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China’s Endless Frontier: “Organized Scientific Research” and the Quest for Technological Self-Reliance

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Summary

Chinese President Xi Jinping has advocated for scientific and technological self-reliance amid increasing global tensions over emerging technologies. So far though, reforms to China’s innovation ecosystem have fallen short of the goal of developing domestic versions of many of the technologies at the center of U.S.-China competition. The Ministry of Education’s new program called “organized scientific research” seeks to address this shortcoming. In so doing, the ministry aims to channel research resources toward strategically relevant sectors—especially in technologies susceptible to U.S. restrictions—while maintaining space for free scientific exploration.

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Key Findings

- “Organized scientific research” is a catch-all term to describe the Ministry of Education’s advocacy for more basic scientific research funding and greater alignment of universities’ scientific work with China’s national strategic priorities. This includes focusing resources on supply chain-relevant innovations such as advanced semiconductors.
- The Ministry of Education (MOE) commands China’s largest ministerial budget, which covers a host of critical expenses for scientific research such as salaries for talent program recruits. MOE directly oversees 65 of China’s top universities engaged in scientific research.
- To achieve technological self-sufficiency, MOE has developed specific initiatives. Some target the general conditions for innovation in China. Others look to make breakthroughs in “key and core technologies” deemed crucial for China’s industrial development.
- In 2019, MOE launched a new program to organize research on “chokepoint technologies" key to supply chain security. Through “integrated research platforms” based at Chinese universities, researchers work in high-priority sectors including those now subject to U.S. export controls. Organized scientific research shapes this work by breaking down larger problems into smaller projects, using team-based approaches that pool expertise across different disciplines.
- Since 2019, MOE has increased the number of its engineering research centers, a program dating back to the early 1990s to reverse-engineer imported technologies. The program now focuses on indigenous innovation to replace technologies such as advanced semiconductors materials susceptible to foreign restrictions.

Introduction

In a speech delivered at the third study session of the politburo in February 2023, Chinese President Xi Jinping highlighted the importance of boosting domestically produced basic scientific research and reaching "high-level scientific and technological self-reliance" in order to prevail in an ongoing global competition over science and technology.[1] Since then, the most publicly visible reforms to China's innovation system have been to the Ministry of Science and Technology (MOST), which has been largely stripped of its administrative functions while its offices were subsumed by a powerful new Central Science and Technology Commission (CSTC).[2]

However, other ministries are also pitching in. The Ministry of Education (MOE) one year earlier published its vision for self-reliance in a document called "Opinions on Strengthening Organized Scientific Research in Higher Education to Promote High-Level Self-Reliance and Self-Strengthening" (see Figure 2). It states that institutions of higher education are important components of China's "strategic scientific and technological strength."

Several problems plague China's innovation system, including—according to the Chinese Communist Party (CCP)—that it has done too little to address "national needs." Those needs include developing domestic versions of technologies at the center of U.S.-China competition, ranging from high-end microchips to gas turbines in airplanes.

The Ministry of Education's answer to these challenges is something called "organized scientific research" (有组织科研). This concept is meant to channel science toward "national and regional strategic needs" by addressing the "pressing problems faced by national security as well as economic and social development."[3] Despite this ambition, the MOE's document explicitly highlights the importance of continued "free exploration" of science, alluding to a tension between state needs and the imperatives of the research community in China.

Photo: Humphery, Shutterstock

In the policymaking process of the People's Republic of China (PRC), opinions lack the force of legal reforms. Instead, they outline the broad activities or strategies a government entity should undertake. These are often translated into more specific plans or regulations. While the MOE opinions did not trigger major bureaucratic changes like the MOST reforms of March 2023, this document is nevertheless critical for understanding the direction of Chinese innovation policy because it lays out self-reliance strategies for some of China's most critical innovation actors—its universities. While the MOST reforms codified into law a focused policy planning role, the 2022 MOE opinions serve to shape the ministry's role in implementing innovation.

