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# Research on the Coupling Mechanism of the Embedment of New R&D Institutions into National Strategic Science and Technology Forces

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### Abstract

Taking the “embedded behavior” of new R&D institutions as the research object, this paper uses social network analysis to study the theoretical logic of the coupling between new R&D institutions and the national strategic science and technology force, analyzing the mechanism behind the relationship between them at the micro level by utilizing a coupling coordination degree model and Tobit panel regression. This paper methodically reveals the dynamic coupling mechanism and evolution law of the embedding of new R&D institutions into the national strategic science and technology forces and confirms the key role of their collaborative development in enhancing regional innovation capabilities. Research findings indicate that the coupling coordination degree between new R&D institutions and the national strategic science and technology forces in Guangdong Province has been continuously improving, and the core factors such as the intensity of R&D investment and the total number of R&D personnel in the region have a positive impact on the coupling coordination degree, but the differences among regions and the potential innovation polarization effects still deserve necessary attention. The new R&D institutions collaborate with the national strategic science and technology forces through political, organizational, relational, and cultural embeddedness, thereby promoting resource sharing, complementary advantages, and dynamic optimization.

### Keywords

New R&D institutions; National strategic scientific and technological force; Relationship structure; Coupling mechanism;

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The national strategic scientific and technological forces include national laboratories, national research institutions, high-level research universities, and leading science and technology enterprises. It is crucial to strengthen the national innovation system, enhance the overall efficiency of the national innovation system, and build China into a strong science and technology power. The new R&D institutions are a product of China's deepening reform of the science and technology system. Adopting modern management systems and market-oriented operation mechanisms and with a development goal consistent with the national strategic science and technology forces, they play a major role in promoting technological innovation and the transformation of science and technology achievements (Xue *et al.*, 2025). The new R&D institutions and the national strategic scientific and technological forces form an interrelated ecosystem, and there is a continuous collaborative innovation relationship among the various elements of the system. The pursuit of coordinated development between the two is conducive to the generation of regional innovation agglomeration benefits and the high-level development of regional innovation. Investigating the innovative coupling and coordination relationship between the two is of great significance to reveal the mutual connection between the new R&D institutions and the national strategic science and technology forces. The existing literature on the national strategic science and technology forces includes the definition of this system, its concept, its function, and its construction path, etc., but the research on the relationship between the new R&D institutions and the national strategic science and technology forces is relatively few.

Therefore, this paper takes the "embedded behavior" of new R&D institutions as the research object. Through analyzing the "structural hole defects" in the ecological layout of the national strategic science and technology forces, it finds out the intrinsic motivations of new R&D institutions to promote the coupling between the industrial chain and the innovation chain of the ecosystem. This study could help policy makers to take targeted measures to improve the innovation indicators of new R&D institutions and the national strategic science and technology forces. In addition, it could further promote the coordinated development of the dual innovation coupling system of China's new R&D institutions and the national strategic science and technology forces, encourage them to strengthen innovation cooperation, and help them jointly undertake the innovation mission of strengthening the national strategic science and technology forces. And ultimately it could promote the development of China's scientific and technological innovation (Ren *et al.*, 2024).

## 1. Literature Review

### 1.1. Coupling theory

Originated from physics, the concept of coupling is used to analyze the dynamic relationships between multiple interrelated systems. The system coupling theory is an important concept proposed by Ren Jizhou, a Chinese agricultural scientist. He pointed out that when the characteristics of systems are similar but with differences, appropriate measures can be taken to strengthen the connection between them, so that they can promote and complement each other, and finally achieve common development (Ren and Wan, 1994). Society is a complex system, and there are multiple internal coupling relationships among different systems, such as resources, ecology, economy, and people (Wang *et al.*, 2024). Coupling degree can be used to describe the degree of interaction between various systems. Coordination means that the relationship between two or more systems is positive; the relationship between the system or

internal elements is mutually promoting a virtuous cycle, and the systems or elements complement each other. The degree of coordination can assess the degree of positive development between systems, which makes up for the deficiency that the degree of coupling can only reflect the degree of action between systems without showing the comprehensive and coordinated development level of systems (Wang *et al.*, 2021).

With the deepening understanding of scientific development, the evaluation of the development degree of a region or society has shifted from merely measuring its development level to an overall balanced development evaluation based on its coordination level and development level. Therefore, coupling effect and coupling coordination degree have become effective evaluation and research tools. Scholars have increasingly studied the coupling coordination relationship between different complex systems through coupling coordination degree models (Wei *et al.*, 2020). Among them, the coupling of China's regional innovation relationships has become a research hotspot, such as the calculation of the coupling relationship between the innovation environment relationship and the regional economic relationship in Hainan Province (Su and Zhang, 2021), the mechanism, spatio-temporal characteristics, and driving mechanism of the coupling and coordinated development of the relationship between university science and technology innovation and high-tech industry innovation (Liu *et al.*, 2015), the measurement of the coupling synergy between local innovation networks and global innovation networks (You *et al.*, 2024), and the upgrading of cluster enterprises from the perspective of coupling between industrial clusters and the global value chain (Peng and Liu, 2011).

### *1.2. Research on the coupling between new R&D institutions and national strategic science and technology forces*

The existing research on new R&D institutions mainly focuses on their concept, role (Shi *et al.*, 2023; Fang and Qiu, 2025), and performance evaluation (Meng and Song, 2019; Zhang *et al.*, 2022). New R&D institutions can implant innovation genes, increase the supply of science and technology, alleviate the problem of regional technology and talent shortages, and promote the innovation and development of local strategic science and technology forces. Xu *et al.* (2022) studied the performance evaluation system of new R&D institutions in Guangdong Province and Fujian Province by means of a questionnaire and constructed an effective evaluation standard and competitiveness evaluation system for new R&D institutions. Steinberg *et al.* (2015) studied the influencing factors of the performance of new R&D institutions in foreign countries and discovered that the marketization and flexible interest relationships are an important driving force behind their technological innovation. Lin *et al.* (2022) studied the two-way matching problem between teams and talents in new R&D institutions based on the grey relational cloud model.

In recent years, scholars at home and abroad have studied national strategic science and technology strength from a number of different perspectives and divided the research objects through concept analysis (Liu and Zeng, 2022), including high-level research universities (Zhang *et al.*, 2024), science and technology leading enterprises (Zheng and Chen, 2023), and state key laboratories (Zheng *et al.*, 2024). As early as last century, some foreign scholars (Charles, 1967; Edward, 1972) analyzed the "national strategic strength" from the perspective of maintaining national security, and clarified the importance of national strategic strength to maintaining national security. It examines the development mode and function of various entities from the perspective of national strategic needs and finds that national scientific research institutions are mainly committed to major innovation breakthroughs in non-public sectors, such as

aerospace and national defense (Fan and Li, 2022). In view of the collaborative innovation mode among different research objects, Xu *et al.* (2022) studied the synergy of national strategic science and technology forces. By deeply analyzing the theoretical logic of systematically promoting national strategic science and technology forces, he revealed the internal mechanism of national strategic science and technology forces driving innovation and development.

However, at present, there are not enough studies on the relationship between new R&D institutions and the national strategic science and technology force with focus on the coupling between the two. The scholar Fan and Fan (2022) proposed that the new R&D institutions are future-oriented strategic science and technology forces that explore the operation mechanism of market-oriented modern institutions, stimulate the innovation vitality of traditional research institutions, and play an important role in fostering the advantages of the science and technology industry. In particular, Shenzhen has been continuously promoting the construction of new scientific research institutions in recent years, and has gradually developed into the experimental field of deepening the reform of the science and technology system in China, creating a new path for the cultivation of strategic science and technology forces. He *et al.* (2023) found through research on the transformation mechanism of the new R&D institutions in the field of life science and medicine that the new R&D institutions have great strategic significance for cultivating the national strategic science and technology strength in the field of biomedicine, expanding China's biomedical industry, and realizing the self-reliance and self-improvement of biomedicine science and technology. Tan and Chen (2015) suggested that the government should provide classified support according to the advantages and disadvantages of the coupling subjects of the new R&D institutions.

