American Journal of Industrial and Business Management, 2026, 16(5), 525-543
https://www.scirp.org/journal/ajibm
ISSN Online: 2164-5175
ISSN Print: 2164-5167

A Review of Innovation Consortia Research: Conceptual Evolution, Organizational Mechanisms, and Operational Logic

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How to cite this paper: Zhao, Y., Fan, M. X., & Yang, J. (2026). A Review of Innovation Consortia Research: Conceptual Evolution, Organizational Mechanisms, and Operational Logic. *American Journal of Industrial and Business Management, 16,* 525-543.
https://doi.org/10.4236/ajibm.2026.165028

Received: April 18, 2026
Accepted: May 24, 2026
Published: May 27, 2026

Abstract

Against the backdrop of accelerating knowledge flows and increasingly urgent demands for breakthroughs in key technologies, various organizational forms centered on collaborative R&D have emerged continuously. Internationally, Research Joint Ventures (RJVs) and Research Consortia have been proven effective in internalizing technology spillovers, sharing R&D risks, and have played significant developmental roles in high-tech industries such as semiconductors and biomedicine. However, the concept of "Innovation Consortium" proposed in China in recent years, while drawing upon international experience, places greater emphasis on enterprises' leading role in technological innovation, government's organizational guidance in major missions, and the deep integration of diverse entities at the industrial chain and innovation chain levels, forming a cooperative R&D organizational model with distinctive contextual characteristics. Yet existing research remains relatively fragmented in defining the conceptual connotations of Innovation Consortia, and systematic analysis of operational mechanisms is comparatively weak, urgently requiring integration and clarification through literature review. This paper systematically reviews existing research on the concept, organizational structure, and operational mechanisms of innovation consortia. It analyzes the composition of multiple actors, formation models, and key influencing factors, summarizes three types of operational mechanisms—network collaboration, competitive game, and internal coordination—and identifies three governance models: the single-center star model, the core R&D organization-led model, and the non-core consensus-based model. Furthermore, the paper recognizes multiple constraints faced by innovation consortia during implementation, including institutional, interest-related, knowledge transfer, and capability boundary issues, and reveals the potential risks of "remaining loosely coupled instead of truly integrated" and "being easy to establish but prone to disintegration". Finally,

this paper provides feasible practical implications and points out the limitations of current research in terms of micro-dynamic processes, quantitative testing, and dynamic evolution patterns. It also proposes future research directions in areas such as typological studies, enterprise-led mechanisms, and the impact of government policies, aiming to support theoretical development, policy optimization, and governance practices of collaborative R&D organizations in the Chinese context.

Keywords

Innovation Consortia, Industrial Chain, Formation Mechanism, Governance Model, Open Innovation

1. Introduction

The global landscape of technological innovation is undergoing profound reshaping. Accelerated knowledge diffusion, shortened technology iteration cycles, coupled with increasingly fierce competition in key core technologies, have rendered independent R&D activities by single organizations face mounting costs and risks. Against this backdrop, how to achieve efficient allocation of innovation resources through organized cooperative mechanisms has become a topic of common concern to academia and policymakers. In the field of economics, this concern is centrally manifested in sustained discussions of the micro-mechanisms and macro-effects of cooperative R&D. d'Aspremont and Jacquemin (1988) and Kamien et al. (1992) pioneeringly constructed game-theoretic models of R&D cooperation under oligopolistic competition, revealing the dual effects of technology spillovers on cooperative R&D incentives and welfare effects. Subsequently, theoretical research on Research Joint Ventures (RJVs) has continuously deepened, with scholars conducting analyses from multiple dimensions including innovation incentives, welfare effects, and antitrust policies, forming a relatively mature academic discourse system. Following subsequent transformations in forms and mechanisms, concepts such as industry-university-research cooperation, innovation ecological networks, and innovation chains have extended from "Research Joint Ventures", and these related studies have laid the foundation for our understanding of the connotative characteristics and formation-operational mechanisms of Innovation Consortia (Wang et al., 2013; Yu, 2010; Zhang et al., 2024b).

