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Innovation Consortia: Conceptual Characteristics, Organizational Models, and Dynamic Mechanisms

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Abstract. In response to the current situation in which China faces "bottleneck" problems in key core technologies and insufficient strength in scientific and technological innovation, China has clearly proposed the establishment of innovation consortia to undertake major scientific and technological projects. However, as the latest model of China's industry–university–research practice, theoretical research on innovation consortia is still in its initial stage, and a systematic framework has not yet been formed. Taking the practical models of innovation consortia as the entry point, and on the basis of reviewing studies on the dynamic mechanisms of industry–university–research collaborative innovation, this paper combines policy documents, theoretical research, and practical cases, and conducts a layer-by-layer analysis according to the framework of "conceptual connotation—organizational models—dynamic mechanisms." First, it defines the conceptual connotation of innovation consortia. Second, it summarizes five types of organizational models: enterprise-led, university-led, research institute-led, government-led, and innovation platform-supported models. Finally, taking the enterprise-led model as an example, it constructs an integrated framework of dynamic mechanisms that includes the core layer—strategic integration, knowledge integration, and organizational integration; the support layer—government strategic guidance, policy support, and institutional guarantee; and the environmental layer—international competition, market, technology, intermediary institutions, and regional economy. This study aims to provide theoretical guidance and practical implications for the construction of innovation consortia.

Keywords: innovation consortium, enterprise-led model, conceptual connotation, organizational model, dynamic mechanism

1. Introduction

With the deepening of a new round of scientific and technological revolution and industrial transformation, China's problems of "bottlenecks" in key core technologies and insufficient strength in scientific and technological innovation have become increasingly prominent [1]. Traditional models of joint research, such as R&D alliances and industry–university–research cooperation, are mainly characterized by loose coupling and market-driven mechanisms. They are difficult to adapt to the needs of high-quality development and are also unable to solve bottlenecks such as the mismatch between technological supply and demand and the separation between scientific research

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and the economy [2]. China's "14th Five-Year Plan" and the 2021 Law on Scientific and Technological Progress clearly propose supporting enterprises in taking the lead in establishing innovation consortia to undertake China's strategic scientific and technological projects, with the aim of strengthening the position of enterprises as the main body of innovation and promoting breakthroughs in key core technologies. However, the current construction of innovation consortia faces difficulties such as unclear functional positioning, unclear organizational forms, imperfect management mechanisms, and institutional and mechanism-related obstacles. The willingness of innovation actors to collaborate and their degree of integration still need to be improved [3].

Existing studies have conducted preliminary discussions from such aspects as conceptual connotation [4], governance mechanisms [5], and influence effects [6]. However, these studies are scattered and fragmented. They have neither clarified the conceptual connotation nor reached a consensus on organizational models, and they further lack an integrated framework for dynamic mechanisms. In view of this, this study takes the practical models of innovation consortia as the entry point and deconstructs them layer by layer according to the analytical framework of "conceptual connotation—organizational models—dynamic mechanisms," with the aim of constructing a relatively complete theoretical framework and providing practical implications for the construction of innovation consortia.

2. Literature review and theoretical perspective

Innovation consortium is a Chinese-style innovation concept derived from policy, and theoretical research on it is still in its initial stage. However, because innovation consortia are similar to industry–university–research collaborative innovation in terms of organizational form, research on the dynamic mechanisms of the latter has important reference value.

Etzkowitz and Leydesdorff proposed the "Triple Helix" innovation model [7]; Barnes proposed the "behavior–process–performance" model [8]; Zhu Guilong et al. adopted the "elements–process–performance" model [9]; Chen Jin et al. constructed a collaborative innovation framework from the dimensions of integration and interaction intensity [10]; Wu Yue et al. emphasized key influencing factors such as environmental factors, willingness to collaborate, and knowledge differences [11]; Rao Yanting pointed out that collaboration among multiple elements, including innovation actors, goals, organizations, institutions, and environments, is needed [12]; Zou Bo et al. proposed "goal–structure–process" collaboration [13]; and Wang Jinfu et al. constructed an analytical framework from dynamic collaboration, path collaboration, and knowledge management collaboration [14].

