Analysis of International Policy Trends in Basic Research and Implications: Postprint

Authors: Huang Minzhuo, Wu Jinglei, Ren Zhen, Meng Qingfeng

Date: 2024-03-27T00:00:00+00:00

Abstract

International competition in science and technology is growing increasingly fierce, and basic research has become a critical battleground for strategic contest. Major countries worldwide are evaluating the connotation of basic research in the new era and its repositioning within the national innovation system, while continuously exploring new funding models. Through monitoring and analyzing the latest policy developments in foreign basic research in 2022, and based on policy analysis and data mining, this article conducts a preliminary assessment of basic research policy trends and future directions in major countries, aiming to provide references for relevant departments and institutions in formulating science and technology policies for basic research.

Full Text

Analysis and Enlightenment of International Policy Trends in Basic Research

Citation: Huang M Z, Wu J L, Ren Z, et al. Analysis and enlightenment of international policy trends in basic research. *Bulletin of Chinese Academy of Sciences*, 2024, 39(1): 176-187, doi: 10.16418/j.issn.1000-3045.20230504002. (in Chinese)

Authors: Huang Minzhuo[1,2], Wu Jinglei[2], Ren Zhen[3,4], Meng Qingfeng[2*]

[1] Sir Run Run Shaw Hospital, Zhejiang University School of Medicine, Hangzhou 310016, China
[2] Bureau of Planning and Policy, National Natural Science Foundation of China, Beijing 100085, China
[3] National Science Library, Chinese Academy of Sciences, Beijing 100190, China
[4] School of Economics and Management, University of Chinese Academy of Sciences, Beijing 100049, China

Abstract

As international competition in science and technology intensifies, basic research has become a critical arena for strategic competition among nations. Major countries worldwide are reassessing the connotation of basic research in the new era and its repositioning within national innovation systems, while continuously exploring new funding models. This study monitors and analyzes the latest policy developments in foreign basic research from 2022, and based on policy analysis and data mining, provides a preliminary assessment of the policy trends and future directions in major countries. The aim is to offer valuable references for relevant departments and institutions in formulating basic research policies.

Keywords: basic research, science and technology policy, basic research personnel, international science and technology cooperation, innovation culture

DOI: 10.16418/j.issn.1000-3045.20230504002

1. Data Sources and Research Methods

This study addresses the policy research needs of basic research by first identifying major developed countries for tracking, including the United States, United Kingdom, Germany, France, Switzerland, Sweden, Japan, and South Korea. Second, we established a monitoring framework centered on scientific funding agencies that support basic research in these countries, focusing on national science and technology development strategies and R&D plans, funding agency development strategies, institutional reforms, research evaluation, research integrity, and international cooperation. We systematically reviewed policy developments in basic research for 2022, while also examining relevant policy perspectives from government departments from a national innovation system perspective. Additionally, we supplemented our analysis by summarizing policies, initiatives, and commentaries from representative think tanks, research institutions, international organizations, civil society groups, enterprises, and news media, tracking over 100 official websites. For the United States, monitoring focused primarily on three funding agencies—the National Science Board (NSB), National Science Foundation (NSF), and National Institutes of Health (NIH)—while also covering six government departments including the Government Accountability Office (GAO) and Congress, 11 think tanks such as the RAND Corporation, five civil society organizations including the American Association for the Advancement of Science, and two companies (IBM and Google) as supplementary references. The monitoring and analysis framework for international basic research policy trends is illustrated in [Figure 1: see original paper].

2. Policy Dynamics in Major Countries and Regions

North America, Europe, and Asia represent the core regions of global scientific and technological innovation. Comparative analysis of basic research policy dynamics across these three regions helps identify common concerns and unique policy measures, thereby revealing international policy trends. Overall, the countries and regions studied are continuously increasing investment in basic research and attaching greater importance to its role in addressing future challenges and empowering scientific innovation and economic growth. Moreover, by comparing national science and technology development plans and strategies, we find convergence in R&D deployment and investment in key areas critical to national competitiveness, such as artificial intelligence, quantum information, clean energy, digital transformation, semiconductors, and biotechnology.

