Postprint: Research on China's Open Science Governance Framework

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Abstract

Open science is experiencing vigorous development, driving transformation in the global scientific research paradigm. Open science governance aims to gradually enhance transparency and global participation in the process of scientific and technological advancement, ensure low-cost openness on a global scale, accelerate the worldwide dissemination and sharing of research outcomes, and elevate the scientific and humanistic literacy of the entire citizenry. As the momentum of open science development grows increasingly robust, a series of challenges are gradually emerging. Through analytical research on open science governance framework models, it facilitates further clarification of governance logic, identification of governance actors and mechanisms, effective advancement of China's open science governance system construction, acceleration of the nation's scientific and technological development, facilitation of China's emergence as one of the "navigators" of the global knowledge community during 2040–2050, and promotion of the realization of China's strategic objective of becoming a world leader in science and technology.

Full Text

Preamble

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Research on China's Open Science Governance Framework Model

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Abstract

Open science is thriving and driving a global paradigm shift in scientific research. Open science governance aims to gradually increase the transparency and global participation in the process of scientific and technological progress, ensure low-cost openness worldwide, accelerate the global dissemination and sharing of research outcomes, and enhance the scientific and humanistic literacy of the entire population. As the momentum of open science development grows stronger, a series of challenges have gradually emerged. Analyzing and studying the open science governance framework model helps to further clarify the governance logic, identify governance subjects and mechanisms, effectively promote the construction of China's open science governance system, accelerate the development of science and technology, help China become one of the "leaders" of the global knowledge community by 2040–2050, and promote the realization of the strategic goal of becoming a world leader in science and technology.

Keywords
open science, open science governance, governance framework, evaluation system, world science center

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Concept and Value of Open Science Governance

Openness is one of the essential attributes of science. Open science governance aims to gradually increase the transparency and global participation in the process of scientific and technological progress, ensure low-cost openness on a global scale, accelerate the worldwide dissemination and sharing of achievements, and enhance the scientific and humanistic literacy of all citizens. It triggers a re-examination of innovation activities regarding participating subjects, process evolution, environmental interaction, and outcome evaluation by creating organizational mechanisms for global open sharing. According to theories of science and technology governance, the logic of governance unfolds across three dimensions: "what to govern," "who governs," and "how to govern". Therefore, this paper defines "open science governance" as the joint management of open science activities by various actors through governance tools and mechanisms to accelerate the development of global open science. The elements of open science

governance include governance subjects, governance tools, governance mechanisms, governance actions, and governance objectives.

Open Science Governance Accelerates Solutions to Global Public Health Emergencies

The novel coronavirus poses a threat to human health and has caused the most severe global economic crisis since World War II. To address the challenges posed by the virus, countries have adopted a series of governance measures, including initiatives to promote research collaboration and knowledge sharing, increased sharing of research infrastructure, enhanced property rights incentives, and flexible regulation, which have accelerated the development and production of vaccines and therapeutic drugs. In terms of policy and regulation, the National Research Council of Canada formulated a pandemic response challenge program and launched data collection and sharing protocols. For research data sharing, the Chinese Center for Disease Control and Prevention submitted COVID-19 and viral genome sequence data to the World Health Organization (WHO) and the Global Initiative on Sharing All Influenza Data (GISAID) through the "Novel Coronavirus National Science and Technology Resource Service System," sharing with the international community. The Allen Institute for Artificial Intelligence in the United States collaborated with the government, relevant research companies, foundations, and publishers to create the COVID-19 Open Research Dataset, providing a foundation for using machine learning technologies to mine coronavirus research. Regarding research infrastructure sharing, the German High-Performance Sequencing Center established coordinated access channels to its infrastructure; Genome Canada, together with the Canadian national platform for genome sequencing and analysis, national and provincial health laboratories, hospitals, academia, and industry, launched the Canadian Coronavirus Genomics Network (CanCOGeN); and Japan advanced access to its supercomputer "Fugaku" to help rapidly identify candidate drugs for treating COVID-19. In terms of regulation, Australia's Therapeutic Goods Administration under the Department of Health has prioritized regulatory evaluation of applications for COVID-19-related therapeutic products, while the UK's Medicines and Healthcare products Regulatory Agency issued a set of flexible regulatory mechanisms to support healthcare measures for COVID-19.