In the global trend of pursuing collaborative open innovation, China's practical explorations present unique historical trajectories and institutional characteristics. Over the past four decades, China has attached high importance to organizations for jointly tackling technological bottlenecks, experiencing multiple stages from initial exploration, pilot promotion to rapid development. These organizations have provided important support for China's scientific and technological progress and industrial upgrading. Since entering the 21st century, with the rise of open collaborative innovation concepts, collaborative innovation has been re-

defined as an innovation organizational model with knowledge value-added at its core and multi-actor, large-span integration. China's practices in this regard have once again demonstrated vitality—vigorously supporting enterprises to lead Innovation Consortia and undertake major science and technology projects (Zhang et al., 2018).

Organizations for joint tackling of key technologies have ushered in opportunities for comprehensive enhancement. A series of signals at home and abroad have attracted scholars' attention, with numerous scholars conducting discussions on relevant aspects of collaborative innovation. However, current research still exhibits two prominent issues: First, theoretical construction lags behind practical exploration, with conceptual confusion between Innovation Consortia and industry-university-research collaborative innovation organizations or industrial technology innovation alliances, failing to form a theoretically explanatory framework; Second, the absence of international comparative perspectives, with few studies placing China's Innovation Consortia within internationally prevalent cooperative R&D organizational forms such as RJVs and Research Consortia for comparative analysis, limiting the external validity of research conclusions.

Based on the above issues, this paper focuses on the conceptual connotations and operational mechanisms of Innovation Consortia, systematically reviewing existing research with the intention of clarifying the conceptual boundaries and core characteristics of Innovation Consortia, distinguishing their similarities and differences with traditional industry-university-research cooperative organizations; summarizing formation models and operational mechanisms of Innovation Consortia under different contexts, extracting key factors affecting their operational efficiency, and proposing future research directions combining international experience with local contexts, with the aim of expanding Innovation Consortia research, deepening innovation management theory, and promoting the implementation of collaborative innovation practice.

This study employs a systematic literature review method to synthesize research on Innovation Consortia. The literature search primarily covers the following Chinese and English databases: CNKI, Wanfang Data Knowledge Service Platform, Web of Science Core Collection, and Google Scholar. The search time span is set from 1988 to 2026 to encompass both foundational works on early collaborative R&D theories and recent advances in research on Innovation Consortia. The Chinese and English search terms include "innovation consortium", "research joint venture", "R&D collaboration", and "collaborative innovation". Throughout the review process, the following literature screening criteria are adhered to: inclusion of peer-reviewed journal articles, conference papers with clear research objectives, and policy reports whose research focus centers on the conceptual connotation, formation mechanisms, operational logic, or governance models of innovation consortia. The research methods may include theoretical analysis, case studies, empirical testing, or comparative research. After deduplication and initial content screening, a final set of over 50 core articles is included.

2. Conceptual Origins and Theoretical Evolution of Innovation Consortia

As one of the macro-theoretical foundations of Innovation Consortia, Research Joint Ventures have consistently been a focus of attention for domestic and international scholars. As an early practical form of cooperative innovation, Research Joint Ventures (RJVs) emerged against the backdrop of international industrial competition, bringing significant positive effects to industrial development in developed countries such as the United States, Japan, and Germany (Ma & Jiang, 2023). In the late 1980s, Japan occupied nearly half of the global semiconductor market, forming market control and comprehensively enhancing innovation efficiency and productivity. This industry-disruptive change benefited from the Japanese government-led establishment of the semiconductor industry Research Joint Venture (VLSI). The U.S. government also passed the National Cooperative Research Act in 1984, providing government support for RJV operations (Pan & Liu, 2007).

The progression from Research Joint Ventures to industry-university-research cooperation and then to Innovation Consortia is a gradual process influenced by multiple factors. Understanding the background of the proposal of Innovation Consortia is a prerequisite for achieving contextual synthesis. In the market economy environment, as technology gradually becomes the primary factor of production, the innovation path of industry-university-research collaboration—with enterprises as the main body and reaching cooperation with knowledge and technology holders—has gradually become an objective law for enhancing comprehensive national strength and improving international competitiveness. China's industry-university-research collaborative innovation similarly began developing from the 1980s as a time node, making significant contributions to national scientific and technological progress and industrial development during critical periods. However, with the acceleration of technological progress and increasingly fierce market competition, simple industry-university-research cooperation has become insufficient to meet the needs of building an innovative country. Some scholars view the emergence of Innovation Consortia as the result of deepened iteration of industry-university-research collaborative innovation, believing that their construction process is essentially the spatiotemporal transformation of industrial evolution (Gao et al., 2022), defining Innovation Consortia as extensions of industry-university-research collaborative innovation, an inevitable product of the evolution of China's technological innovation system toward deep industry-university-research integration, and a profound manifestation of Chinese-style innovation in industry-university-research practice. By comparing Innovation Consortia with traditional industry-university-research cooperative forms (such as alliances, joint research bodies), it can be found that some scholars position them within the category of joint tackling organizations, conducting vertical comparisons as new forms of industry-university-research collaborative innovation, with emphasis on their dynamic evolutionary characteristics (Zhang & Peng, 2021).