North America, particularly the United States, as a leading nation in basic research, increasingly emphasizes the supporting role of basic research in national development. Through its highest-level medium- and long-term science and technology development strategy, the *5th Science and Technology Basic Plan (2023-2027)* [4], the U.S. proposes a vision of "science and technology innovation leading a bold future" and increases research funding in key areas. A review of 2022 U.S. policies reveals that U.S.-China technological competition forms the main thread running through recent U.S. basic research policies. The U.S. also uses "research security" as a pretext to restrict scientific and technological exchanges in key areas through collaboration between the intelligence community and academia, launching the "Safeguarding Science" toolkit and establishing research security programs to maintain American leadership in scientific frontiers and emerging technologies. Compared to other countries and regions, the U.S. currently has numerous publicly available think tank reports covering talent competition, international cooperation, open science, and emerging technologies, providing consulting reports to maintain long-term U.S. competitiveness.

Europe has a strong tradition in basic research, insisting on leveraging the collective strength of European countries to increase investment and support for basic research while promoting the free cross-border flow of knowledge, researchers, and technology within the European Research Area. For example, UK Research and Innovation (UKRI) proposes in its *Strategy 2022-2027: Transforming Tomorrow Together* [3] to increase the UK' s R&D intensity from the current level of approximately 2.0% of GDP to 2.4% by 2027. Additionally, Europe funds research in health, climate, energy, and digital domains through the "Horizon Europe" program, building a closely connected and efficient European research and innovation ecosystem to enhance Europe' s capacity to lead in scientific research and innovation frontiers. Europe also emphasizes innovation system building and scientific environment cultivation, taking the lead in open science practices, and attaches great importance to reforming research evaluation systems for the long-term development of scientific research by establishing a coalition for research assessment reform to promote a unified framework for research evaluation reform at the international level. Following the outbreak of the Russia-Ukraine conflict, the EU, Germany, the UK, and other countries launched special programs to attract Russian and Ukrainian scientific talent, providing targeted support to Ukraine by establishing special funds to support Ukrainian researchers' research and living expenses and providing them with access to European research infrastructure, while also simplifying work visa and residence permit procedures for Russian scientists.

Asia has witnessed rapid development in basic research, with countries increasing investment in recent years to support high-level basic research. For example, in South Korea' s *2023 Fiscal Year Consolidated Appropriations Act*, the NSF received a total of $1.039 billion in new appropriations compared to the 2022 fiscal year [2]. South Korea has made scientific and technological innovation an important tool for implementing the new government' s economic policies, promulgating the *Republic of Korea Digital Strategy* and determining national strategic technologies at the first meeting of the National Committee on Advanced Strategic Industries in 2022, aiming to overcome development crises through scientific and technological innovation. Japan, while vigorously ensuring R&D investment in key areas, fully recognizes the importance of international cooperation, using science and technology diplomacy as a lever to enhance research capabilities, optimize research environments, and cultivate and attract international talent.

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3. Main Characteristics of International Basic Research Policy Trends

3.1 Prioritizing Application-Oriented Basic Research

Confronted with challenges and crises such as climate change, zoonotic diseases, population aging, and the Russia-Ukraine conflict, major developed countries fully recognize the importance of scientific and technological innovation for national and regional development and global health, prosperity, and well-being. They increasingly emphasize application-oriented basic research to fully leverage scientific and technological innovation as an engine for sustainable economic and social development. On one hand, traditional funding agencies focused on application-oriented research, such as the U.S. Department of Energy and Department of Agriculture, continue to specifically support research activities within their departmental mandates, providing technical support and policy guidance to solve applied problems in their respective fields. On the other hand, funding agencies that primarily support curiosity-driven basic research, such as the U.S. NSF, German Research Foundation (DFG), and Japan Society for the Promotion of Science (JSPS), have also increased support for application-oriented basic research in recent years to address real-world socioeconomic development challenges.

(1) Using institutional and programmatic reforms as breakthroughs

to systematically deploy application-oriented basic research. To address major challenges such as climate change, educational equity, and infrastructure improvement, the U.S. has facilitated technology transfer pathways and achieved new breakthroughs through cross-sector collaboration. For example, after many years, the NSF has restructured its organizational framework for the first time, establishing its 8th directorate—the Directorate for Technology, Innovation and Partnerships (TIP) . This directorate spans six existing directorates, emphasizing interdisciplinary integration and collaboration, aiming to support application-oriented research and translation across all fields of science and engineering to shape and consolidate long-term national competitiveness. One of TIP' s key missions is to support application-oriented basic research. The *CHIPS and Science Act* stipulates that TIP will focus on funding R&D and commercialization in 10 technology areas including artificial intelligence, quantum information science and technology, and biotechnology, and has launched new funding programs such as the Regional Innovation Engines to promote application-oriented research in key technology areas .