### 1.3. Research review and research opportunities

In view of their importance, the discussion on new R&D institutions and the development of national strategic science and technology forces has become a common focus in both academic and practical communities. As part of the social organizations, and the important function of new R&D institutions is to develop more practical technologies and innovations that suit the actual needs of enterprises. National strategic science and technology forces are one of the most important collaborative innovation networks to realize the innovation and development strategy. As a new R&D organization emerging in recent years, new R&D institutions should be embedded in the original national strategic science and technology forces innovation network; however, the current research lacks empirical research on the embedding of new R&D institutions into the national strategic forces. Therefore, it is of great theoretical and practical significance to analyze the coupling data between the new R&D institutions and the national strategic science and technology forces through the coupling coordination degree model and the grey correlation degree model, to analyze the innovation coupling coordination relationship between the two systems from a macro perspective, and to deeply analyze the micro coupling mechanism behind the relationship between the two systems.

## 2. The Relationship Structure of the New R&D Institutions Embedded in the National Strategic Science and Technology Forces

Most of the R&D organizations in the innovation networks regard "relationship" as a kind of expectation norm, that is, an understanding of how others within the group are expected to behave.

“Relationship” is a prerequisite for external exchange or the allocation of innovation resources, and “relationship” constitutes a structural barrier for other organizations to establish connections with them. Under the influence of organizational changes, new R&D institutions and national strategic science and technology forces show the characteristics of dynamic “embedded collaboration.” Innovative individuals embedded in such networks tend to accumulate network relations and technical experience, which is conducive to their future purposive behavior. Based on the change trajectory and logic of the relationship between the two, this paper collects cooperative text cases and uses the idea of social network analysis to extract the dynamic relationship characteristics of the two from the three stages of “embeddedness-disembeddedness-autonomous embeddedness”.

### 2.1. “Embedded collaboration” relationship between new research and development (R&D) institutions and national strategic science and technology forces

The case data are the cooperation documents between the new R&D institutions and the national strategic science and technology forces in Guangdong Province. All the data are derived from the public information of project cooperation of various organizations. The duration of the data spans from June 1996 to December 2024. June 1996 was selected as the starting point because the first new R&D institution in Guangdong Province, “Research Institute of Tsinghua University in Shenzhen,” was established in June 1996, initiating comprehensive collaboration between new R&D institutions and national strategic scientific forces. The national strategic science and technology forces primarily select sample entities such as national laboratories, national key laboratories, high-level universities, and leading technology-based enterprises.

The analytical approach based on social network analysis is carried out in the following steps: Firstly, content coding and concept clustering are conducted to obtain the characteristics of cooperation subjects and themes, including the category of cooperation institutions, intensive collaboration areas, and the distribution of collaboration hotspots. By using statistical analysis methods, the external manifestations of the “collaborative cooperation” between new R&D institutions and national strategic science and technology forces are analyzed from three perspectives: the distribution of collaborative entities, the distribution of collaborative themes, and the distribution of collaborative regions. Secondly, the social network analysis method is used to identify the main structure of the cooperative network; the UCINET software is used to measure key indicators such as “degree center number” and “structural hole”; the tool is used to draw the network map of the cooperative event, and further summarize the “embedded” relationships and structure of the main entities in the cooperative event based on the cooperation situation. The main measurement indicators to be selected in this part are as follows:

(1) Collaborative entity analysis. “Degree centrality” refers to the number of entities that a cooperative entity has direct cooperative relationships with. The greater the degree centrality is, the more the entity is needed by other entities in the collaborative network, the deeper the embedding degree is in the collaborative network, and the stronger the dominant role is. Based on the index of “degree centrality,” the collaborative relationship between the two entities can be measured in a region, and the spatial “subsidence area” of the collaborative network between the two innovation entities in a region can be found, indicating the differences in the degree of different institutions and cities embedded in the collaborative network in a region.  $CD(N_i)$  Is the “degree centrality  $i$ ” of the collaborative subjects, where and is the collaborative subjects, and the expression is as follows:  $i j$

$$C_D(N_i) = \sum_{j=1}^8 I(x_{ij}) \quad (1)$$

$$I(x_{ij}) = \begin{cases} 1, & i \text{ and } j \text{ collaborate directly} \\ 0, & i \text{ and } j \text{ don't collaborate directly} \end{cases} \quad (2)$$

As shown in Table 1, from July 2019 to December 2024, with patents and papers as citation indicators, it is found that the top ten institutions in the “degree centrality” of the collaborative network between new R&D institutions and national strategic science and technology forces are mainly distributed in Shenzhen, Guangzhou, and Dongguan, indicating that regional science and technology collaboration has achieved an “government-industry-university-research” embedded collaborative development model. From the perspective of institution category, among the top ten institutions in “degree centrality,” public institutions occupy 4 seats, and the cumulative “degree centrality” is 237, which is the most deeply embedded in the collaborative governance network and the most needed subject. In terms of the cities that institutions belong to, among the top ten institutions in “degree centrality,” Shenzhen is more prominent, occupying 5 seats, which together constitute the central governance pattern of science and technology innovation collaboration in Guangdong Province, indicating that most other cities in the network need to rely on this city to generate cooperative relations. In addition, although Foshan Institute of Intelligent Equipment Technology and Shenzhen Guangqi Institute of Advanced Technology are among the top 10 of the “degree centrality” of the collaborative network in the region, their cooperation activity is much lower than that of Shenzhen Institute of Advanced Technology. Chinese Academy of Sciences and Research Institute of Tsinghua University in Shenzhen. It can be seen that there is a structural disconnection of innovation resources in the region, which indicates that there are significant differences in the degree of different institutions and cities embedded in the collaborative network in the region.

**Table 1**

Ranking of degree center number of their coupling.

Name of institution	Degree centrality	Sort
Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences	36	1
Research Institute of Tsinghua University, Shenzhen	34	2
Fok Ying Dong Research Institute, HKUST, Guangzhou	33	3
Institute of Industrial Technology, Huazhong University of Science and Technology, Guangdong	29	4
Shenzhen BGI Institute of Life Sciences	26	5
Dongguan Songshan Lake International Robot Research Institute Co., Ltd.	22	6
iFLYTEK South China Artificial Intelligence Research Institute (Guangzhou) Co., LTD	19	7
Guangdong Institute of Electronic Information Engineering, University of Electronic Science and Technology of China	16	8
Foshan Institute of Intelligent Equipment Technology	14	9
Shenzhen Guangqi Institute of Advanced Technology	8	10

(2) Key node analysis. A “structural hole” is the only intermediary that connects two entities in a social network when there are non-repeated connections between them. The smaller the value of restrictive institutions is, the less restricted an entity is in the collaborative network, and the more structural holes it has. The index value of “limited institution” is 0, which means that the subject does not have structural holes and belongs to an isolated point. In the relationship structure of new R&D institutions embedded in national strategic science and technology forces, the “structural holes” reflect the resource advantages of both sides. The partners with more “structural holes” have stronger embedding ability and play a leading role in the collaborative network. This project intends to analyze the “structural holes” of collaborative innovation between the two parties. From the perspective of institution types, the centrality index values are compared and analyzed, and the typical examples of university institutions acting as key “dominant” players in regional collaborative networks are studied. This project refers to the “limited system” index proposed by Burt (1995) to measure the “structural hole” index, and its calculation formula is as follows:

$$C_i = \sum_j (P_{ij} + \sum_q P_{iq} P_{qj})^2, (q \neq i, q \neq j) \quad (3)$$

Among them,  $C_i$  represents the entity's limit system,  $P_{ij}$  represents the innovative resources consumed by the entity  $i$  when connecting with the entity, compared to the total innovative resources consumed by all entities,  $P_{iq}$  represents the proportion of the innovative resources consumed by the entity  $i$  when connecting with the entity, relative to the total innovative resources consumed by all other entities,  $P_{qj}$  represents the proportion of the innovative resources consumed by the entity  $q$  when connecting with the entity, relative to the total innovative resources consumed by all other entities.