He Yubing proposed the "strategy–knowledge–organization" collaborative framework of industry–university–research cooperation, emphasizing that the core of the collaborative process lies in the collaboration among such elements as the strategies, knowledge, and organizations of innovation actors, and that it relies on the external environment, including policy support, institutional guarantee, technological promotion, market drive, science and technology intermediaries, and financial institutions [15]. This framework echoes the studies of the above-mentioned scholars and is applicable to the analysis of the dynamic mechanisms of multi-actor innovation cooperation. Therefore, this study draws on this framework and, taking the most universal enterprise-led innovation consortium as an example, constructs an integrated framework of dynamic mechanisms.

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3. Conceptual characteristics and organizational models of innovation consortia

3.1. Definition of conceptual connotation

In 2020, the Fifth Plenary Session of the 19th Central Committee clearly proposed "supporting enterprises in taking the lead in establishing innovation consortia." In 2021, the Law on Scientific and Technological Progress encouraged the establishment of cooperation mechanisms featuring complementary advantages, shared achievements, and shared risks. At the 2021 Conference of Academicians of the Chinese Academy of Sciences and the Chinese Academy of Engineering, it was emphasized that innovation consortia should be constructed with leading enterprises taking the lead, universities and research institutes providing support, and various actors collaborating with one another. In 2022, the work conference on central state-owned enterprise innovation consortia required the creation of an upgraded version of innovation consortia. In addition, existing studies have defined innovation consortia from different perspectives: Sun Bingmei et al. emphasized the traction of strategic scientific and technological forces [16]; Bai Jingyu et al. proposed that they are new alliances that are either physical organizations or have equity-related connections [17]; and Liu Xielin et al. argued that they are important carriers for achieving self-reliance and self-strengthening in science and technology [18].

By integrating policy documents and theoretical research, this paper defines innovation consortia as follows: to strengthen strategic scientific and technological forces, they are a new model of deep industry–university–research integration organized by the government as the organizer, in which enterprises, universities, research institutes, and other actors are encouraged to form consortia according to such principles as market orientation, equity distribution, benefit sharing, and risk sharing. In essence, they are innovation carriers or communities of interests characterized by efficient multi-actor collaboration oriented toward breakthroughs in key core technologies. Their characteristics include goal compatibility, interest integration, element complementarity, link integration, and self-organization.

3.2. Summary of organizational models

According to differences in leading actors and functional positioning, this study divides innovation consortia into five types of organizational models (see Figure 1).

First, the enterprise-led model. This model is led by leading enterprises and organizes innovation activities around market demand and enterprises' core technologies. Enterprises serve as the problem setters and are responsible for the direction of technological breakthroughs, target tasks, operating mechanisms, and other aspects. At the same time, market-oriented operation is adopted to achieve deep integration between science and technology and the market. Examples include the Shaanxi Province High-End CNC Machine Tool Innovation Consortium and the Anhui Province Intelligent Human–Computer Interaction Innovation Consortium.

Second, the university-led model. In this model, universities determine the direction of technological breakthroughs and operating mechanisms, and give full play to their advantages in cultivating strategic scientific and technological talent and conducting basic research. It is applicable to fields where leading science and technology enterprises are scarce or where there are high requirements for basic research, such as the Western China Science and Technology Innovation Harbor.

Third, the research institute-led model. This model gives full play to the advantages of research institutes as "engines" of original scientific and technological resources and "incubators" of original

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innovation, and promotes resource allocation and chain integration, such as the joint research and development conducted by the Chinese Academy of Sciences in fields such as biomedicine and information technology.

Fourth, the government-led model. With policies and funding as the links, this model carries out overall design and conducts "organized scientific research" to solve common technological problems in industries, such as the Jiangsu Industrial Technology Research Institute and Zhejiang Lab.

Fifth, the innovation platform-supported model. Relying on platforms such as national laboratories and technology innovation centers, this model involves the joint participation of multiple parties and undertakes key technological breakthroughs in key industries, such as the Suzhou Hydrogen Energy Innovation Consortium.