(2) Leveraging the bridging role of convergence to drive paradigm shifts in application-oriented basic research. The NSF has increased its support for convergence research in recent years, listing "collaboration and interdisciplinarity" as specific measures in its latest *2022–2026 Strategic Plan* [6], and will improve various mechanisms to support large-scale collaboration and interdisciplinary research ranging from small teams to multi-institution centers. The U.S. National Academies of Sciences, Engineering, and Medicine (NASEM) released the report *Automated Research Workflows for Accelerated Discovery: Closing the Knowledge Discovery Loop* [7], which argues from a forward-looking perspective that automated research workflows (ARW) will lead to explosive growth in scientific data, driving unprecedented large-scale experimental collaboration among researchers across laboratories, teams, and departments. Additionally, UKRI proposes in its strategy to achieve "world-class impact" by providing new funding opportunities for multidisciplinary research, leveraging cross-disciplinary and cross-domain expertise to collaboratively address major societal challenges [3].

3.2 Emphasizing the Cultivation and Recruitment of Basic Research Talent

Talent represents the primary resource and core element of current international scientific and technological competition, prompting countries to strengthen basic research talent cultivation and improve global talent attraction policies.

United States. To continue leveraging America' s powerful asymmetric advantage in attracting and retaining international talent, the Center for Strategic and International Studies (CSIS) recommends reforming Science, Technology, Engineering, and Mathematics (STEM) immigration policies. For example, creating new green card categories for workers in critical emerging technology fields related to national security and prioritizing visa applications in emerging technology fields [8]. The *CHIPS and Science Act* specifies that the NSF will focus on STEM education, including PreK-12 STEM education, undergraduate STEM education, graduate STEM education, STEM workforce data, and human resource development in microelectronics, and authorizes the NSF to provide grants, scholarships, and training funds for STEM education [9]. Additionally, the NSF launched the "Experiential Learning for Emerging and Novel Technologies" (ExLENT) program in 2022 to expand experiential learning opportunities in emerging technology fields and provide new pathways for learners to enter careers in these areas .

United Kingdom. UKRI acknowledges the negative impact of high-pressure work environments on stimulating researchers' innovative spirit and outlines a blueprint for establishing a flexible research and innovation system in its strategic plan. By establishing world-class scholarship programs and improving visa mechanisms to support research talent, the UK aims to become the most attractive country for global talent. It supports talent mobility across government, industry, and academia, provides training in knowledge and professional skills for researchers, cultivates skilled R&D personnel and teams, reduces bureaucracy in the research system, and supports researchers in realizing their creative ideas [3].

Japan. To address declining PhD enrollment rates, unstable employment positions for young researchers, and reduced research time, Japan will provide funding to approximately 8,800 doctoral students (about double the previous year' s number) through programs such as the "Challenge Research Program for Next-Generation Researchers" and "University Fellowship Program," fully covering their living and research expenses .

France. The French Academy of Sciences has systematically proposed recommendations to enhance young researchers' enthusiasm for research from multiple perspectives, including improving their salary 待遇, reducing age limits for establishing independent research teams as needed, granting academic research and funding expenditure autonomy to talented researchers under 45, and appropriately lowering recruitment thresholds for permanent positions [10].

Notably, following the outbreak of the Russia-Ukraine conflict, European countries launched special programs to attract Ukrainian scientific talent. The German Alliance of Science Organizations issued a position paper *Solidarity with Partners in Ukraine*, demonstrating that German scientific organizations have long maintained diverse and fruitful scientific cooperation with their Ukrainian partners and will continue close collaboration at all levels . The UK government initiated a "£3 million package for Ukrainian researchers" to support the preservation of Ukraine' s research ecosystem. The European Commission launched the "Marie Skłodowska-Curie Actions (MSCA) Direct Aid Program," investing €25 million to fund researchers from Ukraine.

3.3 Balancing Research Security and International Cooperation

3.3.1 International Scientific and Technological Cooperation Represents an Irreversible Trend International cooperation has become an important aspect of science diplomacy and is crucial for addressing global challenges and benefiting humanity.