However, some scholars argue that understanding the essence of Innovation Consortia should be based on distinguishing them from industry-university-research collaborative innovation organizations or innovation and entrepreneurship alliances, and incorporating them into the innovation ecosystem category for research in combination with the contemporary context. Bai et al. (2020) believe that Innovation Consortia differ from strategic alliances, industry-university-research cooperation, and other forms, representing new alliances that include equity relationships. Some scholars through comparative research found that existing joint tackling models for innovation (such as enterprise R&D alliances, Research Joint Ventures, and industry-university-research cooperation) mostly feature loose coupling, market-driven orientation, and economic interests as guidance, making them difficult to support the urgent needs for breakthroughs in current key core technologies (Cao et al., 2023b). Understanding Innovation Consortia from the perspectives of innovation chains and innovation ecosystems also constitutes one of the angles of existing research. Xie (2013), introducing a network perspective, positions Innovation Consortia as open innovation networks where enterprises unite supply chain partners, research institutions, universities, and government entities to construct innovation chains through interactive collaboration, forming long-term stable open networks to achieve knowledge spillovers and technology transfer.

Synthesizing existing research, although perspectives vary, most scholars agree on the organizational or platform attributes of innovation consortia. This study argues that innovation consortia are not a simple replacement for existing collaborative R&D organizations, but rather a new organizational form with clearly distinct conceptual boundaries and operational logics. To clarify their uniqueness, it is necessary to distinguish them from four common types of related concepts. Compared with research joint ventures (RJVs), which are project-specific and focus on internalizing technology spillovers and reducing duplicate costs, as well as research alliances—often found in high-tech industries of developed countries and organized loosely for pre-competitive generic technology R&D—innovation consortia place greater emphasis on long-term, deep integration along the industrial chain and innovation chain, highlight the dominant role of enterprises and the coordinating role of government, and exhibit stronger mission orientation and institutional embeddedness (Yin et al., 2024a). At the same time, innovation consortia also differ from traditional industry-university-research collaborations that adopt project-based or contractual cooperation with limited synergy—where rights and responsibilities are clearly defined but factor coupling is insufficient. In contrast, innovation consortia achieve deep coupling of knowledge, capital, and talent through mechanisms such as equity participation, jointly established platforms, or long-term agreements (Yu, 2022). Furthermore, distinct from industrial technology innovation alliances that focus primarily on standard setting, technology diffusion, and industry services, innovation consortia take the breakthrough of key core technologies as their direct goal, feature a more selective formation

process, and emphasize institutionalized arrangements for risk sharing and benefit sharing in their operational mechanisms (Li & Xu, 2026). In summary, innovation consortia constitute a distinctive form in the evolution of collaborative R&D organizations within the Chinese context, in terms of goal orientation, actor relationships, institutional constraints, and operational logic.

3. Organizational Framework and Operational Mechanisms of Innovation Consortia

As China's economic development enters a new stage, the problem of disconnection between technological development and actual industrial needs has become increasingly prominent. Establishing sustainable and effective collaborative innovation models has become an urgent priority (Yin et al., 2022). Among various industry-university-research cooperative consortiums, Innovation Consortia take innovation as the core orientation, more prominently featuring enterprises' leading positions and emphasizing the interactive driving effects of government and market in the process of achievement generation and transformation. Zhang et al. (2024b) believe that Innovation Consortia, aiming to achieve deep integration of various innovation entities and links and efficient coupling of elements, can become an important path to addressing the dilemma of disconnection between scientific and technological innovation achievements and technological application. However, current academic research on Innovation Consortia remains in its initial stages and presents a fragmented state. Only a few case studies have preliminarily revealed the connotative characteristics and organizational models of some pilot consortiums, with relatively weak overall theoretical foundations. Based on this, this paper will systematically explain and analyze Innovation Consortia from dimensions including constituent entities, core characteristics, typological classification, and formation and operational mechanisms, with the aim of providing relatively clear conceptual definitions and theoretical references for subsequent related research.