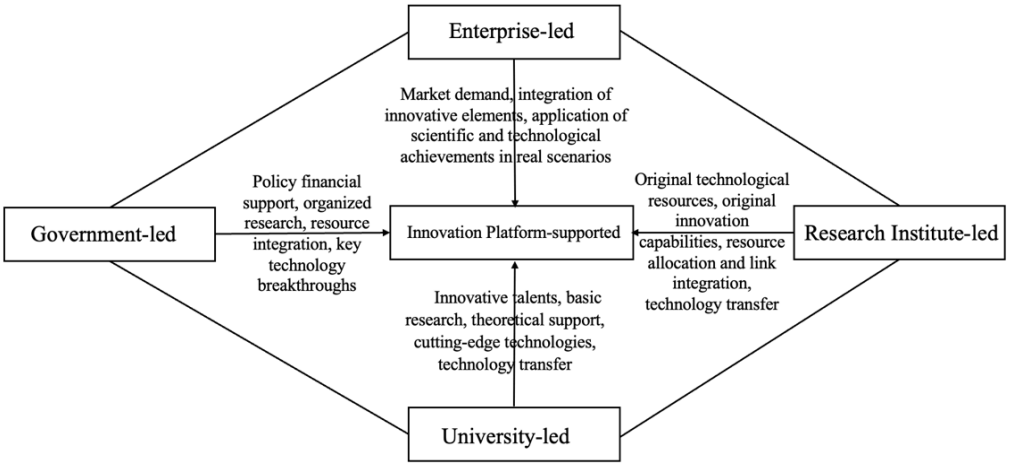

Figure 1. Different organizational models of innovation consortia

4. Dynamic mechanisms of enterprise-led innovation consortia

Drawing on the "strategy–knowledge–organization" collaborative framework, this paper constructs an integrated framework of the "core layer–support layer–environmental layer" dynamic mechanisms of enterprise-led innovation consortia (see Figure 2). The core layer focuses on the interaction and integration among innovation actors, including strategic integration, knowledge integration, and organizational integration. The support layer focuses on the role of government, such as strategic guidance, policy support, and institutional guarantee. The environmental layer emphasizes the influence of external factors, including international competition, market demand, technological promotion, science and technology intermediary institutions, and the regional economic foundation.

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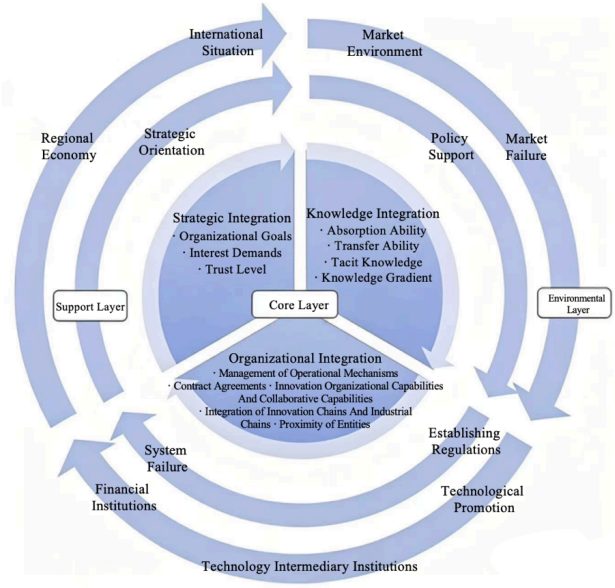

Figure 2. Integrated framework of the dynamic mechanisms of enterprise-led innovation consortia

4.1. Core layer of the dynamic mechanisms of enterprise-led innovation consortia

The core layer of the dynamic mechanisms of enterprise-led innovation consortia focuses on the deep integration among innovation actors such as enterprises, universities, and research institutes, and pays attention to and emphasizes the influence effects of the internal motivation of innovation actors on cooperative innovation. Specifically, it includes the guiding force of strategic integration, the collaborative force of knowledge integration, and the guaranteeing force of organizational integration. Among them, strategic integration is the foundation, knowledge integration is the core, and organizational integration is the guarantee.

