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Research on the Mechanisms and Pathways for Deepening and Expanding International Science and Technology Cooperation under the New Circumstances: A Review Based on Domestic and International Literature

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Abstract: *Against the backdrop of changes in globalization and the reshaping of geopolitics, this paper reviews the theoretical basis, practical difficulties, and feasible pathways for China to deepen international science and technology cooperation. Combining literature review and comparative analysis, this paper integrates and discusses the evolution of cooperation mechanisms, the selection of policy tools, and the practices of different models. The study shows that current cooperation is constrained by both the external environment and domestic institutional and mechanistic constraints; the Belt and Road Initiative and the participation of multiple actors provide new possibilities for addressing these challenges. The next step should begin with removing policy bottlenecks, improving value assessment, and building a global knowledge chain, so as to promote the transformation of international science and technology cooperation from pursuing scale to emphasizing quality and foster an open, inclusive, and mutually beneficial situation.*

Keywords: *international science and technology cooperation; mechanism innovation; policy tools; global knowledge chain; pathway optimization*

1. Introduction

The positioning of international science and technology cooperation is undergoing changes, with the focus shifting from efficiency-oriented approaches in the past to placing equal emphasis on security and resilience, while geopolitical competition has also, to a considerable extent, reshaped the landscape of global innovation networks. The transnational R&D division of labor system, established on the basis of traditional globalization, is now facing the impact of unilateralism, technological nationalism, and the "decoupling and disruption of chains" in key fields, and the trend toward fragmentation of science and technology governance is becoming increasingly evident [23]. Cooperation is no longer simply regarded as a means of optimizing resource allocation, but is increasingly becoming part of the strategic competition among major powers, with countries shifting from openness and sharing toward selective and strategic collaboration.

Reshaping science and technology governance through high-level opening-up and promoting the cross-border flow of innovation factors are regarded as important pathways at present. Against the backdrop of intensified geopolitical competition and the rise of science and technology protectionism, how to form a cooperation framework that is both independently controllable and compatible and inclusive has become a topic of considerable debate in academic and policy circles [1]. The "small yard, high fence" strategy pursued by Western countries, through the formation of exclusive technology alliances, tightening restrictions on the export of critical equipment, and restricting the mobility of talent, has caused significant fragmentation and bloc formation in global research networks; relying solely on intergovernmental agreements or spontaneous market mechanisms is no longer sufficient to address such systemic risks, and solutions need to be sought through institutional opening-up and coordination among multiple actors. Accordingly, this paper reviews domestic and international literature and discusses the theoretical foundations, practical challenges, mechanism design, and typical experiences of international science and technology cooperation under the new circumstances, with a view to contributing to the development of more resilient cooperation mechanisms.

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2. Theoretical Foundations and Current Assessment of International Science and Technology Cooperation

For a long time, the generalized perception that "anything that claims to be international can be regarded as internationalization" has been treated as a self-evident consensus in many studies, which is precisely a fundamental issue that needs to be clarified in research on international science and technology cooperation. Hans de Wit pointed out that the definition of "internationalization" in the field of scientific research has always been relatively vague; if it is judged solely on the basis of formal transnational mobility or self-proclaimed internationalization, it is easy to obscure the insufficient depth of the substance of cooperation [2]. Ren Xiaoping also noted that the unclear definition of the connotation of "internationalization" has led the literature to often conflate different levels of exchanges, such as personnel exchanges and joint R&D [3]. This misinterpretation also has practical implications: Xu Lijun argued that it directly weakens the pertinence of policymaking [4]; Zhou Xiaolin attributed some of the bottlenecks in building an internationalized research environment to an exclusive focus on hardware standards while neglecting soft institutional environments and cultural integration mechanisms [5]; He Chenhui further cautioned that when the boundaries of the definition of internationalization are unclear, global knowledge becomes difficult to truly integrate, and research is prone to falling into low-level repetition [6].