As shown in Table 2, from 2016 to 2024, the top ten institutions in the collaborative network between new R&D institutions and national strategic science and technology forces in Guangdong Province are ranked by the index value of “restriction system”. From the perspective of institution type, Peking University Shenzhen Graduate School has a low index value of “restriction system,” which is a typical example of new R&D institutions acting as key “leaders” in the collaborative network of innovation resources. The Shenzhen Science and Technology Innovation Commission, as a government functional department, ranks third in the index ranking of “limited system,” indicating that local government departments are also forming innovation resource networks with “visible hands.” Scientific research institutes are also embedded in the regional innovation resource network and play a certain role. Most importantly, new R&D institutions have the most seats among the top ten institutions in the index value of “limited system”, which is the resource gathering place of innovation resource collaborative network.

**Table 2**

Ranking of the coupling structural holes between the two institutions.

Name of institution	Limited system	Sort
Peking University Shenzhen Graduate School	0.0253	1
Shenzhen Research Institute, Hong Kong University of Science and Technology	0.0652	2
Shenzhen Fresh Power Source Research Institute	0.0878	3
Guangdong New Generation Communication and Network Innovation Research Institute	0.0990	4
Guangdong Guangdong-Hong Kong-Macao Greater Bay Area Collaborative Innovation Research Institute	0.125	5

**Table 2. (continued)**

Name of institution	Limited system	Sort
Shenzhen Wanze Central South Research Institute Co., Ltd.	0.250	6
Huizhou Guanggongda Internet of Things Collaborative Innovation Research Institute Co., LTD	0.289	7
Guangzhou Yuncong Artificial Intelligence Technology Co., LTD	0.306	8
Guangdong Juhang New Material Research Institute Co., LTD	0.445	9
Huizhou Research Institute of Sun Yat-sen University	0.546	10

## 2.2. Manifestations of new R&D institutions embedded in national strategic science and technology forces

New R&D institutions are based on maternal universities and research institutions, and are oriented towards market service; they also take into account scientific research and development, technology development, achievements transformation, and industrialization of function, and set up a platform for technology and market docking. This paper deconstructs the network relationship of new R&D institutions and divides this organizational embeddedness into positive embeddedness and reverse embeddedness. Positive embeddedness refers to the active embeddedness behavior of new R&D institutions, such as participating in academic conferences of the main universities, using the industrial funds of the universities to incubate technology, and undertaking research projects of the parent institutions. Reverse embeddedness means that the new R&D institutions accept the embeddedness behavior of the parent institutions. For example, the board of directors, as the decision-making body set up within the new R&D institutions, is the decision-making carrier for the constructors to embed the new R&D institutions, and the constructors send representatives to join. In specific management practice, the embedded cooperative relationship between the new R&D institutions and the builders shows the characteristics of multi-subject collaborative construction, deep interembedding of the organizational system, market demand-driven, and complementary advantages between the subjects.

(1) Property rights relationship. A new R&D institution is a cooperative organization constructed by multiple subjects, which is essentially a cooperative property right relationship between multiple entities. A new R&D institution is the result of the long-term stable relationship established by multiple embedded subjects, and the property right relationship is the result of the long-term stable relationship established by the institution and other embedded subjects (Ren, 2023), which is an institutional relationship in essence. Among them, local governments provide policy and financial support for new R&D institutions (Castellacci and Lie, 2012), research institutes and universities provide technical and talent support for new R&D institutions, and enterprises provide market demand guidance for new R&D institutions. The organizational embeddedness of the new R&D institutions is an institutionalized and impersonal relationship between organizations. Through the market-oriented operation mechanism such as the board of directors or the board of directors, multiple subjects are gathered to build together. This relationship is similar to the "intra-circle relationship," which can reduce the transaction cost of cooperation between each subject and push the development of a multi-agent joint innovation. The joint governance model of new R&D institutions builds an institutional channel among the government, universities, and enterprises, which puts them in the "structural hole" position of the innovation network and enables

them to integrate the capital, talent, and technology resources of multiple subjects.

(2) Mutual embeddedness of structure. There is a deep interembedded structural system in the new R&D institutions, which is the product of reducing the coordination cost within the organization. In theory, both new R&D institutions and other social organizations should function as players to make up for government failure and operate independently from the government. However, in practice, each entity has a strong adsorption force on each subject during the period of resource advantage, which makes universities, research institutions, and enterprises deeply embedded in the organizational system of new R&D institutions. As a hybrid organization, the organizational embeddedness of new R&D institutions can overcome the disadvantages of unitary organizations in terms of management efficiency, resource scarcity, and insufficient infrastructure, and then give full play to the advantages of scale economies or risk sharing. It can enhance mutual trust in a short period of time, reduce communication costs and risks brought by institutional innovation, and help ensure the execution and implementation of projects. On the other hand, due to the diversity of new R&D institutions inside the main body, the variety and complexity of development goals, goal conflict, and internal coordination costs, the resulting organizations will also be important factors that affect new R&D innovation efficiency.

(3) Institutional relationship. The organizational embeddedness of new R&D institutions can realize the complementary advantages among the embedded subjects and improve the overall efficiency of collaborative innovation. Based on the relationship between the concepts of embedded structure, the relationship between new R&D embedded structures depends on the multi-agent system relations. The system formed by the relationship between the elements of versatility is stronger; the stronger the externality diversity, the more suitable the new research institution for being embedded in multiple relations. New R&D institutions should absorb multiple entities in collaborative construction rather than replacing existing entities; the core lies in strengthening the function of innovation services. In other words, the institutional integration of various entities is to better coordinate the goals and actions of multiple parties, promote complementary advantages, improve service efficiency, and form an efficient management system. The complementary advantages of each entity in the target function help to guide the new R&D institutions to play a role in the areas of management innovation, professional innovation, and transferring in the realization of scientific research institutions. At the same time, they improve the overall level and performance via absorbing the transfer services of other organizations. In this process, the other main body, in turn, also uses the new R&D institutions in the management resources and the superiority of power system, to achieve their own goals.

### **3. New R&D Institutes Embed Coupling Mechanism of National Strategic Science and Technology Forces**

From the perspective of “embeddedness theory,” this paper analyzes the structural characteristics and potential motivations of regional multi-subject cooperation networks and constructs a new integrated “embedded collaboration” analysis framework to respond to the actual needs of new R&D institutions embedded in the layout of national strategic science and technology forces. With the deepening of cooperation among research institutions and the continuous interaction of multiple governance subjects, the “embedded collaboration” features such as multiple resource embeddedness, multi-directional relationship embeddedness, and multi-dimensional interest embeddedness are increasingly emerging. The data in this paper are mainly from the Guangdong Statistical Yearbook, the EPS data platform, and

statistics and annual reports released by new R&D institutions. Some indicators are from China National Knowledge Infrastructure, China Engineering Science and Technology Knowledge Center, and other websites. The analysis covers data from 2016 to 2024, focusing on newly established R&D institutions in Guangdong Province and key indicators reflecting the development and capacity of China's national strategic science and technology forces. Due to the lack of data in some years and regions, the mean value method, average growth rate method, and estimation method were used to supplement the data.

This study selects Guangdong as a sample, whose representativeness is reflected in three aspects: First, the data sources are authoritative and diverse, integrating statistical yearbooks, platform data, and institutional annual reports to ensure comprehensive and reliable information. Second, the time span covers the period from 2016 to 2024, which can fully present the dynamic evolution process of the coupling development between new research and development institutions and national strategic science and technology forces. Third, as a pioneer area of science and technology system reform, Guangdong has a high concentration of new research and development institutions and rich forms of cooperation, and its experience has typical demonstration significance for analyzing the "embedded collaborative" network structure of multiple subjects.