3.1. Composition of Multiple Stakeholders and Division of Roles

From the perspective of constituent entities, Innovation Consortia can be defined as task-oriented cooperative innovation organizations jointly constructed by advantageous participating entities in the industrial chain, including enterprises, higher education institutions, research institutions, and intermediary organizations, with the goal of achieving innovation tackling (Yin et al., 2024b). Most scholars agree that Innovation Consortia involve multi-actor participation, but different scholars vary slightly in their emphasis on entities. Zhong et al. (2026) emphasize the role of leading enterprises in their research, believing that leading enterprises are responsible for integrating resources, establishing standards, and undertaking major R&D tasks to solve "chokepoint" technology problems. Some scholars conduct policy analyses, highlighting the guiding role of government departments in the formation and operation of Innovation Consortia. Regarding the

division of labor among various entities: government provides policy foundations and institutional guarantees for industry-university-research deeply integrated Innovation Consortia; enterprises hold leading or backbone positions in the industry or possess technological advantages, have strong independent innovation capabilities and complete R&D organizational systems, and actively participate in and coordinate knowledge resource sharing and other innovation activities in industries or regions; higher education institutions and research institutions understand academic frontiers and disciplinary dynamics, bridge the central channel for transforming scientific and technological achievements into market applications, and provide high-quality talent for deeply integrated industry-university-research Innovation Consortia (Zhang et al., 2024a).

Furthermore, some research has begun focusing on entities traditionally in marginal positions in narratives: although small and medium-sized enterprises lack large-scale R&D capabilities, their proximity to market applications makes them acutely aware of technological pain points, and their effective participation depends on open technology sharing and reasonable benefit distribution mechanisms; higher education institutions and research institutions have evolved from simple knowledge providers to collaborative organizers deeply embedded with industries in bidirectional ways; technology intermediaries and financial institutions respectively play ecological catalytic roles by reducing information transaction costs and providing capital support adapted to innovation cycles (Du & Zhang, 2025). Thus, multi-actor participation in Innovation Consortia is not a superposition of roles, but a complex system of functional complementarity and collaborative evolution, with any link affecting the overall innovation effectiveness of the consortia. Accordingly, this paper will review the formation models and operational mechanisms of Innovation Consortia below, reflecting the dynamic evolutionary characteristics of the consortia.

3.2. Formation Models and Key Influencing Factors

Determining research directions, work tasks, management systems, and operational mechanisms; drafting co-construction agreements; soliciting co-construction units; and being responsible for daily operations after establishment constitute the basic approach for forming Innovation Consortia (Cao & Zhao, 2022). Wang et al. (2023) analyzed the construction process of Jiangsu Industrial Technology Research Institute's Innovation Consortia, revealing the progressive logical chain of formation work: first determining selection criteria for partners (covering growth potential, technological level, and strategic thinking and capabilities of senior managers), then clarifying formation methods, operational methods, and basic principles, on this basis summarizing and forming construction models, and finally measuring and evaluating construction effectiveness. Identifying potential partners is the starting point of formation and also a key factor determining success or failure. Through analysis and selection of appropriate participating entities, it helps improve innovation efficiency, reduce R&D costs, and formulate

strategic plans (Wu & Hao, 2023). After confirming participating entities, forming Innovation Consortia depends on the following three factors: first, complementary resource advantages among entities; second, establishing good cooperative trust relationships; and third, perfecting risk and benefit mechanisms.

Complementary resource advantages are the foundational prerequisite for forming Innovation Consortia. Different entities possess differentiated resource endowments in the innovation chain: enterprises master market demands, production capabilities, and application scenarios; universities and research institutions possess advantages in basic research, frontier exploration, and talent reserves; government provides policy guidance and public platform support; financial institutions and intermediary organizations can inject capital and professional services (Li & Ge, 2025). Only when these resources achieve effective integration within the consortia, forming a synergistic effect of "1 + 1 > 2", does the consortia possess the rationality and efficiency foundation for continued existence.