United States. The American Academy of Arts and Sciences' Challenges to International Scientific Partnerships (CISP) project released the report *Global Connections: Emerging Science Partners*. The report argues that the U.S. should continue to play a leadership role in enhancing global scientific capacity and seeking solutions to challenges such as pandemics and climate change. It recommends that the U.S. follow principles of transparency and fairness, actively promote and establish cooperation with emerging science partners (ESPs), and continue to support and expand international scientific cooperation, including with countries that have tense relations with the U.S., such as China [11].

Russia. The Russian Academy of Sciences proposed to the federal government the establishment of a Russia-UNESCO special fund for countries worldwide to promote Russian higher education in basic research .

European Union. The EU proposed the necessity of respecting fundamental values and principles in international research and innovation, strengthening synergy with higher education, and engaging in dialogue with international partners on these issues . French President Emmanuel Macron proposed common understanding of these values and principles in the *Marseille Declaration on International Research and Innovation Cooperation*, including freedom of scientific research, research ethics and integrity, gender equality, and open science . The "Horizon Europe (2023–2024) Program" includes several initiatives to support and strengthen international cooperation in renewable energy, food systems, global health, and environmental monitoring .

Japan. Japan' s Ministry of Foreign Affairs proposed strengthening research capacity through science diplomacy to address four major crises facing Japan' s science and technology sector: optimizing research environments at Japanese universities and research institutions, cultivating international talent, improving talent mobility, and promoting international talent exchange to enhance science diplomacy [12].

3.3.2 Balancing Scientific Openness and Research Security Mutual benefit and trust form the foundation of international scientific cooperation, representing a broad consensus among global scientific communities to maintain open exchanges in basic research. However, in recent years, against the backdrop of complex international situations including geopolitical tensions, the COVID-19 pandemic, and the Russia-Ukraine conflict, the U.S.-led Western blockade of China' s key core technologies has gradually extended to basic research in related fields.

United States. The U.S. regards science as an important tool for national security, emphasizing that science serves national security and public welfare. Its series of science and technology initiatives are essentially launched in the name of national security. For example, the NSF explicitly states its service to national security in its strategic positioning. The U.S. primarily employs four measures for research security: information control, classified research, government review, and self-review (where sensitive but not classified content is reviewed by the scientific community). The 2022 policy trends indicate that the U.S. has further strengthened technology blockades in the name of research security. The *CHIPS and Science Act of 2022* proposes establishing an Office of Security and Policy within the NSF Director' s Office to coordinate all science and technology security and policy issues at the NSF, identify potential security risks, and develop procedures and policies to safeguard scientific and technological security [9]. Beyond semiconductors, biotechnology, quantum information technology, and artificial intelligence have been identified as security risk areas. For example, on September 12, 2022, President Biden signed the "National Biotechnology and Biomanufacturing Initiative," explicitly proposing to protect the U.S. bioeconomy and prevent foreign adversaries and strategic competitors from using legal and illegal means to obtain U.S. technology and data, including biological data and proprietary or pre-competitive information [13].

The U.S. intelligence community has strengthened cooperation with the scientific community. The National Counterintelligence and Security Center (NCSC) collaborated with the NSF, National Institute of Standards and Technology (NIST), White House Office of Science and Technology Policy (OSTP), and Association of American Universities (AAU) to design and launch the "Safeguarding Science" toolkit, focusing on protecting emerging technology fields such as artificial intelligence, bioeconomy, autonomous systems, quantum technology, and semiconductors that have the greatest impact on U.S. economic and national security. The toolkit helps stakeholders in emerging fields develop methods to protect research and innovation from potential misuse or theft . According to the *2022 Annual Threat Assessment of the U.S. Intelligence Community* released by the National Intelligence Council (NIC), the greatest characteristic of the global security environment in the coming year will be the intensification of great power competition and conflict, with transnational threats competing for global attention and limited resources against the backdrop of COVID-19, global climate change, and technological development [14].

NIST established a Safety Commission advisory body to advise the NIST Director on matters related to NIST' s safety policies, safety management systems, practices, and performance, as well as safety culture. Its task is to assess NIST' s safety culture status and the implementation of existing safety protocols and policies at NIST . The NSF funded four new research security projects in 2022, aiming to strengthen the foundation of U.S. research security while encouraging principled international cooperation. These projects focus on developing training modules detailing research security insights and best practices, addressing the importance of information disclosure, identifying and bridging knowledge gaps in risk management and mitigation, and providing training for principled international cooperation .