The Importance of the Ministry of Education to Chinese Innovation

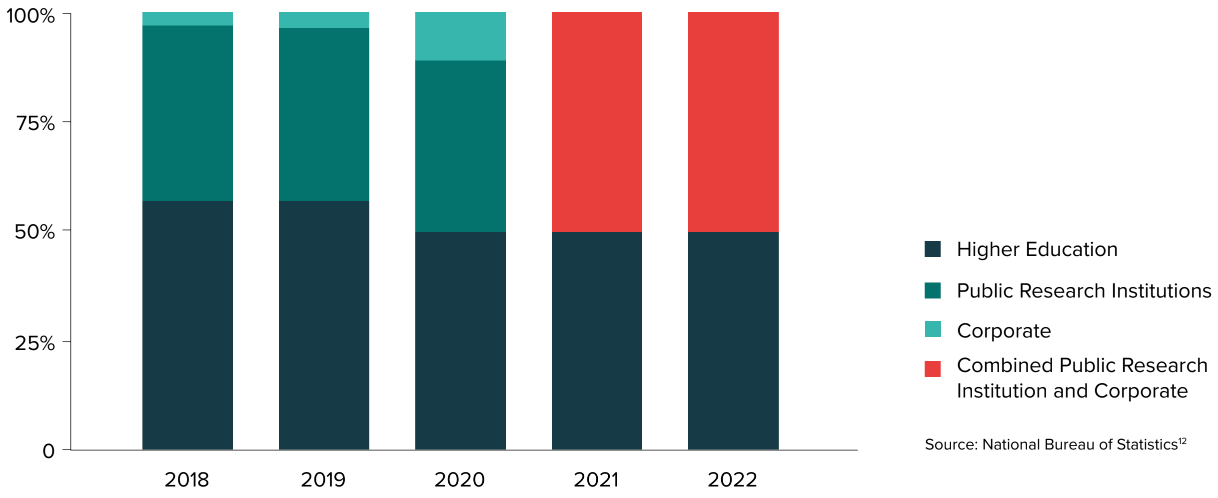
The Ministry of Education's vast resources are central to realizing President Xi's vision of technological self-reliance. China's MOE commands the country's largest ministerial budget.[4] Its 2023 expenditures on higher education alone totaled 403 billion yuan ($211 billion), dwarfing the annual budgets of MOST and the Chinese Academy of Sciences (CAS).[5] While that number covers non-technical subjects such as political science, the education budget covers a host of critical expenses for scientific research such as salaries for talent program recruits.[6]

The Ministry of Education directly oversees 76 universities, 65 of which are engaged in science and technology, including China's most prestigious research universities such as Tsinghua University and Peking University.[7,8] Over the past several years, the budgets of these top research universities have ballooned.[9] For instance, Tsinghua University's annual operating budget grew from 26.9 billion yuan ($14.1 billion USD) in 2018 to 41.1 billion yuan ($21.5 billion) in 2023, a 52 percent increase.[10] These institutions also house the ministry's key labs, research groups with special MOE funding, and two research and development (R&D) programs—the integrated research platform and the engineering research center—which focus on developing supply chain-relevant "chokepoint" technologies. Supply chain stability is central to China's self-reliance drive, and these two programs are critical for understanding China's science and technology policy.

Institutions of higher learning are the country's most important players in basic research. Over the past five years, the higher education sector deployed about 50 percent of the country's basic research funds. Public research institutions came in second, while corporations deployed the smallest fraction of basic science funding. However, as of 2020, private sector basic science funding is now the fastest growing sector in this field. A 2021 note from the National Bureau of Statistics credits recent reforms, including generous tax deductions, for this increase in corporate-funded basic research.[11] Despite this, higher education remains the biggest and most important actor in basic science in China (see Figure 1).

FIGURE 1

China's Distribution of Basic Research Funding by Sector



Source: National Bureau of Statistics[12]

Organized Scientific Research in China's Drive for Technological Self-Reliance

MOE opinions have institutionalized a new term—organized scientific research—that first circulated in specialized scholarly debates at least a year prior to the release of the opinions.[13] This concept conveys a unique MOE contribution to the country's self-sufficiency drive. It generated a broad debate within China's higher education community including commentary by renowned scientists, respected innovation experts, and university presidents, each attempting to give meaning to the term.[14] Universities also proceeded to organize workshops to discuss the term's implications for their work.[15] Recognizing the term's importance, President Xi in his 2023 speech noted that "basic science was becoming more organized."[16]

In proposing and analyzing "organized scientific research," several Chinese experts reference a U.S. report entitled *Science: The Endless Frontier*. It was prepared in 1945 by Vannevar Bush, a former dean of the Massachusetts Institute of Technology School of Engineering, upon request from President Franklin Roosevelt who asked for advice on how the United States should reconfigure its post-World War II scientific enterprise.[17] The report's central recommendation was that the U.S. federal government direct research funds toward U.S. universities. The White House then created an independent agency called the National Science Foundation (NSF) to disperse these funds. The outcome was remarkable—the U.S. government lifted the country's still emerging research universities to the forefront of global science.