In terms of the evolution of mechanisms, early cooperation mostly remained at superficial forms such as personnel exchanges and information exchange, as documented relatively early by Sudan's empirical investigation [7]. Subsequently, China's cooperation policies shifted from passive responses to proactive planning, and Ren Xiaoping believed that this transformation promoted the preliminary institutionalization of cooperation mechanisms [8]. In examining the European Union, Huo Hongwei observed that standardized service processes and multilevel coordination mechanisms had enabled it to shift from loose alliances to close coordination [9]. Xu Qing proposed that the cooperation mechanism under the Belt and Road Initiative should not remain at the level of resource matching, but should also be upgraded to model innovation [10]. Han Bingyang highlighted the role of risk-sharing and benefit-sharing mechanisms in deepening cooperation [11]. Following the changes in actors and forms, Fan Qinghua reviewed the path of university cooperation from one-way introduction to two-way mutual learning [12], Wang Yiqi observed that cooperation actors had evolved from government-led arrangements into a complex network of multi-stakeholder co-governance [13], and Yang Ye argued that cooperation mechanisms were evolving toward digitalization and ecological development [14].

In practice, China's international science and technology cooperation has moved beyond single-project coordination toward the development of a multilevel and broad-based ecosystem. At the local level, Xu Hong took Hefei as an example and analyzed efforts to deepen cooperation through the joint establishment of laboratories [15]. At the national level, Wang Xiao evaluated the overall effectiveness of international science and technology innovation cooperation, arguing that substantial progress had indeed been made in major science and technology programs and talent exchanges, while structural imbalances also remained [16]. In terms of platform development, Wang Jing emphasized the role of platform-based operations in integrating global knowledge resources [17]; Xu Hongjiao proposed identifying potential cooperation partners according to thematic granularity and illustrated this approach with China-Russia cooperation as an example [18]. Focusing on national key laboratories, Zhang Mengya found that national strategic orientation had a significant stimulating effect on high-level cooperation [19]; Qi Yanru designed a performance evaluation framework for government-funded projects that takes into account both academic influence and socioeconomic benefits [20]. At the regional level, Xu Lijun summarized Henan's practices in deeply integrating into international science and technology cooperation under the Belt and Road Initiative [21]. Regarding the policies themselves, Zhai Yunkai conducted a dynamic quantitative evaluation using the Policy Modeling Consistency Index Model, concluding that improving policy coordination is the key to deepening cooperation [22].

The external environment is not optimistic. From the perspective of social networks, Guo Fenglin observed that U.S. technological containment of China is changing the structure of global science and technology cooperation networks, with cooperation nodes in key fields becoming disconnected and network density declining [23]. Zhong Shanshan shifted the focus to universities and argued that the trust deficit arising from geopolitics has hindered the deep integration of the academic community [24]. Wang Xiao emphasized that uncertainty in the external political environment has forced cooperation to shift from comprehensive openness toward selective cooperation [16]. Internal institutional constraints are equally prominent. Sudan pointed out that research actors generally face the contradiction between cumbersome approval procedures and insufficient autonomy [7]; Zhou Xiaolin reviewed bottlenecks in

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areas such as talent mobility, cross-border data flows, and the use of research funds, arguing that there is tension between the administrative management approach and the laws governing international scientific research [5]; Zhai Yunkai found that the existing policy instruments are not evenly balanced in terms of the allocation of supply-side, environmental, and demand-side tools [25]; Zhang Mengya cautioned that excessive reliance on administrative directives has caused many cooperation projects to lack endogenous motivation [19]; Xu Lijun argued that the management system lacks sufficient flexibility and resilience when confronted with complex international circumstances [4].

3. Mechanism Design and Model Innovation in International Science and Technology Cooperation

The interaction between policy guidance and resource complementarity constitutes the underlying driving force of international science and technology cooperation. Zhu Chonggao established a strategic framework for cooperation among scientific research institutes using SWOT analysis and argued that whether resource endowments match the policy environment largely determines the success or failure of cooperation [26]. Taking the hybrid rice project as an example, Tu Yan demonstrated that the output and input of core technologies constitute an intrinsic mechanism for sustaining the advancement of transnational cooperation [27]. Regarding the role of policy tools, Zhai Yunkai verified that a combination of policies can significantly improve the efficiency of resource exchange and advocated aligning policy drivers with cooperation needs at different stages [22][25]; Zhang Mengya examined the applicable scope of the two models of “policy-driven development” and “resource exchange” and found that high-level laboratories tend to be more willing to achieve technology spillovers through resource exchange [19]; Guo Fenglin observed that external policy blockades would force cooperation actors to restructure resource exchange networks [23]; Wang Liang advocated internalizing policy guidance as a catalyst for resource flows in order to build an open innovation ecosystem [28].