European Union. The European Commission released a toolkit on how to reduce foreign interference in research and innovation, providing best practices to support EU higher education institutions and research organizations in safeguarding their fundamental values and protecting their staff, students, research outcomes, and assets. The toolkit can help EU higher education institutions and research organizations develop comprehensive strategies to address risks and challenges in values, governance, partnerships, and network security from abroad .

3.4 Shaping a New Scientific Culture

A sound scientific culture forms the foundation for stimulating the vitality of scientific and technological innovation entities. In response to the international phenomenon of "emphasizing quantity over quality and form over content" in research evaluation, major countries introduced reform measures in 2022, continuously improving research ethics governance in fields such as life sciences and artificial intelligence. As leaders in open science, the U.S. and UK have spearheaded the global open science movement.

3.4.1 Research Evaluation To reduce the negative impact of quantitative research evaluation on scientific activities and give researchers confidence to prioritize quality over quantity in academic publishing, thereby maximizing research quality and impact, the EU led over 350 institutions from more than 40 countries in signing a research assessment reform agreement in 2022 [15], promoting peer review-centered qualitative evaluation to drive global research evaluation system reform. In October 2022, the French Academy of Sciences' "Evaluation and Open Science" Committee published recommendations for transparent and rigorous evaluation of researchers and research teams [16], specifically advocating for representative works, enriching evaluation dimensions, scientifically viewing and using bibliometric data, using homogeneous international evaluation standards where possible, simplifying evaluation processes and materials, and reducing evaluation frequency. The German DFG developed a package of measures at the institutional level to change scientific assessment culture , shifting the focus of research evaluation from quantitative indicators to research content and improving inequality of opportunity in academia. In April 2022, the DFG released a position paper *Academic Publishing as the Foundation of Research Evaluation: Challenges and Actions* , aiming to trigger a cultural shift toward open publishing and content quality-oriented research evaluation, reducing the negative impact of quantitative research assessment on scientific activities.

Following the outbreak of the Russia-Ukraine conflict, Ukraine' s scientific community pressured international academic journals to ban Russian scientists from publishing. The Russian government decided to stop using two indicators—"publications indexed in international databases" and "participation in international academic conferences" —in all research evaluations in 2022, reducing the weight of bibliometric and scientometric indicators in research evaluation. Meanwhile, Russia increased indicators such as "application of research outcomes in industry" and "joint research with enterprises," and developed new research evaluation guidelines for individual scientists, teams, laboratories, universities, and research institutions .

3.4.2 Research Ethics Major scientific discoveries often entail significant ethical issues. The U.S. NSF explicitly states in its latest strategic plan that its investments in research and training help promote understanding of ethical dimensions in engineering and science [6]. Future NSF investments will generate cutting-edge knowledge about what constitutes or promotes responsible research conduct and develop new methods to disseminate this knowledge to researchers and educators at all career stages. The U.S. NIH also proposes in its *2021–2025 NIH Strategic Plan* [17] to "develop a set of ethical principles for NIH-funded researchers when using artificial intelligence." Germany' s 10-year strategic plan *The Role and Future of the DFG in the German Research System* [18] states that "the DFG will ensure that research activities comply with legal requirements in genetic engineering, animal protection, copyright, and data protection." The DFG also developed action guidelines to minimize misuse risks and help research institutions, universities, and researchers conduct self-regulation. Specifically: research institutions and universities must establish ethical rules to handle security-related scientific issues while complying with laws and regulations; researchers should conduct risk analysis, minimize risks, responsibly publish sensitive results, and avoid misuse of high-risk research; project applicants must assess whether their projects involve direct dual-use risks, and if so, conduct risk-benefit analysis and explain measures to minimize risks. If the applicant' s institution has a research ethics committee, they should consult it in advance and attach the committee' s opinion to the project proposal.

3.4.3 Open Science In 2022, the U.S., UK, and other Western countries actively formulated policies to promote open science development.

United States. The U.S. government released a policy memorandum requiring that by the end of 2025, all federally funded academic papers must be immediately made freely available to the public after peer-reviewed publication, and the underlying data must also be made freely available "without delay." At the institutional level, the U.S. NSF deployed a special program to support open science in 2022 and released the *Open Knowledge Network Roadmap*, establishing short-, medium-, and long-term goals for developing an Open Knowledge Network (OKN).