Open Science Governance Promotes Scientific and Technological Innovation and Narrows the Digital Divide

Faced with major scientific challenges, global scientists jointly advance scientific research through equal, open, and cooperative efforts, creating a relatively complete governance system to enhance their scientific and technological innovation capabilities and address global technological challenges. The International Thermonuclear Experimental Reactor (ITER) program is one of the largest and most extensive research collaboration projects in human history. To better advance the ITER program, the ITER Council has conducted effective governance work,

including formulating policy plans based on advisory recommendations, evaluating research activity management, and promoting infrastructure construction and utilization, thereby advancing ITER cooperation on a global scale. The European Organization for Nuclear Research (CERN) is the world's largest particle physics laboratory, where 6,000 researchers from different countries and regions conduct scientific work. Adhering to the principle of global openness, CERN has formulated a framework for non-member state participation in CERN research activities, redefining additional membership categories and criteria, standardizing procedures for granting and reviewing (associate) membership qualifications, and defining member rights and obligations. From its founding in 1954 to 1999, CERN's member states increased from 12 to 21. In September 2022, the CERN Council approved a new open science policy aimed at making all research fully accessible to other researchers and the broader public, promoting inclusion, democracy, and transparency at CERN.

Open Science Governance Advances Citizen Science and Improves Science-Society Relations

Citizen science is the process by which the public participates in the exploration and discovery of new scientific knowledge. Any individual or organization wishing to participate in scientific research can be involved in the scientific research process, including formulating research questions, refining project design, conducting scientific experiments, collecting and studying data, developing technology, and applying results. Citizen science can improve the relationship between scientific research and society, enabling better satisfaction of both scientific research and social needs. To better promote the development of citizen science, the U.S. National Oceanic and Atmospheric Administration (NOAA) has formulated a series of governance measures, including conducting practical activities that effectively attract public participation, raising awareness and relevant skills regarding citizen science, and designing flexible and diverse indicators and processes to track and evaluate impact to better standardize citizen science and advance related processes. Core considerations include formulating relevant policies to ensure data quality and credibility and providing strategic standards. Simultaneously, accessibility to data and related tools is maximized, transparency is maintained in demonstrating data collection methods, and data applications are ensured for appropriate purposes. Partnerships are established with all public and private sectors to leverage and complement each party's unique skills and advantages, strengthening and expanding partnerships to promote citizen science development. Targeted training is provided to citizens interested in citizen science to help them understand when, where, and how to better use citizen science. At the same time, partnerships with relevant departments help people better advance citizen science projects and achieve expected project goals.

Global Trends in Open Science Governance Development

Over 20 years ago, as commercial publishing groups monopolized academic communication and journal prices skyrocketed, making libraries overwhelmed, the concept of open access (OA) was proposed for publicly funded research results to be published, disseminated, and used autonomously through the internet. Having evolved from green OA based on institutional repositories to gold OA centered on OA journals and OA books, OA has gradually developed into a publishing and open communication integration model dominated by preprints. As the scale continues to expand, OA development has encountered bottlenecks. The European Commission realized that OA policies only addressed open publishing but could not solve the problem of insufficient innovation capacity, and therefore announced the comprehensive advancement of a research data open system. Open data helps enhance global digital inclusivity and improve the quality and reliability of scientific data, with some regional data platforms gradually developing into global infrastructure. Against the international backdrop of open science, issues of science and technology innovation governance have become increasingly prominent, and open science governance has received growing attention. Europe and the United States have reached agreements on the necessity of data preservation, sharing, and digital data infrastructure construction, and have advanced discussions on science policy review, formulation, and necessary basic investments.