### 3.1. Research methods

(1) Coupling coordination degree model. In order to quantify the coupling and coordination relationship between new R&D institutions and national strategic science and technology forces, this study draws on the research of Liao (1999) and other scholars, and establishes the form of comprehensive evaluation function as follows:

$$f(y) = \sum_{i=1}^m \omega_i y_i \quad (4)$$

$$g(y) = \sum_{i=1}^n \omega_i y_i \quad (5)$$

Among them,  $m$  represents the number of indices used to describe the development status of new R&D institutions,  $\omega_i$  represents their index weight, and meet the formula  $\sum_{i=1}^m \omega_i = 1$ ,  $x_i$  represents the standardized value of the  $i$ -th indicator for the development status of the new R&D institutions.  $n$  represents the number of indices used to describe the development status of national strategic science and technology forces,  $\omega_i$  represents their index weight, and meet the formula  $\sum_{i=1}^n \omega_i = 1$ ,  $y_i$  represents the standardized value of the  $i$ -th indicator for the development status of the national strategic scientific and technological forces. The larger the values of  $f(x)$  and  $g(y)$  are, the higher the comprehensive development level of the two systems is.

The degree of dispersion of the two systems is expressed by their respective dispersions, and the coefficient of dispersion is:

$$C_v = \frac{S}{\frac{1}{2} [f(x) + f(y)]} = \sqrt{1 - \frac{f(x)f(y)}{[\frac{1}{2} (f(x) + f(y))]^2}} \quad (6)$$

Among them,  $S$  is the standard deviation of  $f(x)$  and  $g(y)$ . The coupling degree is calculated as follows:

$$C = \frac{f(x)f(y)}{[\frac{1}{2} (f(x) + f(y))]^2} \quad (7)$$

Sometimes the coupling degree  $C$  cannot truly reflect the development status of the two systems, so the coupling coordination degree  $D$  is further adopted to express:

$$D = \sqrt{C \cdot R} \quad (8)$$

Where,  $R$  is the comprehensive evaluation index of new R&D institutions and national strategic science and technology forces, and the calculation formula is as follows:

$$R = \mu f(x) + \theta f(y) \quad (9)$$

In the formula,  $\mu$  and  $\theta$  are the development level weights of new R&D institutions and national strategic science and technology forces, respectively, which are generally 0.5 respectively. Referring to the existing research results (Li *et al.*, 2018), the coupling coordination degree is divided into the following five levels: weak coupling coordination (0.20–0.39), primary coupling coordination (0.40–0.49), intermediate coupling coordination (0.50–0.69), good coupling coordination (0.70–0.89), and high-quality coupling coordination (0.90–1.00).

(2) The Tobit model of the panel. Since the range of coupling and coordination degree is between 0 and 1, the observed value is limited to a certain point. Using the OLS estimation method may lead to biased and inconsistent regression results. Construct Tobit panel model, therefore, to explore new research and development institutions and the influencing factors of the national strategic power coupling relationship of science and technology. Taking the coupling and coordination degree ( $X_{it}^*$ ) of new R&D institutions and national strategic science and technology forces as the explained variable, the model is set up as follows:

$$X_{it} = \delta_0 + \beta X_{it} + \delta_t t \quad * \quad (10)$$

If  $X_{it}^* > 0$ , then  $X_{it} = X_{it}^*$ . If  $X_{it}^* \leq 0$ , then  $X_{it} = 0$ .

Among them,  $i=1,2,\dots,28$ ;  $k=1,2,\dots,9$ ;  $t=2010, 2011, \dots, 2022$ .  $i$  represents province,  $t$  represents time,  $X$  is a series of variables, including registered capital, total number of R&D personnel, total annual R&D expenditure, invention patent ownership, local government support, innovation infrastructure, regional economic development level, science and technology development level, industrial structure, and other 9 variables as control variables. At the same time, the introduction of a virtual time variable to control the heterogeneity of the influence of coupling coordination degree.

### 3.2. The coupling connotation and measurement of new R&D institutions and national strategic science and technology strength

(1) Analysis of the coupling connotation of new R&D institutions and national strategic science and technology forces. Coupling mainly refers to the process in which two or more subsystems and things are combined into an organic whole in a certain form and interact and influence each other. New R&D institutions and national strategic science and technology forces have significant coupling characteristics in theory and practice. It is shown in Fig. 1. New R&D institutions and the national strategy of science and technology strength of coupling are both nonlinear relationships of mutually dependent and interacting. Specifically, the coupling is a process through which new R&D institutions are embedded in national strategic science and technology forces to achieve resource sharing and complementary advantages and

promote the common development of both sides and the improvement of innovation capabilities. The basic connotation of the coupling is analyzed from four aspects: the goal, the way, the process, and the result.

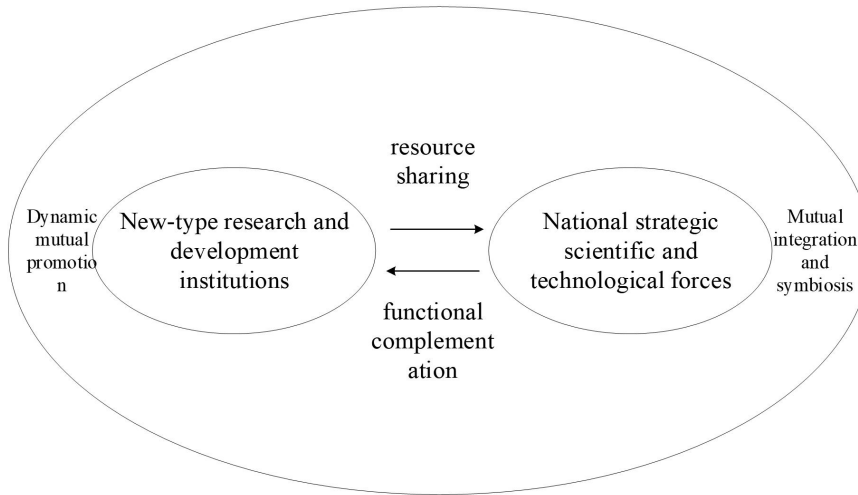


Fig. 1. Connotation analysis of the coupling between the two.

Firstly, the coupling development of the two is an efficient integration of resource sharing and complementary advantages. The coupled development of the two does not simply integrate new R&D institutions into the national strategic science and technology force system, but realizes their organic integration and mutual penetration through political, organizational, relational, and cultural embeddedness. Under the new situation, the flexibility and innovation of the new R&D institutions are combined with the authority and systematization of the national strategic science and technology forces, and the common development of the two sides is realized through resource sharing and complementary advantages. Among them, political embedding, organizational embedding, relational embedding, and cultural embedding, as the core mechanisms for the coupled development of new R&D institutions and national strategic science and technology forces, are systematically transformed into specific driving factors of the degree of coupling coordination. Political embedding, through policy supply, institutional guarantee, and strategic guidance, is transformed into an institutional coupling driving force, determining the institutional basis and policy stability of their collaboration; organizational embedding, through institutional integration, resource integration, and process connection, is transformed into a structural coupling driving force, influencing the organizational matching degree and operational efficiency of the collaborative subjects; relational embedding, through trust building, benefit sharing, and long-term cooperation, is transformed into a relational coupling driving force, determining the stability and depth of the collaborative network; cultural embedding, through value recognition, concept integration, and innovation consensus, is transformed into a cultural coupling driving force, influencing the behavioral consistency and innovation synergy in the collaborative process. The four types of embedding are interwoven and progress step by step, jointly constituting the driving chain for the transformation from “formal integration” to “substantive collaboration,” promoting the degree of coupling coordination to evolve from low-level loose association to high-quality deep integration.