BOX 1

An Official Take on the Meaning of "Organized Scientific Research"

An official explanation of organized scientific research was provided by Lei Chaozi, director of the MOE Department of Science, Technology, and Information Technology, in an article that appeared in a 2023 edition of China Higher Education, a journal overseen by the ministry.[18] As is typical in CCP discourse, the essay clusters issues and goals into triplets and quadruplets.

Lei names three areas requiring "integration," including the need to connect scientific and national strength, boosting double-class universities, and shifting toward multidisciplinary and problem-oriented work. Lei argues that China's innovation system needs to undergo "four transformations." Researchers should take greater initiative and stop fixating on credentialism, says Lei, and China's science and technology (S&T) platforms—such as its labs and centers—have grown unchecked, misaligning resource distribution with policy needs. He also named "four aspects" that are important for China's future S&T progress, including the need to solve original problems, develop "chokepoint technologies," and support regional initiatives, such as in the region around the cities of Chengdu and Chongqing, and boosting domestic industry.

He concluded by outlining "three challenges" for China's scientific enterprise. Lei laments the inadequate monitoring of work in key and core technologies, and that many research teams in China are not really working as teams but instead act like "straddlers and disbanded soldiers." Finally, Lei argues that that research teams needed to become "combat ready," and claims researchers are not bold enough and prefer to be big fish in a small pond rather than small fish in a big pond.

In referencing the *Endless Frontier* report, Chinese experts make two broad arguments. First, that China can claim global leadership in science and technology by investing in basic research in its universities. Second, that the Chinese research community should embrace the realignment of scientific work with national goals. Both are critical to the country prevailing in an ongoing international competition over technology, in particular with the United States.

In 2023, two science policy scholars at Renmin University wrote that over the past several years the U.S. science policy community went through a period of reflection, including on the legacy of Bush's report. The result was the creation of the Directorate for Technology, Innovation, and Partnerships, a new NSF office that increases government funding for translating basic science into marketable technologies. In creating the directorate, the United States expanded the role of "organized scientific research," the authors argue. China, they write, should proceed in a similar direction by focusing research in key areas, embracing the government's role in coordinating science, emphasizing "application-oriented basic research," and supporting China's top research universities.[19,20]

The influence of organized scientific research will likely stay confined to Chinese universities. That is because the MOE oversees only university-based research, and not research based at state-owned enterprises or private companies. Furthermore, MOE has significantly less power than the newly established Central Science and Technology Commission in shaping national science and technology policy and will struggle to propagate its ideas beyond its purview without the endorsement of the commission.[21,22]

Photo: Humphery, Shutterstock.com

However, the debate over the importance of basic science is likely already settled. Xi Jinping dedicated an entire politburo speech to the matter in February 2023. Vannevar Bush's work is now likely being deployed to advocate for MOE's position in a marketplace of actors within the Chinese system, where different ministries are competing for central government funds.

Because of the ministry's vast resources, the centrality of universities to innovation, the list of self-reliance activities—especially those focused on chokepoint technologies—and the rallying call around "organized scientific research," the MOE deserves special attention from those interested in understanding China's self-reliance drive.

BOX 2

The Legacy of Vannevar Bush in Global Science Policy Discourse

Vannevar Bush's 1945 report *Science: The Endless Frontier* has had an enduring impact on science policy discourse worldwide. It is often referenced when science is experiencing political headwinds, as was the case when the report was first written. Bush led the charge to reorganize American science toward military applications during World War II. Once the war concluded, he then advocated for basic science funding to go toward universities.[23]

In 2020, NSF republished Bush's seminal report on its 75th anniversary.[24] At the time, the U.S. Congress would soon enter tense negotiations over U.S. innovation. One proposal, the Endless Frontier Act, was repackaged into the CHIPS and Science Act. "NSF's mandate was designed from the first moment to serve the national interest," France A. Córdova, the agency's director, wrote in her commemoration letter.[25] The *Endless Frontier* was used in both the United States and China to advocate for increased science funding.