Second, establishing cooperative trust relationships is key to reducing coordination costs and promoting tacit knowledge sharing. As existing research has pointed out, innovation activities are highly uncertain and characterized by information asymmetry; if participating parties lack mutual trust, they can easily fall into opportunistic behavior or knowledge protectionism, causing joint tackling to become mere formality (Zhou et al., 2024). Therefore, it is necessary to gradually cultivate inter-organizational trust capital through long-term interaction, contractual norms, and third-party supervision.

Finally, perfecting risk and benefit mechanisms is the institutional guarantee for sustainable operation of consortia. Innovation Consortia face high-risk, long-cycle R&D tasks; how to reasonably share risks such as technological failure and market fluctuations, and how to fairly distribute benefits such as intellectual property rights and achievement transformation returns, directly determine the willingness and degree of participation of various entities. Deng & Huang (2026), starting from the dilemma of enterprise-led deep integration of industry, academia, and research, point out that goal differences among multiple actors and the lack of benefit distribution mechanisms can easily cause collaborative innovation to remain only at the level of shallow cooperation. A mature risk-sharing and benefit distribution mechanism typically includes clear risk-sharing proportions, transparent contribution evaluation systems, and dynamically adjusted benefit-sharing rules, thereby achieving balance between incentives and constraints (Wang, 2024).

The above three factors do not exist in isolation but are mutually supportive and progressively layered: resource complementarity provides the "possibility" for cooperation, trust mechanisms reduce the "friction costs" of cooperation, and risk-benefit institutions lock in the "sustainability" of cooperation, jointly constituting the cornerstone for Innovation Consortia to move from formation to efficient operation.

Focusing on specific formation models of Innovation Consortia, some research

has revealed the mechanisms and pathways through which enterprises gather social innovation elements by deploying innovation chains and building Innovation Consortia, using "goal aspirations, pathway exploration, guarantee mechanisms" as a logical framework. Additionally, some research has analyzed opportunities, challenges, and path countermeasures for local governments guiding enterprises to lead the formation of Innovation Consortia from specific cases. Going further, existing research has constructed multi-level theoretical models. Wang & Wang (2025) divided the leadership and coordination command models of Innovation Consortia into three levels according to the degree of power centralization, from centralized to decentralized, corresponding to governance needs of Innovation Consortia under different technological complexity and resource dependency situations. First, the single-center star model, where leading enterprises and relevant government departments jointly form a coordination command committee with relatively centralized decision-making power, coordinating resources from all parties through formal agreements, suitable for major technological tackling requiring concentrated forces. Second, the core R&D organization-led model, where one or several R&D organizations with comparative advantages lead the coordination of specific work packages, with limited centralized decision-making power, and can adopt rotating leadership to adapt to needs of different R&D stages, playing a connecting role (Davis & Eisenhardt, 2011). Third, the coreless consensus model, when participating parties are of comparable strength with no absolute core, the team forms bottom-up coordination through equal interaction and mutual trust, with completely decentralized decision-making power, relying on continuous communication and consensus to achieve cooperation. For regions lacking innovative leading enterprises, Wang et al. (2022) proposed a "3 + 5 + 3" model, using high-level research universities as stage-specific leaders, achieving integration of strategic science and technology talent cultivation, breakthroughs in key core technologies, and major achievement transformation through three-party integration of central and local governments, universities, and leading enterprises, and "five-chain" integration of policy, innovation, talent, industrial chain, and capital. This model is a refinement of the six-element model, reflecting increasingly close connections among entities.

At the practical level, regional Innovation Consortia led by governments and led by enterprises in Beijing-Tianjin-Hebei, Yangtze River Delta, and other areas have provided beneficial references for subsequent construction. However, changes in entity roles under different contexts and transitions in innovation stages pose challenges to the applicability of existing models. The development of Innovation Consortia is essentially a process in which various interest entities continuously adapt to internal and external environments and proactively respond to changes. Therefore, dynamic management systems must be introduced to make structural frameworks flexible, fully considering interactive influences among entities and stage characteristics of innovation links, reserving elastic operational space for all parties (Yue & Huo, 2024).

3.3. A Multi-Dimensional Analytical Framework for Operational Mechanisms

Regarding the operational mechanisms of innovation consortia, existing research has adopted diverse theoretical perspectives, resulting in multi-layered and differentiated explanatory frameworks. In summary, these can be categorised into three dimensions: network synergy, competitive game theory, and internal coordination.