Research under the Belt and Road framework has generally developed along three lines. In terms of mechanism design, Xu Qing proposed a top-level approach [10], Wang Jing focused on mechanism innovation in platform development [17], and Chen Shuiyuan explored the pathways for constructing new cooperation mechanisms from a macro perspective [29]. In terms of regional practice, Xu Lijun analyzed practices for deep regional integration using Henan as an example [21], while Fan Qinghua reviewed the evolution of regional university cooperation models [12]. From the perspective of regional and country comparisons, Han Bingyang used the case of Israel to illustrate the aspects of specific national models that could be drawn upon [11], Huo Hongwei summarized the EU’s experience in cooperation management in the context of regional integration [9], Fang Ci supplemented the case of Japan’s differentiated cooperation [30], Liu Kaiqiang provided U.S. experience from the perspective of the national laboratory system [31], and Wang Liang compared typical developed countries to provide differentiated references for China’s cooperation with Belt and Road countries [28]. With regard to universities and scientific research institutes, Zhu Chonggao proposed a strategic vision for cooperation [26], Wang Yiqi extended the research to non-governmental actors [13], Zhong Shanshan emphasized that universities need to adopt countermeasures in response to changes in the environment [24], and Zhang Mengya focused on the motivation of national key research platforms to participate in cooperation [19].

For platform development to achieve tangible results, the management system, cooperation model, and operational mechanism need to work in coordination with one another. Huo Hongwei summarized the experience of systematic operations within the EU system [9], Wang Jing provided a macro-level pathway for platform development [17], Yang Ye emphasized the significance of ecological platforms for resource integration [14], Wang Yiqi regarded the participation of multiple actors as the key to improving platforms [13], Wang Liang provided differentiated insights into international management [28], and Xu Qing proposed designing platforms according to specific strategic needs [10]. In terms of the management and service system, Fang Ci observed that Japan had combined policy guidance with institutional safeguards [30], while Liu Kaiqiang considered the open management model centered on national laboratories in the United States to have reference value [31].

4. Comparative Analysis of International Experience and Implications

The practices of different countries vary significantly, and each offers its own implications. The European Union has pursued a path of an open innovation ecosystem, integrating policy guidance,

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financial leverage, and transnational coordination mechanisms. Huo Hongwei noted that the European Union has achieved full-chain coverage through multilevel project applications and evaluations [9]; Yang Ye argued that the key to its success lies in breaking down administrative barriers among member states and establishing unified scientific research data-sharing platforms and joint funding programs [14]. The U.S. national laboratories are more complex, with an overall shift from comprehensive openness toward a combination of strategic contraction and targeted screening. Liu Kaiqiang observed that their cooperation strategies have significantly strengthened scrutiny of the backgrounds of cooperation partners, technology sensitivity, and potential risks [31]; Guo Fenglin pointed out that U.S. technological containment of China is triggering structural disruption and restructuring of global scientific research cooperation networks [23]; Wang Liang found that the United States remains open in the field of basic research but has tightened access in cutting-edge strategic fields such as artificial intelligence and quantum computing [28]. Japan and Israel have limited resources, yet they have explored a model of "government guidance, enterprise leadership, and market-driven development." Fang Ci explained that Japan has connected limited scientific research resources to global innovation networks by establishing special funds and overseas joint R&D centers [30]; Han Bingyang found that Israel has achieved "great intelligence in a small country" through its civil-military integration system and venture capital ecosystem [11].

The role of non-governmental entities has become increasingly prominent, promoting the transformation of cooperation from government-led arrangements toward multi-stakeholder co-governance. Wang Yiqi systematically analyzed the pivotal role of non-governmental entities in cooperation and exchanges and their policy needs [13]; Sudan pointed out that non-governmental entities are important actors in building regularized cooperation networks, but still face many institutional obstacles [7]. The operation of an open innovation ecosystem depends on breaking organizational boundaries and enabling the dynamic optimization of the allocation of innovation resources. In this regard, Xing Wenming regarded the FAIR principles of scientific data management as fundamental norms for an open innovation ecosystem [32]; Xu Qing emphasized the need to establish flexible and adaptable cooperation frameworks within an open ecosystem [10]; Wang Jing argued that physical and digital platforms are the primary carriers for the operation of an open innovation ecosystem [17]; Chen Shuiyuan advocated adapting to the complex needs of an open innovation ecosystem through mechanism restructuring [29].