(1) Guiding Force of Strategic Integration

First, the integration of organizational goals. Innovation consortia are jointly committed to breakthroughs in key core, generic, basic, and underlying "bottleneck" technologies and to the strengthening of strategic scientific and technological forces. They are a systematic and task-oriented model of deep industry–university–research integration.

Second, the integration of interest demands. Interest drive is the fundamental internal driving force of cooperative innovation [19]. Innovation consortia are physical communities of interests, breaking through the limitations of short-term project cooperation. Enterprises obtain theoretical knowledge and cutting-edge technologies, while academic and research institutions obtain funding and market information, thereby forming a dynamic balance.

Third, the establishment of trust relationships. Good trust alleviates short-sighted behavior, suppresses opportunism, enhances information transparency, and promotes long-term and in-depth cooperation. However, excessive trust that neglects supervision may also leave risks.

(2) Collaborative Force of Knowledge Integration

Knowledge integration refers to the transfer, absorption, sharing, integration, and re-creation of knowledge among actors. The absorptive capacity of enterprises and the knowledge transfer capacity of universities are crucial. The tacit characteristics of knowledge affect the effectiveness of transfer; therefore, strengthening the position of enterprises as the main body of innovation and promoting the concentration of elements toward enterprises become the essential points. However, knowledge integration is affected by factors such as strategic goals, partner selection, trust level,

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actor proximity, and the vision of knowledge transfer. It is necessary to establish transparent mechanisms, build knowledge integration platforms, and reduce knowledge friction and gradient differences [20].

(3) Guaranteeing Force of Organizational Integration

First, sound operation and management mechanisms and contractual agreements should be established. Mechanisms such as interest distribution, risk sharing, communication and coordination, and property-right protection break through the limitations of short-term cooperation. Formal contracts establish rights and obligations and suppress opportunism.

Second, a technology innovation system featuring deep industry–university–research integration should be established. Leading enterprises give full play to their innovation organization and management capabilities and integrate industrial-chain resources. Universities and research institutes give full play to their advantages in original innovation and organize interdisciplinary technological breakthroughs.

Third, multidimensional proximity promotes organizational integration. Geographical proximity promotes the dissemination of tacit knowledge; technological proximity is a necessary condition for knowledge exchange; and organizational and cognitive proximity enhance trust and reduce risks.

(4) Cooperation Risks

The construction of innovation consortia also faces risks such as differences in organizational goals and interest demands, knowledge and technology spillovers, opportunistic behavior, uneven interest distribution, and innovation path dependence [21]. For example, enterprises focus on short-term commercial value, while universities focus on basic research, resulting in a disconnection between supply and demand; knowledge and technology spillovers also hinder cooperative innovation.

4.2. Support layer of the dynamic mechanisms of enterprise-led innovation consortia

The support layer of the dynamic mechanisms of enterprise-led innovation consortia focuses on and emphasizes the role of government, such as strategic guidance, policy support, and guarantees through rules and regulations. However, as an emerging model, the construction process of innovation consortia involves systemic failure problems such as the absence of guidance for establishment, insufficient resource supply, imperfect incentive mechanisms, and inadequate systems of laws and regulations for supervision and management.

(1) Strategic Task Orientation

Policies such as the "14th Five-Year Plan" and the Law on Scientific and Technological Progress clearly support enterprises in taking the lead in establishing innovation consortia and undertaking breakthroughs in key core technologies. Beijing, Chongqing, Guangdong, and other places have deployed the construction of innovation consortia in light of their own conditions, forming systematic and task-oriented models of technological breakthroughs.

(2) Science and Technology Policy Support

The construction of innovation consortia is affected by such elements as funding, technology, talent, and platforms, and requires comprehensive policy support. Measures such as R&D subsidies, tax incentives, and science and technology commissioners alleviate constraints on funding and talent. For example, Zhejiang Province issued guidelines for the construction of innovation consortia, provided subsidies, commissioners, and platform systems, and successfully established several high-level innovation consortia.