Bush left a mark on European science debates as well. His work influenced the European Commission's 2005 expert group report *Frontier Research: The European Challenge*.[26] In the lead up to it, the Commission acknowledged Bush's role in setting up a funding mechanism that would largely allow researchers to choose their own areas of work, which benefited industry further down the line. As a result, the European Union set up—for the first time—a basic science funding scheme.[27]

General and Sectoral Self-Reliance

To contribute to technological self-sufficiency, MOE opinions have identified nine overarching measures or goals and specific initiatives to accomplish them (see Figure 2).

Some of these initiatives target the general conditions for innovation in China. One such example is China's "double first-class construction" (双一流建设) plan launched in 2015 (see Figure 2, Goal 1, Initiative a) to shape China's best universities into world-leading ones.[28] Others, such as a high-level policy issued by China's State Council, focus on improving the general "atmosphere" and work culture of the scientific enterprise (see Figure 2, Goal 9).[29]

MOE's initiatives strive for academic excellence and resemble what UC San Diego professor Barry Naughton describes as policies that seek to improve "the overall innovation environment, rather than any specific sector."[30] Such programs aim at general—rather than sector-specific—self-reliance.

Meanwhile, other programs are aimed at making breakthroughs in what the Chinese government calls "key and core technologies," a loosely defined group of products that PRC leadership believes it needs to develop and produce domestically. These technologies include chokepoint technologies deemed critical for China's supply chain security. The programs involve specific technologies or industries and aim at sectoral self-reliance.

Addressing a conference of scientists in 2018, President Xi declared that "past experience has shown us over and over again that we cannot expect to acquire critical and core technologies through requests, purchase, or begging."[31] The message was clear; Chinese researchers must find ways to make critical technologies at home.

Already a month before the release of the MOE opinions, the ministry launched a detailed initiative called the "Thousand Schools, Ten Thousand Companies" to help develop critical technologies domestically. It sets out goals to create 30 integrated research platforms (IRPs)—a new program—and 100 additional engineering research centers (ERCs), a pre-existing program.[32]

A key aim of the initiative is to deepen integration of industry, academia, and research institutes (产学研) in order to develop "key and core technologies and common technologies" without which "industrial development is restricted." If official statements are any indication, the program seems to be making headway. According to Lei Xiaoyun, director of the Intellectual Property Utilization Promotion Department of the State Intellectual Property Office, as of June 2023, 1,500 patent holders—among them 600 different universities—had been matched with 76,000 companies.[33]

FIGURE 2

Measures and Initiatives of the "Opinions on Strengthening Organized Scientific Research in Higher Education to Promote High-Level Self-Reliance and Self-Strengthening"

Goal	Initiatives to achieve goal
1. Reinforce the construction of national strategic scientific and technological power	a. Push forward the "double first-class universities" b. Speed up reorganization of key state laboratories c. National technology innovation centers d. National engineering research centers e. National and regional laboratories
2. Speed up major breakthroughs in goal-oriented basic research	a. Study the establishment of basic and cross-disciplinary research projects b. Pharmaceutical basic research innovation centers c. Everest Program for Basic Research in Higher Education
3. Speed up major breakthroughs in key and core technologies of urgent national strategic need	a. Implement the "cultivation plan for major projects organized to tackle key problems" through the construction of an integrated research platform b. Implement the "Thousand Schools, Ten Thousand Companies" plan, including the establishment of more engineering research centers
4. Improve the ability to commercialize scientific and technological achievements to serve industrial transformation and upgrading	a. "Hundred Schools, Thousand Patents" plan b. National intellectual property pilot demonstration in higher education institutions c. "Hundred Schools, Thousand Cities" plan d. National university science and technology parks e. Pilot future industry, science, and technology parks

FIGURE 2, CONTINUED

Measures and Initiatives of the "Opinions on Strengthening Organized Scientific Research in Higher Education to Promote High-Level Self-Reliance and Self-Strengthening"