Firstly, the network synergy perspective, grounded in value co-creation and digital empowerment, highlights the pivotal role of core enterprises in networked operations, as well as the amplifying effect of digital technologies on collaborative efficiency. Zhu & Zhou (2023), drawing on digital innovation theory and value co-creation theory, focused on innovation consortia led by core enterprises in smart manufacturing, revealing the process mechanisms and pathway paradigms of cross-boundary network synergy within such consortia. Building on this, some studies emphasise that enterprises at the network's centre must integrate digital empowerment throughout the entire entrepreneurial incubation process, continuously cultivate incubation capabilities, and proactively expand the boundaries of the entrepreneurial ecosystem centred on themselves (Zhu & Yang, 2023; Yao, 2024). Some scholars utilise the concept of "resource orchestration"—the dynamic integration, allocation and utilisation of resources, involving the fusion and interaction of new and existing resources—to explain the logic by which innovation consortia achieve competitive advantage (Sirmon et al., 2007). Taking the Beijing-Tianjin-Hebei Green and Low-Carbon Technology Collaborative Innovation Platform as an example, by coordinating existing resources across the three regions, it facilitates innovation in Beijing's laboratories, the incubation of research outcomes in Tianjin, and industrial implementation in Hebei, thereby bridging regional gaps; simultaneously, the construction of a unified information network integrates new data resources and narrows the information gap between industry and the research system, thus driving the transformation of innovative achievements into industrial applications (Li & Sun, 2023).

Second, the competitive game perspective focuses more on driving mechanisms regarding knowledge and technology spillovers and R&D competition. In increasingly competitive business environments, in the innovation process, enterprises' integration and recombination of new elements cannot be separated from contact with and absorption of new concepts and new knowledge elements (Yayavaram & Ahuja, 2008). Actively sharing knowledge and jointly creating value are effective pathways for organizations to obtain competitive advantages. Zhou et al. (2021), combining the structural characteristics of Innovation Consortia, constructed a multi-oligopoly three-stage R&D game model, systematically analyzing the influence mechanisms of technology spillovers on cooperative R&D. In addition to explicit knowledge, personalized tacit knowledge transmitted among entities based on good trust relationships is also key for Innovation Consortia to break through technological innovation bottlenecks. Combining market performance results,

moderate spillovers can incentivize knowledge sharing, but excessive spillovers may weaken members' R&D investment motivation. Therefore, operational mechanisms need to seek dynamic balance between "open sharing" and "intellectual property protection".

Third, the internal coordination perspective focuses on governance structures and institutional arrangements. The governance emphasis of Innovation Consortia lies in contractual governance and relational governance: the former focuses on ensuring execution of commitments through law, clarifying entity obligations and common goals, intending to regulate relevant entity behaviors through ex ante control to maximize consortia benefits (Keller et al., 2021); the latter tends to constrain partner behaviors through informal relationships, possessing stronger social attributes, emphasizing good trust relationships and stable cooperative willingness (Li et al., 2024). Beyond governance structures, Ding & Zhang (2018) point out that Innovation Consortia transform knowledge and technology transfer into intra-organizational activities, a transformation highly dependent on perfect operational mechanisms including communication mechanisms, management mechanisms, supervision mechanisms, benefit mechanisms, and risk mechanisms. Through a series of institutional arrangements, ensuring that interest appeals of various participating entities receive reasonable responses, members can make high-level commitments to achieving common goals, thereby truly enhancing collaborative innovation efficiency.

In summary, Innovation Consortia aim to achieve efficient operation and continuous evolution in multi-actor, multi-objective, high-risk contexts. Their operational mechanisms are not static institutional lists, but dynamic systems that continuously evolve with changes in cooperation stages, technological routes, member compositions, and external policy environments. They are also positive cycles composed of formation conditions, operational mechanisms, feedback iteration, and innovation realization. To more intuitively present this overall logic, this paper draws an organizational operation flowchart of Innovation Consortia (see **Figure 1**). Furthermore, a clear causal chain exists among the formation conditions, governance mechanisms, and innovation outcomes of innovation consortia: formation conditions are the prerequisites for launching a consortium, governance mechanisms serve as the mediator that transforms conditions into effectiveness, and innovation outcomes are the ultimate manifestation of the mechanisms' proper functioning. Resource complementarity, trust foundation, and risk-benefit framework address the questions of "why a consortium can be established", "how to achieve low-cost collaboration", and "how to ensure sustainability", thereby providing necessary inputs for governance mechanisms. Mechanisms such as network synergy, competitive dynamics, and internal coordination respectively respond to the operational needs of "how to amplify collaborative efficiency", "how to balance openness and protection", and "how to regulate actor behavior". Only when the formation conditions are complete and governance mechanisms are well-matched can knowledge flow and R&D investment be effectively promoted,