(3) Guarantees Through Rules and Regulations

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The government supervises and constrains opportunistic behavior by establishing rules and regulations, thereby providing guarantees for technological innovation. However, attention should be paid to being "proactive" without "overstepping," and specific operating mechanisms should be independently formulated by participating members. Shaanxi, Zhejiang, and other provinces require the signing of the Agreement on the Establishment of an Innovation Consortium, clarifying project management, intellectual property protection, interest distribution, and other matters.

(4) Innovation System Failure

At present, China's scientific and technological innovation system has problems such as unreasonable allocation of scientific and technological resources, incomplete industry–university–research cooperation mechanisms, and immature innovation policies, which constrain the connection between the innovation chain and the industrial chain. Innovation consortia emphasize the combination of top-down overall design and bottom-up flexible establishment, and achieve voluntary participation and open competition through the "open competition mechanism for selecting the best candidates" and the "horse-racing mechanism," so as to overcome system failure.

4.3. Environmental layer of the dynamic mechanisms of enterprise-led innovation consortia

(1) New Situation of International Competition

Western countries continue to impose technological blockades and suppression on China, while deglobalization has led to a narrowing of technological sources and intensified supply-chain security risks. China's proposal to establish innovation consortia reflects policy needs of an emergency nature that are clearly higher than routine needs.

(2) Market Environment

First, market demand. Market demand is the basic starting point of innovation activities, driving enterprises to improve technologies and seek cooperation. The monoclonal antibody innovation consortium operates according to the principles of "risk sharing and benefit sharing" and is market-oriented.

Second, market competition and risks. When market competition is intense, enterprises are more willing to participate in cooperative innovation in order to share costs and risks. In fields such as big data and new energy, high-level innovation consortia such as computing power networks, smart energy, and intelligent vehicles have already emerged.

Third, market failure. Technology R&D has long cycles, high risks, and difficulties in achievement transformation. Knowledge and technology spillovers and "free-riding" behavior lead to inefficient allocation of market resources [22].

(3) Technological Promotion

In the face of the "bottleneck" problems of key core technologies, point-to-point collaboration is difficult to adapt to new requirements. As a supply system for generic technologies, innovation consortia have become a better strategic choice [23].

(4) Science and Technology Intermediary Institutions and Financial Institutions

Science and technology intermediary institutions have functions such as technology diffusion, achievement transformation, and allocation of innovation resources, and serve as bridges for industry–university–research integration. Science and technology financial institutions promote the connection between science and technology and finance through fiscal, tax, and financial instruments. Together, the two optimize the allocation of innovation resources and constitute important driving forces for the operation of innovation consortia.

(5) Regional Economic Foundation

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A sound regional economic environment, including complete industrial chains and resource agglomeration, provides a solid foundation for innovation consortia. Shanghai, Beijing, Suzhou, Ningbo, and other places have successfully built high-level innovation consortia in multiple fields. If the industrial foundation is weak and leading enterprises are lacking, the leading role of high-level research universities can be brought into play, such as the Western China Science and Technology Innovation Harbor.

5. Conclusions and prospects

5.1. Research conclusions

First, innovation consortia are a new model of deep industry–university–research integration guided by the government and established by multiple actors according to market-oriented principles. In essence, they are communities of interests oriented toward breakthroughs in key core technologies.

Second, according to differences in leading actors and functional positioning, innovation consortia can be divided into five types of organizational models: enterprise-led, university-led, research institute-led, government-led, and innovation platform-supported models.

Third, the integrated framework of the dynamic mechanisms of enterprise-led innovation consortia includes the core layer, which consists of strategic integration, knowledge integration, organizational integration, and cooperation risks; the support layer, which consists of government strategic guidance, policy support, institutional guarantee, and innovation system failure; and the environmental layer, which consists of international competition, market environment, technological promotion, science and technology intermediaries, and regional economic foundation.

5.2. Limitations and prospects

This study lacks support from empirical data and mathematical modeling methods. The constructed dynamic mechanism model is applicable only to the enterprise-led model, and its applicability in different industrial environments needs to be further tested. Future research should adopt empirical research methods to explore the specific needs and challenges of various types of innovation consortium models under different industrial backgrounds, so as to enrich and improve the dynamic mechanism model.

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