International Countries Have Adopted a Series of Governance Measures to Advance Open Science

The European Commission proposed the "European Open Science Cloud" plan in 2016 as part of the European Cloud Initiative, aiming to establish a competitive European data and knowledge economy. In March 2018, the European Commission released the "European Open Science Cloud Implementation Roadmap," promoting rapid open science development in EU member states through six action routes covering architecture, data, services, access and interfaces, rules, and governance to ensure Europe possesses excellent research governance levels and innovation capabilities. The U.S. National Science Foundation (NSF) released a report in 2007 focusing on research infrastructure development, advocating for the construction of world-class research infrastructure supporting high-performance computing, data analysis and visualization, and virtual workspaces. In 2013, the U.S. Center for Open Science (COS) released the "Open Science Framework," providing a series of targeted services for different actors participating in scientific research based on the entire research lifecycle. In December 2018, the U.S. Congress passed the "Open Government Data Act," opening "non-sensitive" government data to the public. In August 2022, the White House Office of Science and Technology Policy (OSTP) issued a memorandum ensuring "free, immediate, and equitable access to federally funded research," making taxpayer-funded research immediately freely accessible and fully usable by the public. This new guidance calls on all federal agencies

to formulate policies eliminating the current 12-month embargo period for accessing federally funded research results (including articles and data). NASA launched its Year of Open Science in 2023, planning to hold various activities on campuses and at association annual meetings to inspire public participation in open science. In 2017, the Japan Science and Technology Agency (JST) formulated the "Open Access Policy for Scientific Publications and Research Data Management," incorporating research data generated by projects into the scope of recommended open access and making paper deposition and submission of data management plans mandatory. On February 26, 2020, Canada released the "National Open Science Roadmap," providing important principles and recommendations to guide Canadian open science activities and applying these recommendations to scientific research funded by the Canadian federal government. In 2021, the Australian Academy of Science released a position statement on open science publishing, supporting the development of an open science strategy for Australia.

China Highly Values Open Science Development and Promotes Governance Work from the National Level

Open science is of great significance in expanding the dissemination of research results, maintaining core scientific values, and improving social return on investment. The realization of open science requires a series of governance measures, including policy planning, infrastructure construction, and skills training. China attaches great importance to open science development, providing support at the national level in strategic planning, laws and regulations, and operational plans to safeguard the advancement of open science. In 2014, the State Council issued the "Opinions on National Major Scientific Research Infrastructure and Large-Scale Research Instruments Opening to Society," requiring increased social openness of national major scientific research facilities and instruments to improve the utilization rate of scientific and technological resources. In 2016, the "Several Opinions on Doing a Good Job in Opening Up Education to the Outside World in the New Era" emphasized the need to consider the educational levels and development needs of different regions, improve the quality and level of educational openness, and create a new situation of more quality and higher-level educational openness. In 2017, the Ministry of Science and Technology, the National Development and Reform Commission, and the Ministry of Finance issued the "Management Measures for the Opening and Sharing of National Major Scientific Research Infrastructure and Large-Scale Research Instruments." In May 2017, the Ministry of Science and Technology formulated the "13th Five-Year Plan for International Science and Technology Innovation Cooperation," proposing to "plan and promote innovation with a global vision, enhance the level of international science and technology innovation cooperation, deeply integrate into the global innovation system, effectively utilize global scientific and technological innovation resources, and build an open innovation mechanism at a higher level." In March 2018, the State Council promulgated the "Management Measures for Scientific Data," requiring the promotion of scientific data manage-

ment according to the sharing concept of "openness as the norm, non-openness as the exception." In March 2021, the "14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through 2035" was released, proposing to implement a more open, inclusive, and mutually beneficial international science and technology cooperation strategy and to more actively integrate into the global innovation network.

Open Science Governance Framework and Measures

While promoting the rapid development of open science, open science governance also faces challenges. Countries worldwide are at different stages in their journey toward open science—some have achieved breakthrough progress in policy and practice, while others have not yet fully recognized the importance of open science, making global open science governance full of uncertainty and complexity. Meanwhile, UNESCO's guidance and evaluation policies for open science are not yet clear enough. Although scientific research institutions worldwide are actively embracing open science, they do not have relatively consistent policy opinions in actual implementation and lack a policy framework to guide practice. Additionally, due to uneven development in infrastructure capabilities and data analysis capabilities among countries worldwide, new data divides may emerge, and relevant professional skills training for open science will also be a "necessary tool" for open science development.