Secondly, the coupled and coordinated development of the two is a process of mutual promotion

through dynamic optimization. The coupled and coordinated development of new R&D institutions and the national strategic science and technology forces can not only solve the bottleneck problem of new R&D institutions in technological innovation and market application, but also improve the innovation efficiency and market competitiveness of the national strategic science and technology forces. Through political embeddedness and relationship embeddedness, the government can build policy incentive mechanisms and social trust mechanisms to promote the cooperation and collaborative innovation between the two sides. Through organizational embeddedness and cultural embeddedness, new R&D institutions and national strategic science and technology forces can achieve integration in organizational structure and cultural concept, and improve the stability and sustainability of cooperation. This mutually promote process of dynamic optimization, not only promoted the innovation ability, also to expand the development space and on both sides of the market opportunities, so as to realize mutual promotion. Among them, political embedding refers to the government's use of policy incentives and institutional arrangements to deeply integrate new research and development institutions with the country's strategic science and technology forces into the political framework, establishing a collaborative innovation mechanism and a foundation of social trust. Organizational embedding refers to mutual infiltration in organizational structure between the two sides, achieving deep integration and stable collaboration through institutional alignment, resource integration, and process coordination.

Thirdly, the coordinated development of the two is the complementary innovation of functional value. The coupled development of new R&D institutions and national strategic science and technology forces aims to give full play to the flexibility and innovation of new R&D institutions, as well as the authority and systematization of national strategic science and technology forces, and realize the complementary role and superposition effect of the two through functional reorganization and value innovation. New R&D institutions can improve their R&D capabilities and innovation level by taking advantage of the policy support and resource advantages of national strategic science and technology forces. At the same time, the national strategic science and technology forces can better adapt to market demand and technological changes through the market sensitivity and flexibility of the new R&D institutions, and achieve a win-win situation of technological innovation and market application.

Fourth, the coupling coordination is a kind of multiple carrier mutual harmony symbiosis. The coupling coordination between new R&D institutions and national strategic science and technology forces involves innovation systems, industrial systems, infrastructure, space carriers, economic benefits, factor "flows," ecosystems (Edquist, 2019), and resources and markets. Interaction through multivariate, multi-field coupling, new technology R&D institutions and national strategy in different positions of the innovation chain embedding and coordination, promote the independent innovation ability promotion and optimization of the industrial structure. New research and development institutions may, for example, by embedding national strategy of science and technology innovation chain upstream of power, and the creative main body produces mutual exchange and resource sharing in the value chain, knowledge search cost and innovation risk, the level of knowledge technology spillover, and enhance industrial innovation complexity; At the same time, the new R&D technology industrialization of downstream link, embedded in national strategy will produce associated with upstream link between demand and technology spillovers through upstream link technology innovation, strengthen independent innovation ability.

(2) The coupling coordination degree index system. Scholars based on the reference (Dong *et al.*, 2023) the experience of system index selection and index evaluation system of building, in principle,

combined with the data availability, the coupling coordination degree of the construction of index system respectively from the basic conditions of national strategy of science and technology forces, strategic support, looking forward to leading layout, system, And for the development of new research conditions, research and development team, innovation and innovation efficiency considerations, as shown in Table 3.

**Table 3**

Evaluation system and index weight of the coupling between the two.

Layer of object	Criterion layer	Sub-criteria layer	Indicator layer	Units	Weight
National strategic science and technology power	Basic conditions	Resource input	R&D investment intensity	%	0.0526
			Total R&D investment	Ten thousand yuan	0.0289
		Infrastructure	Number of lab platforms	a	0.0661
			Major science and technology infrastructure construction	Number of points	0.0305
			Completion rate of major science and technology projects	%	0.0119
			Number of state-level science and technology awards	a	0.0458
	Strategic support	Industry contribution	Share of high-tech industry exports	%	0.0239
			Total revenue of high-tech industries	RMB'000	0.0406
	Forward-looking layout	Policy implementation	Implementation of science and technology policies	Score	0.0229
			Cutting-edge technology layout	Proportion of prospective research projects	%
		Number of forward-looking technology patent applications		a	0.0423
		High-level scientific research output		a	0.0802
		Forward-looking technical achievement conversion rate		%	0.0236
		System leadership	Regional synergy	Level of regional synergy in science and technology innovation	%
	Degree of regional innovation resource allocation			Score	0.0062
	Overall construction scale		Registered capital	RMB'000	0.0703
			Office and R&D site area	Square meters	0.0113
	New research and development organization	R&D conditions	R&D basic conditions	The unit price is more than ten thousand yuan of the original value of scientific research equipment	Ten thousand yuan
Number of national and provincial innovation platforms				a	0.0258
Size of R&D staff		Total number of R&D personnel	people	0.0103	
		The proportion of R&D personnel in the total number of people in the organization	%	0.0504	

Table 3. (continued)

Layer of object	Criterion layer	Sub-criteria layer	Indicator layer	Units	Weight
New research and development organization	R&D team	High-level innovative personnel	The number of innovation teams above the municipal level introduced	a	0.0603
			Number of high-level innovative talents	people	0.0115
	Innovative activities	Level of R&D investment	Total annual R&D expenditure	RMB'000	0.0369
			Proportion of annual R&D expenditure in total revenue	%	0.0222
	Innovative benefits	Achievement transformation benefits	Number of invention patents owned	a	0.0106
			Number of criteria for lead or participation in the last three years	a	0.0053
	Business incubation ability	Business incubation ability	Annual average income of the organization in the past three years	RMB'000	0.0622
			Annual average achievement transformation income of the organization in the past three years	Ten thousand yuan	0.0231
			Cumulative number of start-ups	home	0.0595
			Cumulative number of incubated businesses	home	0.0298

(3) Overall characteristics of coupling coordination degree. The coupling and coordination degree between newly established R&D institutions and China's national strategic science and technology forces in Guangdong Province exhibited a significant upward trend from 2016 to 2024, evolving through three distinct phases: (i) a low-level, loosely coupled stage; (ii) a rapid promotion phase; and (iii) a highly coordinated stage. Since 2018, the coupling coordination degree has exceeded the threshold of 0.8; it stabilized above 0.9 after 2020—indicating a transition from weak, superficial interaction to deep, systemic integration. Correspondingly, the system shifted from a “high-quality disorder” state in 2016 to a “well-coordinated” state by 2024.

① 2016–2017 on the brink of disorder stage. This stage new R&D innovation elements concentration is not enough, and the national strategy of science and technology forces device (such as the big science, state key laboratory) linkage mechanism is not perfect, the coupling coordination degree of the average annual growth rate is only 3.2%.

② 2018–2020 into the rapidly increasing stage, the coupling coordination degree of the average annual growth rate of 8.5%. New R&D innovation achievements transformation efficiency is significantly improved, and the alignment of demands with national strategy of science and technology also enhanced.

③ 2021–2024 entering the high-quality coordination stage. New research in the field of cutting-edge technology and the national strategy of form jointly, 2024 together accounted for over 60% of science and technology projects, drive coupling coordination degree is 0.95.

From the differences in characteristics, the coupling coordination degree, and the absolute difference of fluctuations (standard deviation), the U type is: The standard deviation of regional collaborative intensity declined steadily from 0.082 in 2016 to 0.058 in 2018, indicating an improvement in the proportionality and balance of interregional collaboration. It rebounded to 0.104 during 2019–2021—coinciding with the rapid establishment of new R&D institutions in several localities—before reaching

a peak of 0.121 in 2024, reflecting heightened spatial differentiation in frontier resource allocation. The coefficient of variation closely tracks this trend, suggesting that regional disparities are driven primarily by absolute differences rather than relative imbalances—highlighting the emerging risk of innovation polarization. At the policy level, the implementation of the “Double Ten” industrial cluster strategy in 2019 aimed to deepen collaborative integration; however, in the short term, it appears to have intensified interregional competition for innovation resources.