Germany. In 2022, the German DFG released a position paper *Open Science as Part of Scientific Culture* , summarizing the DFG' s understanding of open science, conditions for successful open science, open science for society and economy, and the DFG' s tasks in the open science field. The document states that open science can improve research processes, enhance transparency and reproducibility of research outcomes, support equal access to scientific information, strengthen research collaboration, and promote breakthroughs in basic research.

United Kingdom. In 2022, UKRI required that from April 1, 2022, all peer-reviewed academic papers funded by UKRI and submitted for publication must be immediately open access. From January 1, 2024, monographs and book chapters must be open access within 12 months of publication . In December 2022, UKRI updated its open access policy guidelines , with main updates including: co-authored papers with non-UKRI-funded collaborators must also comply with UKRI' s open access policy; since UKRI' s open access policy officially took effect on January 1, 2024, contracts signed with authors before this date may not include open access policies, but UKRI still encourages such authors to make their papers open access within one year of publication; UKRI funding can also be used for managing open access tools and infrastructure.

Think tanks and funding agencies in various countries have also published consulting reports on how to measure participants' contributions in open science, the significance of open peer review in the open science era, and how to balance open science and intellectual property.

United States. The American Geophysical Union' s report *Credit Is Due* [19] points out that traditional methods cannot adequately measure the breadth and depth of participants' contributions in open science. To promote scientific openness, inclusivity, transparency, and traceability, the report emphasizes the need to clarify participants' roles in research, proposing that a contributor role taxonomy will effectively measure the value of data sharing, and that interactive network diagrams will help improve global scientific inclusivity and transparency.

South Korea. The National Research Foundation of Korea released a research report on *The Significance of Open Peer Review in the Open Science Era* [20], analyzing how open peer review curbs problems with predatory journals and peer review issues against the backdrop of evolving open science.

European Union. The European Commission released the report *Open Science and Intellectual Property Rights* [21], exploring the interaction and balance between open science and intellectual property, proposing reflections on the principle of "as open as possible, as closed as necessary" in the context of continuously developing open research and innovation ecosystems, and providing specific recommendations for policymakers and IP practitioners on promoting open science and its balance with intellectual property to better disseminate knowledge for the benefit of all.

3.5 Continuously Promoting Organizational and Management Reform

In recent years, scientific funding agencies such as the U.S. NSF and NIH, UKRI, and German DFG have continuously promoted organizational and management reforms, emphasizing improved internal management in their respective medium- and long-term strategic plans. They aim to enhance funding management effectiveness through strengthened information services, enhanced condition guarantees, and management team building.

United States. The NSF launched its modernization initiative in 2018 [22] to proactively adapt to environmental changes. Key measures include: developing flexible tools using state-of-the-art information technology (IT) and improving current services to make interactions between NSF staff and the academic community simpler and more convenient through IT systems; using new IT solutions to provide automated services to users through robotics; supporting the development of tools such as "business intelligence" to improve institutional flexibility and work efficiency; strengthening workload analysis and workforce planning to promote strategic human resource management; and enhancing talent team building to explore evaluation methods suitable for the NSF.

United Kingdom. UKRI' s *UKRI Delivery Plan 2022–2025* [23] proposes transforming into a more agile and responsive organization to maximize support for research and innovation. To this end, UKRI will further integrate resources to maximize the collective impact of its constituent research councils, continue to create enabling environments, optimize effective decision-making and accountability, support talent, strengthen collaboration, and remove obstacles to completing work. It aims to reduce bureaucracy, make the organization and its activities more efficient and effective, promote the modernization and digitalization of funding management services, and shorten review cycles through data integration systems for information sharing and progress monitoring.

Japan. The Japan Science and Technology Agency' s 2022 annual plan [24] proposes reassessing organizational structure and operations to maximize research quality and funding effectiveness, building efficient operational mechanisms to rationalize and optimize funding use, labor costs, owned asset review, procurement rationalization, and contract optimization. It also aims to strengthen the use of information and communication technology to simplify business processes, improve work efficiency, and enable diverse and flexible work style reforms.