China is currently in the research and discussion stage of open science. Existing open science policies are mostly constructed around various open elements, and there are still deficiencies in overall national layout of open and inclusive plans, supporting policies, practical activities, organizational promotion, and monitoring and supervision mechanisms. Moreover, Yang Yang et al. believe that China's "hard foundation" for participating in international governance is increasingly strong, but the "soft environment" has shortcomings and constraints. Management of foreign science and technology cooperation is imperfect, lacking soft science research related to science and technology governance in international cooperation projects; professional service support is insufficient, and major science and technology cooperation projects lack professional and comprehensive international cooperation team support. There are institutional obstacles to establishing international organizations, making it very difficult to initiate, establish, and introduce science and technology international organizations. At the same time, China is still in the initial stage of digital risk prevention, and the governance model of infrastructure is not yet aligned with international standards, posing significant challenges to open science governance.

Clarify Governance Objectives to Accelerate Open Science Development

Increasingly prominent global issues have prompted countries worldwide to attach importance to open science development, hoping to use open science to address and resolve various major international challenges. To promote comprehensive and coordinated development of open science and accelerate its pace: (1) the world needs an overall strategic framework and direction that comprehensively considers the development goals of open science in various countries; (2) it should promote collaborative cooperation among countries worldwide to build a community with a shared future for global development; and (3) it should avoid excessive competition, regulate conflicts of interest, and control the negative impacts brought by open science.

To achieve the "five needs" stage goals of China's open innovation ecosystem and become one of the "leaders" of the global knowledge community by 2040–2050, China should actively create policy mechanisms suitable for open science development, cultivate an open science culture, and build a risk prevention system to foster an efficient open science ecosystem.

Cover Multi-Dimensional Governance Subjects to Jointly Promote Governance Activities

On a global scale, as a governance subject, China should actively participate in open science initiative programs under the UNESCO Recommendation on Open Science framework and build an international open science governance system featuring multi-party co-governance, multilateral equality, and open win-win cooperation. Simultaneously, China should actively participate in international cooperation organizations established in different fields and by different subjects that do not exclude third parties, actively advocate for and lead international open cooperation programs in several fields.

In the process of domestic open science governance, government departments (research funding agencies), research institutions, universities, publishing institutions, social organizations (such as societies and associations), enterprises, scientific and technological workers, and the public are all part of the open science governance system and are all main units implementing governance activities, needing to assume different roles in open science governance. Government departments create an environment for open innovation development by formulating national open science development strategies and policies and regulations, investing in open science infrastructure, and strengthening cooperation between public and private sectors. Research institutions, universities, publishing institutions, and scientific and technological workers promote the popularization and development of open science by planning or participating in formulating evaluation standards for scientific research achievements and science and technology evaluation and incentive measures. Enterprises, social organizations, and the public should also gradually participate in the formulation and supervision of

open science policies to advance the implementation of specific policies.

Apply Multiple Governance Tools to Improve Governance Efficiency

Open science governance tools include strategic planning, funding instruments, evaluation and supervision, and norms and regulation. (1) **Strategic planning** is the strategic embodiment of open science development direction and goals, representing major measures and action guidelines chosen to achieve long-term open science development. (2) **Funding instruments** involve the formulation of relevant guidelines and plans for open science cooperation projects to achieve national strategic planning goals. (3) **Evaluation and supervision** motivate actors to carry out efficient actions by examining open science management processes and comparing implementation results with preset goals. (4) **Norms and regulation** standardize the behavioral activities of open science subjects by formulating laws and regulations, establishing guiding principles, and setting behavioral standards, while implementing supervisory responsibilities to minimize various negative impacts in open science development and promote the healthy development of open science.

Coordinate Various Governance Mechanisms to Regulate Governance Activities in All Directions

Open science governance mechanisms include coordination mechanisms, decision-making consultation mechanisms, participation and dialogue mechanisms, monitoring and evaluation with dynamic adjustment mechanisms, and ethics review and supervision mechanisms. (1) **Coordination mechanisms** refer to the coordination of open science policies and systems among different fields, institutions, or departments to ensure policy consistency across departments. (2) **Decision-making consultation mechanisms** allow open science to provide opinions and suggestions for major decisions, which are adopted according to actual conditions, including providing demonstrations for major decisions, bottom-up major recommendations, and moderate participation in decision-making. (3) **Participation and dialogue mechanisms** are mechanisms for policy makers to consult with stakeholders and for public participation in decision-making, allowing stakeholders and the general public to participate in national strategic decision-making. (4) **Monitoring and evaluation with dynamic adjustment mechanisms** aim to accurately grasp the progress of strategic planning implementation, monitor and evaluate implementation, and timely adjust relevant policies to achieve effective alignment between strategic planning and specific practice. (5) **Ethics review and supervision mechanisms** protect the rights and interests of open science subjects and effectively avoid ethical and value conflicts by supervising scientific ethics and relevant laws and regulations.