Goal	Initiatives to achieve goal
5. Raise the collaborative innovation capabilities of regional higher learning institutions to serve high-quality regional development	a. Cooperation agreements between MOE and subnational governments b. Make full use of key provinces and nodal cities in promoting innovation c. Strengthen MOE innovation platforms and high-level scientific research organizations
6. Promote the establishment of a high-level workforce in order to build expertise of strategic importance	a. Implement major scientific and technological tasks and projects b. Actively recruit postdoctoral fellows to participate in key tasks c. Promote outstanding young talent programs
7. Promote the of integration of science and education as well as coordination between industry and education to cultivate high-quality innovative talent	a. Identify a batch of national science and education collaborative innovation platforms b. Cultivate top students in basic science disciplines c. Implement special plan for the cultivation of high-level talent of urgent national need d. Create a layout of academic disciplines and doctoral programs within the establishment of "double first-class" universities
8. Promote high-level international collaboration	a. Establish a batch of first-class international joint laboratories and other platforms b. Launch big international science research plans and projects c. Implement Belt and Road Science, Technology, and Innovation (STI) Cooperation Action Plan
9. Promote reforms of the scientific evaluation system to create a favorable innovation environment	a. Improve the dynamic monitoring system for the establishment of "double first-class" universities b. Guide universities to proactively connect with the national strategic layout c. Enhance national capabilities to support major scientific and technological tasks d. Promote a dedication to the scientific spirit and establish an academic and work style

Source: Ministry of Education[34]

Integrated Research Platforms for Chokepoint Technologies

In 2019, MOE launched the new IRP program to organize research on chokepoint technologies.[35] The author was able to identify 30 new IRPs (集成攻关大平台), confirming that the goal laid out in "Thousand Schools, Ten Thousand Companies" has been reached. All are based at Chinese universities and work in high-priority sectors such as high-end chips currently subject to U.S. export controls.[36]

An illustrative example of an IRP focused on chokepoint technologies is the "Integrated Research Platform for New Generation Integrated Circuit Technology" (新一代集成电路技术集成攻关大平台) at Fudan University. Fudan University has a history working on microelectronics and this group now appears focused on developing advanced chip fabrication processes at three-to-five nanometer (nm) nodes.[37] In fall 2023, Fudan University released two job postings. One role entails work on non-planar three-dimensional transistors—the so-called fin field-effect transistor (FinFET) and gate-all-around field-effect transistor (GAAFET)—advanced semiconductor systems which amplify or switch electrical signals and allow for lower power consumption and higher chip performance.[38]

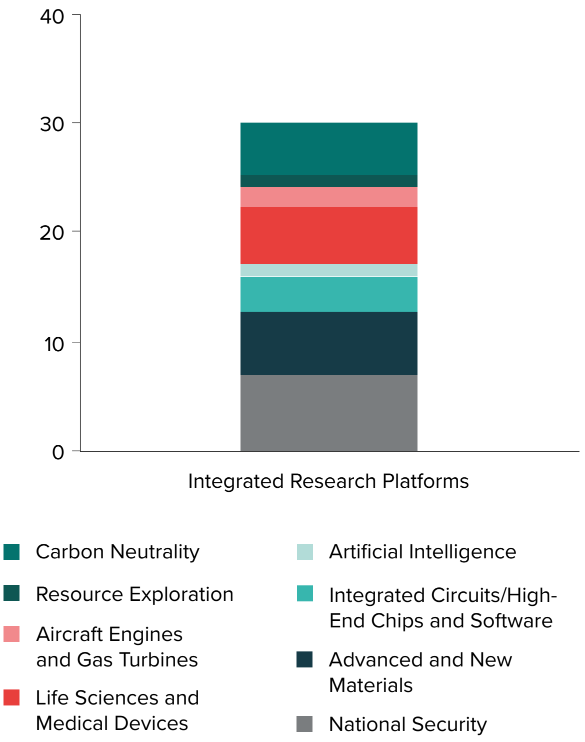
The roles describe chip feature sizes that are well below the 14 nm threshold the U.S. Department of Commerce export controls targeted in October 2022. Work at Fudan University in this area, however, predates the implementation of these controls. The university has been recruiting research associates to work on 3-5 nm process chips for its integrated research platform since at least March 2021.[39] This suggests that the Chinese government deployed research resources to degrading the U.S. chokehold well before restrictions were ever imposed.

Organized scientific research shapes the work of universities by breaking down larger problems into smaller projects, some of which require expertise across different disciplines. Such an effort is team-based and relies on recruiting relevant talent.[40]

A good illustration of this approach is Shandong University's "Integrated Research Platform for New-Generation of Semiconductor Materials" (新一代半导体材料集成攻关大平台).[41] This platform is divided into at least six teams, each focusing on a different material with applications in microchip technology. The platform also receives input from an academic committee and a board composed of industry leaders.[42] One corporate partner claimed that working with Shandong University's integrated research platform allowed the company to tap into the university's technical talent—talent that was otherwise in short supply.