### 3.3. *The influence factors of coupling coordination degree*

(1) Variables, model, and the data. First, the core variable. National strategy of science and technology forces subsystem: R&D expenditure intensity: reflects the national strategic strength in R&D resources of science and technology forces, with R&D intensity (%) as a measure of financial investment, with a weight of 0.06612. Major R&D projects completion: measuring national strategy of science and technology forces in major task completion of implementation, major R&D projects to completion rate (%) as a measure, weight of 0.02984. The number of state-level science and technology awards reflects the performance of national strategic science and technology forces in innovation achievements. The number of state-level science and technology awards is taken as the measurement index, and the weight is 0.0612. High technology industry export proportion: measuring national strategic forces to reflect the contribution of industry science and technology, with high technology industry (%) as a measure of export accounted, weight of 0.02674. In terms of the subsystem of new R&D institutions, the registered capital reflects the overall construction scale of new R&D institutions. The registered capital (ten thousand yuan) is used as the measurement index, and the weight is 0.04355. Researchers to measure the total scale of the new R&D team, with R&D staff (people) as a measure, total weight of 0.02532. In total R&D spending: reflect the new R&D level of research and development institutions, with years of research and development spending (\$ten thousand) as a measure, weight of 0.03622. Invention patent ownership: measure R&D output levels, new research institutes to invention patent ownership (a) as a measure, weight of 0.02659.

Second, control variables. Local governments support: The local fiscal expenditure is a reflection of the various provinces' spending power; select the local fiscal expenditure/GDP to build the support of local government, weight of 0.02259. Information infrastructure: regional information infrastructure can break through time and space limits, innovation platforms for new R&D institutions improve the innovation of national strategic science and technology forces, resource integration, and national strategy provides information communication and transmission medium. It is expressed by the volume of post and telecommunications services per capita, and the weight is 0.01256. Regional economic development level; different regional economic development differences have a certain influence on the coupling of the two subsystems association dispatch meetings, select the per capita GDP, said weight of 0.04656. Development level of science and technology: local endowment, such as differences in the extent of the development of science and technology will affect the new R&D institutions and the coordinated development of national strategy of science and technology forces, choose the proportion of expenditure/GDP of science and technology, said the weight of 0.003. Industrial structure, industrial structure will affect the new R&D institutions and the development of the national strategy of science and technology forces, will also affect the coupling coordination of the two subsystems, here said the second industry to tertiary industry/regional industrial structure level, weight of 0.03902.

(2) Data and descriptive statistics. Data from “China Statistical Yearbook of Science and Technology”,

China Statistical Yearbook on the High-tech Industry (the Chinese statistical yearbook and annual report issued by the relevant government and institutions, the data are the average). The sample data cover the period from 2016 to 2024, and related indicators of new R&D institutions and national strategic science and technology forces in Guangdong Province are involved. All used in the name of the variable or more years for the base period using the provincial statistical yearbook published price index, the second and third industry price index GDP deflator. Descriptive statistics are shown in Table 4.

**Table 4**

Descriptive statistics in variables.

The variable name	Sample size	Mean	Standard deviation	Minimum	Maximum
The coupling coordination degree	425	0.553	0.623	0.020	0.960
R&D expenditure intensity	425	0.236	0.012	0.001	0.362
Major science and technology projects completion	425	0.335	0.221	0.126	0.598
National Science and Technology Reward Amount	425	0.652	1.361	0	0.861
Proportion of high-tech industry exports	425	0.526	0.396	0.005	0.723
The registered capital	425	0.425	0.523	0.351	0.669
Total number of R&D personnel	425	0.102	0.072	0.462	0.998
Total annual R&D expenditure	425	0.263	0.153	0.098	0.695
Number of invention patents held	425	0.880	0.002	0.536	0.881
Local government support	425	0.222	0.362	0.109	0.928
Innovation infrastructure	425	0.363	0.045	0.027	0.362
Regional economic development level	425	0.410	2.369	0.226	0.956
The development of science and technology level	425	0.962	0.556	0.112	0.309
The industrial structure	425	0.884	0.669	0.084	0.641

Note: The data in parentheses are robust standard errors. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively.

### 3.4. Econometric regression analysis

(1) Basic regression results. Table 5 presents the regression results examining factors influencing the coupling and coordination degree between China's national strategic science and technology forces and newly established R&D institutions. With reference to the existing research methods, Tobit model does not consider fixed effect, random effect Tobit model for regression analysis. Table 5 (1) column to report the results of the mixed Tobit model at the same time, the first column (2) the report did not join the results of the control variables, model (3) to join the results of control variables. On the basis of controlling the year fixed effect, it can be seen that the R&D investment intensity is significantly positive at the 5% level, indicating that the increase in R&D investment intensity significantly improves the coupling coordination degree; Major R&D projects completion, national science and technology reward number, total number of registered capital, research and development personnel, years of research and development spending, such as invention patent ownership are significant at the 1% level and are

positive, showing that the increase in these factors significantly improves the coupling coordination degree. However, high technology industry exports accounted for a significant at the 1% level, indicating that the negative effects on the coupling coordination degree.

**Table 5**

The basic factors influencing the coupling coordination degree of regression results.

Explanatory variables	Degree of coupling coordination			
	Mixed Tobit model	Random effects Tobit model	Random effects Tobit model	Marginal effect
	(1)	(2)	(3)	(4)
R&D investment intensity	0.013	0.022 ***	0.506 **	0.004 **
Completion rate of major science and technology projects (Number of major science and technology special projects)	0.263 **	0.069 ***	0.010 ***	0.008 ***
Number of national science and technology awards	0.222 ***	0.258 ***	0.004 ***	0.126 *
Share of high-tech industry exports (Share of revenue from high-tech products)	0.105 *	0.406 **	0.056 **	0.110 **
Registered capital	0.156 **		0.478 ***	
Total number of R&D personnel	0.369 **		0.113 ***	
Total annual R&D expenditure	0.586 *		0.403 ***	
Invention patent ownership	0.023 *		0.004 **	
Local government support	-0.023		0.015	
Constant term	-0.562	-0.481	-0.123	
Annual fixed effect	is	is	is	

Note: data in brackets for the robust standard error; \*, \*\*, \*\*\*, respectively at 10%, 5%, and 1% levels of statistical significance.

## (2) Endogeneity test

Reverse causality test. There may be a functional dependence between the above explanatory variables and the coupling coordination degree. In order to overcome the endogeneity problem caused by the possible bidirectional causality, the lagged term of the main explanatory variable is used as the substitute term for the Tobit regression. The regression results are shown in Column (3) of Table 6. The direction of the core explanatory variables is consistent with the basic regression results, and all of them pass the significance test, indicating that there is no reverse causality between the core explanatory variables and the coupling and coordination degree, and the regression results are relatively robust.

The instrumental variable method is used in the test. In order to further test the possible endogeneity of the model, the first-order lag term of R&D investment intensity is introduced as the instrumental variable, and the two-stage regression method is used for Tobit regression. Column (5) and column (6) of the endogeneity test in Table 6 report the estimated results. The empirical results of instrumental variables pass the validity test, and the regression results of the model are still robust.

**Table 6**

Endogeneity test results of factors affecting coupling and coordination degree.