leading to innovation outcomes such as breakthrough technologies, platform-based achievements, or industrial upgrading. Conversely, if conditions are deficient (e.g., weak trust or improper benefit distribution), even well-designed governance mechanisms will struggle to achieve the expected outcomes. The effectiveness of innovation consortia depends on the closed-loop interplay of conditions, mechanisms, and outcomes, wherein governance mechanisms serve as the critical bridge from static resource endowments to dynamic innovation capabilities.

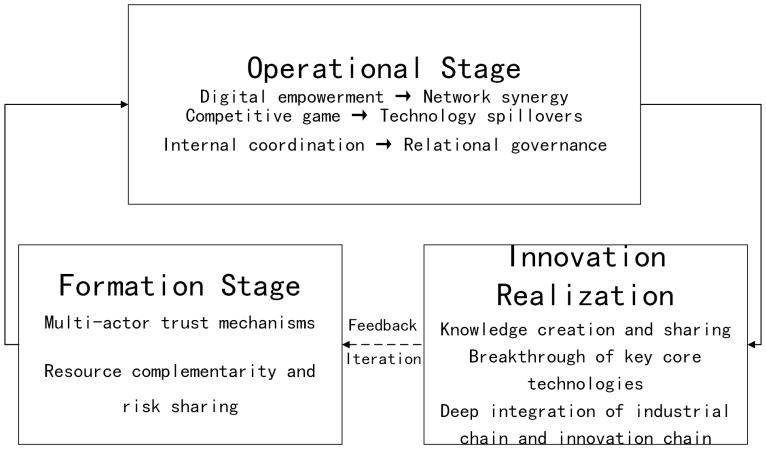

Figure 1. Organizational operation flowchart of innovation consortia.

3.4. Boundary Constraints in the Implementation Process

In addition to the above discussion on mechanisms, this study also notes that some research has elaborated on the problems existing in the implementation process of innovation consortia, explored the boundary conditions for their operation, and clarified the potential risks of failure. From the perspective of integrated and open innovation, integrated innovation has cross-regional and cross-industry networked characteristics. However, insufficient trust among actors and the weak position of small and medium-sized enterprises can easily undermine collaboration stability, thus requiring the introduction of third-party intermediaries to enhance collaborative sustainability (Li, 2023). From the perspective of multi-actor governance, existing studies have pointed out that collaborative innovation in innovation consortia may face risks arising from conflicting cooperation goals, power asymmetries, insufficient policy coordination, and institutional absence. Internal relational imbalances, poor coordination mechanisms, and an imperfect institutional environment intertwine to constrain the depth and sustainability of multi-actor collaboration (Fougère & Solitander, 2020; Jansen & Kalas, 2020; Schaeffer et al., 2021). In terms of the implementation process, innovation consortia also face the following constraints: First, at the level of operational mechanisms and institutions, the lack of sound long-term development mechanisms, insufficient financial support, the persistent disconnect between science and technology and the market within the science and technology system, and deficiencies in shared

goals, collaborative willingness, and information exchange from an organizational perspective collectively constitute fundamental constraints (Bai, 2024). Second, difficulties in integrating the interests of multiple actors, insufficient innovation motivation of leading enterprises, imperfect talent incentive mechanisms, risks of technology spillover and free-riding, as well as bottlenecks such as scarce actors and behavioral distortions, become key nonlinear constraints (Zhou & Zhang, 2015; Cao & Zhao, 2022). Third, intellectual property conflicts and governance difficulties, imperfect legal systems, insufficient trust and cohesion among heterogeneous organizations, and a complex constraint system composed of multidimensional factors limit knowledge co-creation (Zhang & Liu, 2024). Finally, the firm's own capability boundaries, the dual constraints of internal capabilities and external policy incentives, as well as external boundaries such as national capacity and financing conditions, together exert endogenous influences on the vitality of consortia (Cao et al., 2023a).