FIGURE 3

Integrated Research Platforms of the Ministry of Education



Source: The author, using various university, party, association, and government websites[43]

Increasing the Number of Engineering Research Centers

Starting in 2019, the MOE began to dramatically increase the number engineering research centers (ERCs), a program dating back to the early 1990s. Originally launched to reverse-engineer technologies imported from abroad, the program is being repurposed to focus on indigenous innovation of key technologies.[44]

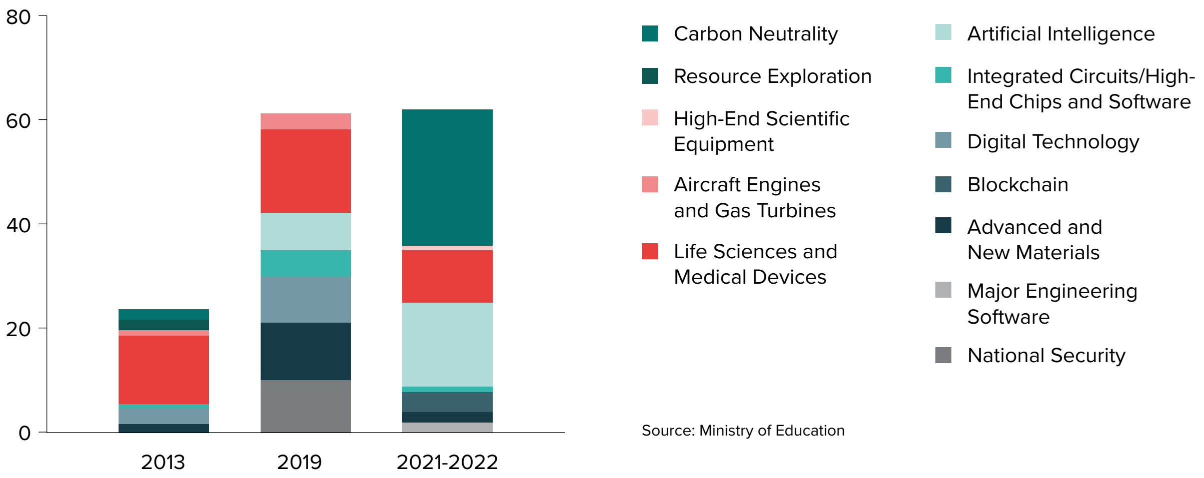
While MOE-ERCs do not have explicit instructions to work on chokepoints, their work overlaps considerably with that mandate and many centers advertise their contributions to chokepoint technologies on their websites. MOE issued calls for applications to the engineering research center program in 2019 with a "basic requirement" that applicants work in the areas of "national security, artificial intelligence, advanced materials, digital technology, high-end chips and software, aircraft engines and gas turbines, and life science and technology" (see Annex A).[45] These areas overlap considerably with China's list of chokepoint technologies.[46] A call for applications to receive MOE-ERC status in 2021 continued the focus on chokepoints by requiring grantees work in similar technologies (see Annex A).[47] Over the course of two batches—in 2019 and again in 2021—MOE added about 120 new research centers, comfortably ahead of its goal of 100. Many of them have already started work. That brings the total number of centers well beyond the government-recorded number of 488.[48]

The MOE responded to China's sudden need for high-end chip technology. Compared to the batch of ERCs established in 2018—prior to heightened U.S.-China tech competition—at least five of the ERCs created in the 2019 batch work on high-end chip-related technologies (see Figure 4). Again, China was already deploying resources toward alleviating the U.S. semiconductor chokehold before the first export controls in October 2022 (see Annex A).

One chip-focused center is the MOE-ERC for Technologies for the Preparation of High-Purity Chemicals for Use in the Manufacture of Integrated Circuits (集成电路高纯化学品制备技术教育部工程研究中心) approved in the 2021-22 batch. The center co-organized the first-ever "Conference on the Development of the High-Purity Chemicals Industry," which explored how China can develop homegrown expertise to develop downstream materials for chipmaking.[49] These chemicals are critical inputs that other countries may exploit. In April of 2023, news broke that the German government was contemplating export restrictions to China of such chemicals.[50]

FIGURE 4

MOE Engineering Research Centers: Batches 2013, 2019 and 2021-22



Source: Ministry of Education

Policy Implications

China's policy of organized scientific research seeks to channel science as a source of national power. Much like in the United States, China's policymakers have embarked on a period of reflection on the role of science in developing national power. Both Chinese and American science policy experts draw on the seminal work *Science: The Endless Frontier* to inform their debates.