Explained variable	Endogeneity test		Variable substitution test		Adding explanatory variables	Delete some control variables
	(5)	(6)	(7)	(8)		
R&D investment intensity			0.020 **	0.006 **	0.004 ***	0.008
Lag * R&D investment intensity	0.002 **	0.111 ***				
Completion rate of major science and technology projects		0.022 **		0.008 ***	0.023 ***	0.106 ***
Lag * Completion rate of major science and technology projects	0.021 ***					
Number of major science and technology special projects		0.006 *	0.003 ***		0.005 **	
Number of national science and technology awards		0.009 **	0.112 *	0.152	0.063 *	0.201 ***
Lag * Number of state-level science and technology awards	0.003 **					
Share of high-tech industry exports		0.081 **			0.004 ***	0.633 ***
Lag * Share of exports in high-tech industries	0.005 ***					
Percentage of revenue from high-tech products		0.223 **	0.336 ***	0.003 ***	0.086 ***	
Registered capital	0.236 **	0.965 *	0.854	0.486 **	0.044 *	0.040 **
Total number of R&D personnel	0.105 **	0.542 ***	0.621 **	0.412 **	0.069 ***	0.604 *
Total annual R&D expenditure	0.639	0.339 **	-0.059	-0.556	0.036 **	
Number of invention patents owned	0.235	0.105 *	0.026 ***	0.363 *	0.014	0.416 **
Local government support	0.110 ***	0.006 **	0.044	0.003 *	0.009 ***	
Innovation infrastructure					0.109 ***	
Level of economic development by region						
Level of science and technology development					0.006 *	
Industry structure					0.007	
Constant term	0.568 ***	0.229 ***	0.556 **	0.645 **	-0.954	0.116 ***
Year fixed effects	is		is	is	is	is

Note: The data in parentheses are robust standard errors. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively.

### (3) Robustness test

① Variable substitution test. In order to verify the robustness of the core explanatory variables, the method of variable substitution was used for testing. As the proxy variable of the completion rate of major science and technology projects, the number of major science and technology projects is selected as the proxy variable. The number of major science and technology projects reflects the ability of national strategic science and technology forces in undertaking science and technology projects, and has a high correlation with the completion rate of major science and technology projects. The estimated results are shown in Table 6. The core explanatory variables in the left column of the replacement test all pass the significance test. As the proxy variable for the proportion of high-tech industry exports, the proportion of high-tech product revenue is selected as the proxy variable. The revenue share of high-tech products can reflect the latest achievements of national strategic science and technology forces in the development of new technologies and new products, and has a strong substitution with the export share of high-tech industries.

② Adding explanatory variables. In order to further verify the robustness of the model, we add the following control variables on the basis of the original model: information infrastructure, regional economic development level, science and technology development level, and industrial structure. It can be seen from Table 6 that after adding control variables, the regression results of core explanatory variables are still robust, and the impact of new variables on the coupling and coordination degree is small, indicating that the model has good robustness.

③ Some control variables are deleted. In order to verify the robustness of the model, we deleted some control variables for testing. Specifically, the following variables were deleted: The regression results are shown in Table 6 by deleting some control variables. The four core explanatory variables and the remaining control variables in the regression results are consistent with the basic regression results, and all pass the significance test, which further indicates that the empirical analysis of the model has certain robustness. There is no “spurious regression” problem.

## 4. Results and Conclusions

### 4.1. Main conclusions

After in-depth research, the following conclusions have been drawn:

First, the coupling coordination degree between the new research and development institutions in Guangdong Province and the national strategic science and technology forces has shown a significant upward trend on the whole, going through an evolution process of “low-level coordination—rapid improvement—high-level synergy.” Specifically, the coupling coordination degree exceeded the 0.8 threshold in 2018 and has remained above 0.9 since 2020, indicating that the interaction between the two has gradually shifted from loose association to deep synergy. In terms of stage division, it was on the verge of imbalance from 2016 to 2017, entered a period of rapid improvement from 2018 to 2020, and entered a high-quality coordination stage from 2021 to 2024. This finding reveals the dynamic evolution law of the coupling coordination between new research and development institutions and national strategic science and technology forces, extending the existing research from static structural analysis to a dynamic process perspective, and providing new empirical evidence for understanding the phased characteristics of the coordinated evolution of multiple innovation subjects.

Second, the analysis results based on the Tobit panel model show that factors such as the intensity of R&D investment, the completion rate of major science and technology projects, the number of national-level science and technology awards, registered capital, the total number of R&D personnel, the total annual R&D expenditure, and the number of invention patents have a significantly positive impact on the coupling coordination degree, while the proportion of high-tech industry exports has a negative impact. Through endogeneity and robustness tests, the regression results of the model remain stable, verifying the validity of the influencing factors and the reliability of the conclusions. This finding empirically identifies the key factors driving coupling coordination, especially the negative effect of the proportion of high-tech industry exports, revealing the potential tension between “scale expansion” and “synergistic quality” and providing a new theoretical explanation for optimizing the allocation of innovation resources.

Third, the regional regression results show that the influencing factors vary among different regions. Although the core explanatory variables generally have a positive impact on the coupling coordination degree, the specific impact degrees differ among regions. For instance, the new product sales revenue of high-tech industries has a negative impact on the coupling coordination degree in both the eastern and central regions, which may be related to the misalignment of scale benefits and innovation capabilities of high-tech industries in these regions. This finding deepens the understanding of the heterogeneity of regional innovation systems, reveals that the same factor may have different mechanisms of action in different regions, and provides a theoretical basis for the formulation of differentiated regional policies, expanding the regional comparative perspective of innovation synergy research.

Fourth, new R&D institutions coordinate with the national strategic science and technology forces through political, organizational, relational, and cultural embedding. Political and relational embedding under government leadership is positive, while organizational and cultural embedding under market leadership is negative, influencing multi-subject industrial collaborative innovation. The coupling degree between new R&D institutions and the national strategic science and technology forces is constrained by technological gaps and transformation capabilities; a small technological gap and strong transformation capabilities lead to a strong coupling. The coupling relationship reflects different values in the embedding of the upstream and downstream of the innovation chain; upstream embedding is conducive to industrial innovation, while downstream embedding is conducive to enhancing the complexity of industrial innovation, promoting the overall development of industrial collaborative innovation, and enhancing national science and technology strength and industrial competitiveness. This finding systematically reveals the differentiated directions and boundary conditions of multiple embedding mechanisms from the perspective of embedding theory, constructs a theoretical analysis framework of “embedding mode—dominant force—synergy effect,” breaks through the existing research’s understanding of the single dimension of embedding mechanisms, and provides a systematic theoretical explanation and practical guidance for the integration of new R&D institutions into the layout of the national strategic science and technology forces.

#### *4.2. Management insights and suggestions*

Based on the above research findings, the following management suggestions are proposed:

First, strengthen dynamic process management and drive the coupling-coordination system toward a higher-level evolution. The coupling coordination between new R&D institutions and national strategic science and technology forces has entered a high-quality development stage with obvious evolution

characteristics. It is suggested to establish a dynamic monitoring and early warning mechanism to observe the degree of coupling coordination, regularly assess the collaborative status of the two, and prevent the relationship of “deep collaboration” from descending into “solidified disconnection.” At the same time, afford differentiated policy supply according to different development stages: focus on policy guidance and resource injection during the rapid improvement period, and shift to mechanism optimization and ecological construction during the high-quality coordination period to ensure that the coupling relationship continues to deepen and spiral upward in the dynamic evolution.

Second, focus on key influencing factors and implement precise and differentiated policy regulation. Factors such as R&D expenditure intensity, the total number of R&D personnel, and the number of invention patents have a significant positive impact on the degree of coupling coordination. These should be taken as the core handles for policy resource allocation, and continuous investment in basic research and talent cultivation should be made. In response to the negative impact of the proportion of high-tech industry exports, it is necessary to be vigilant against the problem of “scale expansion masking collaborative quality” and guide enterprises to shift from an export-oriented approach to an innovation collaboration-oriented approach. At the same time, fully consider regional heterogeneity. Developed regions should strengthen the spillover effect of innovation, while less developed regions need to increase policy inclination and platform co-construction efforts to avoid the intensification of innovation polarization and regional imbalance.

Third, deepen the multi-embedded mechanism reform and build a collaborative system between the upstream and downstream of the innovation chain. As the coupling between new R&D institutions and national strategic science and technology forces depends on the joint effect of political, organizational, relational, and cultural embedding, it is suggested that the government play a leading role in political and relational embedding, building cross-institutional collaborative platforms and trust mechanisms, and, at the same time, respect market laws in organizational and cultural embedding and avoid administratively forced integration. In the layout of the innovation chain, upstream embedding should focus on basic research and breakthroughs in frontier technologies, while downstream embedding should focus on enhancing the complexity and conversion efficiency of industrial innovation. By narrowing the technological gap and enhancing conversion capabilities, a new pattern of integrated development characterized by “vertical integration and chain-like collaboration” can be promoted.