5. Pathways and Strategies for Deepening International Science and Technology Cooperation

Institutional barriers, data silos, and lagging evaluation mechanisms are the major bottlenecks in building the scientific research environment. Zhou Xiaolin clearly proposed that the lack of data-sharing mechanisms and barriers to talent mobility are the most prominent bottlenecks at present [5]. In terms of evaluation orientation, He Guangxi argued that traditional evaluation systems are difficult to effectively incentivize substantive international cooperation, and that policies should promote a shift in evaluation from "quantity" to "quality" [33]. Regarding funding mechanisms, Mu Rongping pointed out that their insufficient flexibility restricts transnational exploration in cutting-edge fields and advocated granting researchers greater autonomy [34]. In terms of policy tools, Zhai Yunkai suggested optimizing their combination through quantitative methods [22][25], while Zhang Mengya cautioned that policies should precisely align with resource needs [19]. Overall, policy planning needs to shift from single-project funding toward full-chain and multidimensional collaborative governance.

In terms of value assessment, Tu Yan used a hybrid rice project as a case to construct an evaluation framework based on technology transfer, demonstrating that technology transfer has significant value in enhancing agricultural productivity in recipient countries [27]. Qi Yanru further found that the efficiency of technology transfer is significantly positively correlated with project performance, with different academic disciplines showing varying patterns [20]. Zhai Yunkai pointed out that the combination of policy tools plays a key moderating role in realizing the value of technology transfer [22]. It can be seen that a scientific evaluation system is a necessary prerequisite for optimizing the allocation of cooperation resources and improving the quality of cooperation.

The core of new mechanisms lies in shifting from single-project-driven development toward institutionalized and ecosystem-based collaborative governance. Existing studies generally cover three levels: macro-level policies (He Guangxi [33], Mu Rongping [34]), meso-level platforms (Wang Jing [17], Chen Shuiyuan [29]), and micro-level projects (Tu Yan [27], Xu Hongjiao [18]), respectively discussing the constituent elements and operational logic of the mechanisms. On this basis, He Chenhui advocated deepening the cooperation chain to pool global knowledge, arguing that chain-based

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collaboration is the key to integrating global knowledge [6]; An Kaixin reviewed the phased evolution, current challenges, and optimization pathways of Belt and Road cooperation [35]; Wang Yiqi proposed specific strategies for research institutions to strengthen international exchanges and cooperation [36]. When full-chain coordination and the participation of multiple actors are effectively combined, traditional barriers are expected to be overcome, and global innovation resources can also be allocated more efficiently.

6. Conclusion and Prospects

Overall, existing studies have achieved considerable results in reviewing the current status of cooperation and analyzing policy tools, but most still remain at the level of linear descriptions of existing models: on the one hand, there is a lack of theoretical analysis of how the endogenous driving forces of cooperation decline and regenerate in the context of "deglobalization"; on the other hand, international science and technology cooperation is often equated with mere technology exchange or resource complementarity, while the institutional friction costs and trust deficits accompanying it as a vehicle for strategic competition among countries are overlooked; as for cooperation at the level of grassroots departments of universities, there is still a considerable lack of research covering the entire process from intention to implementation over a long period. Future research can attempt to advance in several directions: construct a cooperation dynamics model from the perspective of "dual circulation" and explore how institutional opening-up can enhance the resilience of the global knowledge chain under the normalization of technological containment; promote the transformation of cooperation from "project-driven" to "ecosystem-driven," making use of non-governmental entities and open innovation ecosystems to fill the gaps in intergovernmental cooperation; and strengthen the quantitative evaluation of cross-regional, cross-level, and cross-actor collaborative governance mechanisms, so as to provide support for forming an international science and technology cooperation system that is both independently controllable and open and inclusive amid complex changes.

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