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4. Future Priority Directions

4.1 Strengthening Systematic Deployment of Basic Research

Competition with China in basic research and key technologies has become the highest priority for Western countries, evolving from individual legislative proposals to broad consensus. Therefore, while steadily increasing investment in basic research, China must continuously enhance its capacity to respond to a new round of paradigm shifts in scientific research. At a time when society faces more crises and international scientific and technological competition becomes increasingly fierce, it is necessary to strengthen strategic deployment at the national level, leverage the strategic scientific and technological strength of national laboratories and national research institutions, strengthen basic research, enhance systematic deployment, and promote collaboration between universities and leading technology enterprises. This will enable basic research to better align with national needs, bridge the gap between research and practical problems, and enhance the ability to respond to risks and challenges [25, 26].

4.2 Building an Attractive Scientific and Technological Innovation Ecosystem for Research Talent

In talent recruitment, we should innovate forms of international scientific cooperation, attract foreign high-level research talent to conduct large-scale frontier interdisciplinary research in China by relying on world-class large scientific facilities and other research infrastructure, and selectively attract visiting scholars with high potential to stay and work in China through extended visiting periods and financial support. We should also continuously enrich pathways for outstanding foreign researchers to conduct scientific work, project research, and academic exchanges in China [26].

In talent cultivation, we should increase support for young scientists in various funding programs and give young researchers more opportunities to take the lead in major projects. We should improve project and funding management systems and processes, and encourage research institutions to build diversified and classified evaluation systems focusing on research quality, impact, and contribution based on their own characteristics and with reference to international research evaluation reform spirit and practices. For example, using patent quality and transformation application as evaluation indicators will enable researchers to concentrate on scientific exploration and achievement transformation [27].

4.3 Strengthening Research Security and Ethics Governance

In recent years, research security has received increasing attention, with the EU and U.S. launching similar safeguarding science toolkits containing content that targets China both implicitly and explicitly. On one hand, China must continuously monitor and remain vigilant about the spillover effects of these toolkits and develop corresponding contingency plans and countermeasures. On the other hand, as an open platform, these toolkits also provide important information references for China in formulating relevant research security policies.

Furthermore, a sound research ethics governance system constitutes a key link in ensuring research security. The government, research institutions, researchers, and relevant social groups should form governance synergies to establish robust research ethics management systems with clear ethical review responsibilities and improved mechanisms. Researchers should possess the awareness and capability to conduct responsible research, and the entire society should foster an innovation atmosphere that emphasizes ethical values.

4.4 Promoting Systematic Construction of Open Science

The National Natural Science Foundation of China and other departments have conducted practices and explorations in promoting open access to publicly funded research project outcomes in China. Looking ahead, while tracking foreign open science practices, we should identify the main bodies to effectively promote open science construction in China, study the balance between open science and intellectual property rights, enhance understanding of open science among various stakeholders in academic exchanges through various communication means, and expand the influence of open platforms such as the NSFC Basic Research Knowledge Repository to improve utilization rates and promote long-term sustainable development, thereby advancing academic exchange and scientific progress.

4.5 Actively Promoting International Scientific and Technological Cooperation

In the face of common development challenges for humanity, international cooperation and open sharing are more necessary than ever. On one hand, we should actively build an open innovation ecosystem, participate in global science and technology governance, proactively design and lead international big science programs and projects, establish or initiate international science and technology organizations, support domestic universities, research institutes, and science and technology organizations in connecting with international counterparts, strengthen joint R&D with researchers from various countries, and enhance our own scientific and technological innovation capabilities through open cooperation. On the other hand, we should expand and deepen international scientific cooperation around global issues such as climate change, energy security, biosafety, and food security, enhance openness and trust in the international scientific community, and effectively safeguard China' s scientific and technological security interests.

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Author Biographies

HUANG Minzhuo is a staff member of the Scientific Research Office at Sir Run Run Shaw Hospital, Zhejiang University School of Medicine. Her research focuses on science and technology policy and scientific research management. E-mail: huangminzhuo@zju.edu.cn

MENG Qingfeng is Director of the Division of Development Strategy at the Bureau of Planning and Policy, National Natural Science Foundation of China.

His research focuses on science and technology policy, performance evaluation, and research management. E-mail: mengqf@nsfc.gov.cn

Corresponding author

Responsible Editor: Zhang Fan

Note: Figure translations are in progress. See original paper for figures.