Adopt Efficient Governance Actions to Promote Open Science Processes

Open science governance actions include national open science development strategy governance, scientific research system and activity governance, priority area governance, and breakthrough technology and major challenge governance. (1) **National open science development strategy governance** refers to governing the direction and overall layout of national open science development by formulating development strategies aligned with open science goals and governance systems. (2) **Scientific research system and activity governance** combines autonomous governance and cooperative governance, managing scientific research activities with sufficient autonomy and independence while strengthening exchanges and cooperation between research institutions and enterprises to promote widespread and in-depth dissemination of open science concepts in the scientific research community and drive rapid national scientific and technological development. (3) **Priority area governance** refers to selecting several priority areas based on comprehensive consideration of its own development, social needs, and open science development, and promoting new situations in priority area open science development by formulating governance action plans and initiating international cooperation programs/organizations. (4) **Breakthrough technology and major challenge governance** actively leverages the role of major countries through institutional and organizational innovation and extensive participation of stakeholders, increases relevant resource investment, and unites countries worldwide to jointly break through key technologies to address new challenges facing global social development.

Design of Open Science Governance Evaluation System: A Case Study of World Science Centers

Through investigating domestic and international open science governance monitoring and evaluation systems, the open science governance evaluation system is divided into four parts: evaluation principles, evaluation elements, evaluation indicators, and evaluation methods. (1) **Evaluation principles** include globally agreed principles and regional or institutional personalized principles; they should follow relevant policies and regulations and reflect the guiding principles of open science governance. (2) **Evaluation elements** are based on open science governance elements, mainly evaluating governance objectives, governance tools, governance mechanisms, and governance actions. (3) **Evaluation indicators** are set according to each evaluation element, with the focus of the evaluation system varying depending on the evaluation object. (4) **Evaluation methods** mainly include questionnaires, expert evaluation, dynamic monitoring, and third-party evaluation.

Open science can increase the transparency and global participation in the process of scientific and technological progress and may profoundly affect the global

pattern of scientific and technological development. Referring to the research of British scholar J.D. Bernal, Japanese scientist Yuasa Mitsutomo defined the world science center as a country whose scientific achievements account for more than 25% of the total world scientific achievements in the same period. Before the emergence of the open science concept, the world science center shifted five times: first to Italy, then to Britain, then to France, then to Germany, and then to the United States, where it has remained.

Looking at the five shifts of the world science center, each shift had significant markers (Figure 2 [Figure 2: see original paper]). Italy during the Renaissance was the first world science center (1540–1620). The Renaissance movement and the first scientific revolution brought ideological liberation to Italy and gave birth to a group of important natural philosophers, promoting the independent development of natural science. When Galileo died in 1642, the world science center shifted to northern Europe, and Britain became the second world science center (1660–1750). This period saw Britain produce a large number of scientists such as Gilbert, Boyle, Newton, and Harvey, generating many world-leading major scientific and technological achievements, including Newton's classical mechanics, Boyle's elemental theory, Harvey's "blood circulation theory," and Darwin's theory of evolution. From the mid-18th century to the mid-19th century, France replaced Britain as the third world science center (1760–1840). During this period, France experienced a great revolution and unprecedented prosperity in scientific and technological development, with a group of scientific giants emerging in mathematics, physics, chemistry, and biology who made tremendous contributions to disciplinary development. However, France's overly academic research approach gradually undermined its position as the world science center. Germany carried out educational reforms in the early 19th century, creating a brand-new scientific research and education system that attracted numerous outstanding scientific talents from around the world, gradually taking a leading position in mathematics, physics, chemistry, biology, and geology and becoming the new world science center (1840–1910). Since the 20th century, Germany has developed rapidly in natural science, with Nobel Prize winners in natural science far exceeding other countries besides the United States. Since the 1920s, the United States has consistently ranked at the forefront in materials science, electronics and information science, biology, atomic energy science, and aerospace technology, with many important global scientific and technological achievements originating in the United States. With the rise of the United States, the world science center shifted to America (1920 to present). The United States seized the opportunities of the quantum mechanics revolution and the information technology revolution, paid special attention to the introduction of scientific talent, and quickly stood at the forefront of world science. Since the resumption of the Nobel Prize in 1945, the number of American winners has consistently ranked first among all countries, making it still the undisputed world science center.