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## Conflicts of Interest

The authors declare no conflict of interest.

## References

- Burt, R. S., 1995. Structural holes : the social structure of competition. *Harvard University Press*.
- Castellacci, F., & Lie, C. M., 2012. Do the effects of R&D tax credits vary across industries? A meta-regression analysis. *Research Policy*, 44(4): 819-832.

- Charles, B. M., 1967. Strategic power and Soviet foreign policy. *American Political Science Review*, 61(3): 863.
- Dong, G. L., Ge, Y. B., & Liu, J. J., et al., 2023. Evaluation of coupling relationship between urbanization and air quality based on improved coupling coordination degree model in Shandong Province, China. *Ecological Indicators*, 154.
- Edquist, C., 2019. Towards a holistic innovation Research policy: can the Swedish National Innovation Council (NIC) be a role modell. *Research policy*, 48(4): 869-879.
- Edward, A. K., 1972. Strategic power and national security. *Scientific Journal of Silesian University of Technology*, 34(4): 1298-1300.
- Fan, C. L., & Li, Z., 2022. The Positioning and Role of National Research Institutions in the National Strategic Scientific and Technological Forces. *Bulletin of the Chinese Academy of Sciences*, 37(05): 642-651.
- Fan, G., & Fan, J. P., 2022. National Strategic Science and Technology Forces: New-Type Research Institutions. Beijing: China Economic Press.
- Fang, Y., & Qiu, X., 2025. Dual Policy–Market Orchestration: new R&D institutions Bridging Innovation and Entrepreneurship. *Administrative Sciences*, (08): 289.
- He, P., Jin, L., & Xia, L. B., et al., 2023. Research on the Technology Transfer Mechanism of new R&D institutions in Life Sciences and Medicine. *Engineering Science*, 25(05): 81-91.
- Li, J., Fang, H., & Fang, S. R., et al., 2018. Investigation of the Relationship among University–Research Institute–Industry Innovations Using a Coupling Coordination Degree Model. *Sustainability*, (06): 1954.
- Liao, C. B., 1999. Quantitative Evaluation and Classification System of Coordinated Development between Environment and Economy: A Case Study of the Pearl River Delta Urban Agglomeration. *Tropical Geography*, (02): 76-82.
- Lin, J., Jian, J. Z., & Nanekaran, Y. A., 2022. A study on bilateral matching of team-science talents in new R&D institutions based on grey correlation-cloud model. *Journal of Intelligent & Fuzzy Systems*, (01): 813-840.
- Liu, N., Wang, X. L., & Han, H. B., 2015. Research on the Spatio-temporal Characteristics and Driving Mechanism of the Coupled and Coordinated Development of University Scientific and Technological Innovation and High-tech Industrial Innovation. *Science of Science and Management of science and technology*, 36(10): 59-70.
- Liu, Q. L., & Zeng, L., 2022. Research on the Composition and Functional Forms of the Main Body of National Strategic Science and Technology Forces. *China Forum on Science and Technology*, (05): 1-10.
- Meng, W., & Song, J. J., 2019. Research on the Performance Evaluation of new R&D institutions: A Dual Perspective of Resource Dependence and Social Influence. *Science Research Management*, 40(08): 20-31.
- Peng, D. Y., & Liu, C. M., 2011. Research on the Upgrading of Cluster Enterprises from the Perspective of the Coupling of Industrial Clusters and Global Value Chains. *Journal of Nanchang University (Humanities and Social Sciences Edition)*, 42(01): 52-58.
- Ren, J. Z., & Wan, C. G., 1994. System Coupling and Desert-Oasis Grassland Agricultural System: A Case Study of the Qilian Mountains-Linze Profile. *Acta Prataculturae Sinica*, (03): 1-8.
- Ren, Z. K., Li, D. L., & Ma, W. C., et al., 2024. Cultivation of National Strategic Scientific and Technological Forces and Development of new R&D institutions: An Embedded Perspective. *Studies in Science of Science*, 42(11): 2295-2304.
- Ren, Z. K., 2023. Organizational Embeddedness of New R&D Institutions: Theoretical Connotations and Evolutionary Logic. *Science and Technology Management Research*, 43(24): 17-24.
- Shi, W., Huang, K. X., & Chen, Z. Y., et al., 2023. Influencing Factors and Mechanism Model of Technology Transfer in new R&D institutions: An Exploratory Case Study Based on Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences. *Science and Technology Management Research*, 43(02): 127-133.
- Steinberg, P. J., Procher, V., & Urbig, D., 2015. Governance Models of R&D Offshoring: Innovation Performance and the moderating role of Absorptive Capacity. *Governance*, 21-23.
- Su, J., & Zhang, Y., 2021. Coupling Coordination Analysis of Science and Technology Innovation and Regional Economy in Hainan Province. *Science and Technology Management Research*, 41(14): 19.
- Tan, L., & Chen, Y. S., 2015. Research and Suggestions on the Construction Model of new R&D institutions in Guangdong. *Science and Technology Management Research*, 35(20): 45-49.
- Wang, J., Sun, Y. Q., & Yang, Z. W., et al., 2024. Thoughts on the Transformation of Ecological Protection and Restoration from the Perspective of Coupling between Natural Resources, Socioeconomy and Ecosystems. *Geological Bulletin of China*, 43(08): 1297-1304.
- Wang, S. J., Kong, W., & Ren, L., et al, 2021. Misunderstandings and Corrections of Coupling Coordination Degree Models in China. *Journal of Natural Resources*, 36(03): 793-810.

- Wei, W., Fu, Y., & Yang, C. F., 2020. Research on the Measurement of Technological Innovation and High-Quality Economic Development: Based on the Coupling Coordination Degree Model. *China Forum on Science and Technology*, (10): 76-83.
- Xu, S. B., Jia, J. D., & Zhong, W. J., 2022. Systematic Research on National Strategic Science and Technology Forces. *China Forum on Science and Technology*, (03): 18.
- Xu, Y. P., Chen, S., & Zhuang, L. X., 2022. Classification and Evaluation of new R&D institutions in Fujian Province: Based on Data from 147 new R&D institutions. *Science and Technology Management Research*, 42(14): 43-49.
- Xue, M. H., Din, M. L., & Yin, X. M., 2025. The Leading Driving Force for Cultivating and Developing New Quality Productive Forces with National Strategic Science and Technology Strength: Theoretical Logic and Strategic Path. *China Forum of Science and Technology*, (05): 50-59.
- You, Y., Liu, Y., & Zhao, R. X., 2024. Measurement of Coupling Synergy between Local Innovation Networks and Global Innovation Networks: An Empirical Analysis Based on Provincial Data in China. *Studies in Science of Science*, 42(07): 1513-1526.
- Zhang, D., Xue, L., & Liang, Z., et al., 2024. Experiences and Insights of High-level Research Universities in Playing the Role of National Strategic Science and Technology Forces. *Research in Higher Education of Tsinghua University*, 45(04): 4659.
- Zhang, Y. L., Zhang, G. Y., & Ma, W. C., et al., 2022. What kind of new R&D institutions have higher innovation performance? - A configurational analysis based on the TOE framework. *Studies in Science of Science*, 40(04): 758-768.
- Zheng, S. H., & Chen, H. J., 2023. Research on Leading National Strategic Science and Technology Forces by Leading Science and Technology Enterprises. *Journal of Zhejiang University of Technology (Social Sciences Edition)*, 22(01): 61-67.
- Zheng, S. I., Han, X. Y., & Guo, X. D., et al., 2024 National Strategic Science and Technology Forces and Breakthroughs in Key Core Technologies of Enterprises: Evidence from National and Provincial Key Laboratories. *China Industrial Economics*, (09): 62-80.