design, and teaching implementation and cooperate to build new majors and develop new courses; implement financing, land, credit, and tax policies to enterprises integrating production and education; and accelerate the establishment of the "vocational education college entrance examination" system.
- Comprehensively improve the quality of teachers; design and develop courses according to actual production and job needs; update the teaching standards in a timely manner; and incorporate new technologies, new processes, new norms, and typical production cases into the teaching content in a timely manner.
- Explore the international development model of "Chinese + vocational skills" and promote vocational schools to follow Chinese companies to go out; actively create a number of high-level international vocational schools; and launch a number of internationally influential professional standards, curriculum standards, and teaching resources.

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