To become a world science center, a country must possess certain basic conditions, including strategic planning to promote scientific development, an edu-

cation system that promotes rapid talent growth, a research environment that attracts talent, and a solid material foundation. These bear great similarities to the goals of open science governance. To further specify and clarify the instrumental role and indicator system of open science governance, this paper, referring to the "five needs" stage goals of China's open innovation ecosystem and from the perspective of open science governance, evaluates the objectives and implementation paths of world science center shifts. Based on the open science governance framework, a set of evaluation indicators is constructed, selecting governance objectives, governance tools, governance mechanisms, and governance actions from the open science governance framework system as evaluation elements. In terms of evaluation indicators, comprehensive consideration is given to improving the open science policy system for promoting scientific development, creating a competitive research environment, and promoting cooperation and open sharing, ultimately forming 23 evaluation indicators matching the four evaluation elements of governance objectives, governance tools, governance mechanisms, and governance actions (Table 1).

Recommendations for Actively Promoting China's Open Science Governance

As a new research paradigm, open science establishes an ecosystem that promotes scientific and technological innovation and greater transparency while also carrying certain risks. While enjoying the benefits of open science, it is also necessary to guard against its potential negative impacts, which is a major challenge facing open science and the value of open science governance. Currently, China is still in the initial stage of open science governance and has not yet established effective governance frameworks and tools. To achieve the "five needs" stage goals of China's open innovation ecosystem, become a leader in the global knowledge community, and promote the overall development of international open science, China should actively create policy mechanisms suitable for open science development, cultivate an open science culture, and build a risk prevention system to foster an efficient open science ecosystem.

(1) Include More Subjects and Reach Consensus Promoting open science governance must first reach consensus among all stakeholders. Currently, China's open science governance subjects are mainly concentrated in government agencies and a few research institutions and publishing organizations. The open science concepts of some key participants have not yet been established, and participants in some links of scientific research innovation have not yet joined. In the future, China needs to strengthen understanding of the new development needs of scientific and technological innovation subjects, promote active openness and inclusiveness among research funders, enhance the open science governance capabilities of government, clarify the role of libraries in open science, and improve public confidence and participation in open science.

(2) Establish Open and Inclusive Policy Mechanisms Currently, China's open science governance policies mainly focus on open access, open infrastructure, and open data, mostly constructed around various open elements. They are insufficient to support the circulation of various open elements, coordination for open activities, and pay little attention to the inclusiveness of innovation subjects. In the future, China should strengthen overall layout from the national level, build a good innovation ecological environment for open science from the perspective of long-term national planning and ecosystem evolution to attract more subjects; simultaneously, it should consider open science as a policy priority and public interest goal, encourage key subjects to play their innovation advantages, and promote system openness and inclusiveness.

(3) Build a Risk Prevention System Since open science emphasizes knowledge openness, research transparency, and cooperation among different countries and regions, issues inevitably arise in intellectual property protection, data privacy security, and even national data security. The balance between data security and open sharing is a key issue that open science governance must address. It is necessary to establish a risk prevention system compatible with data security and achieve balance between openness and protection of knowledge.

(4) Create a New Culture of Open Science The implementation of open science governance goals is essentially a cultural innovation. China needs to establish a new culture for the open innovation ecosystem, advocate a good international cooperation atmosphere, jointly create international open science communication excellence, jointly plan and take the initiative, tell "China's open science story" globally to enhance international influence, and promote the spiritual quality of China, Chinese scientists, and entrepreneurs in the changing global landscape, injecting positive energy into global open science governance.

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