To enhance China's innovation ecosystem, the Chinese Ministry of Education has begun advocating for basic research. The ministry institutionalized organized scientific research into its policymaking process. This term is being used by the wider Chinese higher education community to highlight the importance of basic scientific research and advocate for greater alignment with national and strategic priorities.

The government is strengthening incentives for institutions of higher learning to assist its efforts to boost innovation. In what the PRC government refers to as a "whole-of-nation" effort, every ministry or agency in China is called upon to contribute to technological self-reliance. The Ministry of Education's special role is to facilitate the participation of universities and other institutions of higher learning in this nationwide program.

The government's efforts aim to drive both general and sectoral self-reliance. The MOE's 2022 opinions compile a host of preexisting and newly initiated programs that aim to improve the general conditions for innovation and focus resources on specific technology sectors.

China's innovation drive is launching new platforms and leveraging existing programs. MOE is channeling R&D resources into chokepoint technologies by launching new programs such as the integrated research platform—started in 2019—and enlarging legacy programs such as engineering research centers, which were created in the 1990s.

The PRC is using these programs to break down barriers between disciplines by bringing together different basic science and engineering talent teams. It is also promoting collaboration between universities and companies. In doing so, Beijing hopes to facilitate commercialization and overcome technical challenges. According to government-reported statistics, MOE has been able to improve university-led technology transfer.

Conclusion

China's Ministry of Education plays a critical role in the country's technological self-reliance drive. Two programs—the integrated research platform and the engineering research center—aim at focusing institutional capacity, talent, and other resources on a narrow set of technologies important for Chinese supply chain security. In order to facilitate this shift, the Chinese Ministry of Education launched a program called organized scientific research that sets out to realign higher education resources and activities toward self-reliance.

China's program of organized scientific research promises to reshape the country's innovation system. If successful, the impact of these programs will be that a larger proportion of university-based research in China will be dedicated to strategically relevant—in particular supply chain-relevant—innovations such as in the advanced semiconductor space.

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Annex A: Technology buckets for the three most recent batches of MOE-ERCs

2010/2013 Batch	2019 Batch	2021/2022 Batch
Medical and health information networks	National security	Integrated circuits
Electronic medical records and intelligent expert system	Artificial intelligence	Artificial intelligence (basic and cutting-edge technologies such as key algorithms)
Mobile digital medical system	Advanced materials	Blockchain
Cardiovascular and cerebrovascular disease treatment technology and equipment	Digital technology	High-end scientific instruments
Eye disease diagnosis and treatment technology equipment	High-end chips and software	Medical devices
Oral therapy technology and materials	Aircraft engines and gas turbines	Major engineering software
Biomedical digital imaging	Life sciences	Rare earth-based new materials
Energy saving and resource utilization of elastomer materials		Carbon neutrality (carbon zero and carbon negative emission technologies)
Exploration and evaluation of metal mineral resources		Drug and vaccine development
Petroleum biotechnology and bio-oil recovery		
Energy-saving and efficiency-increasing intelligent technology and equipment		
Creative and design digital media		

Source: MOE[51]

Endnotes

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4. At least among those budgets made public. The Ministry of National Defense's budget may be larger still, but it is not public. See Ryan Fedasiuk, Emily Weinstein, Ben Murphy, and Alan Omar Loera Martinez, "Chinese State Council Budget Tracker," Center for Security and Emerging Technology (CSET), https://statecouncil.cset.tech/, accessed February 4, 2024.

5. "教育部 2023 年部门预算, (Department of Education 2023 Departmental Budget)," MOE, http://www.moe.gov.cn/srcsite/A05/s7499/202303/W020230328543247647092.pdf, accessed February 4, 2024 (archived: https://web.archive.org/web/20240219180350/http:/www.moe.gov.cn/srcsite/A05/s7499/202303/W020230328543247647092.pdf). While higher education expenses (budget code 2050205) by MOE far exceed that of MOST or CAS, MOE's S&T expenditures (budget code 206) are about 10 times smaller than that of MOST and 20 times smaller than CAS. However, S&T expenditures alone do not capture the full scope of research-related expenses.

6. Fedasiuk, Weinstein, Murphy, and Loera Martinez, "Chinese State Council Budget Tracker," CSET, https://statecouncil.cset.tech/, accessed February 4, 2024.

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