In summary, the implementation process of innovation consortia does not operate in a vacuum but is profoundly constrained by multidimensional boundary conditions. Institutional deficiencies in operational mechanisms, conflicts of interest and imbalance of incentives among actors, governance difficulties in knowledge transfer, and inherent limitations of actor capabilities—these factors intertwine to shape the risk landscape from the formation to the sustainable operation of consortia. Identifying and responding to these boundary conditions is not only key to understanding why innovation consortia often remain "connected in name but not in action" or are "easily formed yet quickly dissolved", but also a theoretical prerequisite for optimizing their governance design and enhancing innovation effectiveness.

4. Conclusions and Implications

4.1. Main Conclusions and Theoretical Contributions

This paper systematically reviews the conceptual evolution, organizational structure, and operational logic of innovation consortia with a focus on their conceptual connotations and governance mechanisms, and draws the following main conclusions and theoretical contributions.

First, this paper distinguishes innovation consortia from four similar concepts: research joint ventures (RJVs), research alliances, traditional industry-university-research collaboration, and industrial technology innovation alliances. On this basis, the paper clearly points out that innovation consortia are not a simple replacement for existing collaborative R&D organizations, but rather a new organizational form with distinct differences in goal orientation, actor relationships, institutional constraints, and operational logic, thus providing a clear logical starting point for subsequent theoretical development.

Second, this paper reveals the logical chain of innovation consortia from formation to outcomes. The three formation conditions—resource complementarity, trust foundation, and risk-benefit framework—address the questions of "why a

consortium can be established", "how to achieve low-cost collaboration", and "how to ensure sustainability". The three governance mechanisms—network synergy, competitive dynamics, and internal coordination—respectively respond to the operational needs of "how to amplify collaborative efficiency", "how to balance openness and protection", and "how to regulate actor behavior". This framework integrates fragmented mechanism studies into a theoretical model with inherent logic, providing a replicable analytical tool for future research.

Third, this paper distills three governance models: single-center star-shaped model, core R&D organization-led model, and leaderless consensus-based model, each corresponding to governance needs under different levels of technological complexity and resource interdependence. Simultaneously, this paper systematically identifies constraining conditions such as operational mechanism deficiencies, interest conflicts and incentive imbalances, knowledge transfer governance difficulties, and actor capability boundaries, revealing the potential risk roots of innovation consortia being "connected in name but not in action" or "easily formed yet quickly dissolved", thereby offering a problem-oriented theoretical basis for optimizing governance design.

4.2. Practical Implications

Based on the above conclusions, this paper proposes the following feasible practical implications, aiming to provide references for consortium governance design and enterprise participation strategies.

First, the risk and benefit distribution mechanism is the core institutional arrangement for the sustainable operation of innovation consortia. Governments or industry organizations should prioritize the establishment of tiered and categorized guidelines for risk and benefit distribution, and develop differentiated principles for benefit allocation according to different technology fields, types of leading entities, and consortium sizes. The establishment of this framework should clarify the ownership and usage rules of intellectual property, suggest a recommended range for the proportion of returns from achievement transformation, and set up dispute resolution mechanisms. The introduction of third-party evaluation agencies or arbitration committees is encouraged to reduce institutional negotiation costs in the early stage of collaboration.

Second, innovation consortia should abandon the static governance mindset of "one-time signing, long-term unchanged" and instead establish phased and adjustable governance mechanisms. During the formation stage, the trust foundation should be laid by clarifying partner selection criteria and signing binding cooperation contracts. During the operation phase, risk sharing ratios, benefit distribution rules, and leadership coordination models should be regularly evaluated and adjusted based on R&D progress, member contributions, and changes in the external environment. In the maturation stage, channels for achievement incubation and secondary development should be established, encouraging members to engage in derivative collaboration within the consortium framework. Meanwhile, a joint management committee composed of representatives from all parties may

be set up to hold coordination meetings on a quarterly basis, enhancing mutual trust through formal and informal communication and reducing opportunistic behavior.

Third, existing research often focuses on leading enterprises, but the technological agility of small and medium-sized enterprises (SMEs) and the basic research capabilities of research institutions are indispensable innovation drivers for innovation consortia. The consortium charter should clearly define the participation rights and interests of SMEs and lower their barriers to participation through mechanisms such as technology sharing. For universities and research institutions, they should be encouraged to transform from mere knowledge providers to collaborative organizers, allowing researchers to participate in consortium spin-off enterprises through a combination of technology equity and cash co-investment, thereby removing bottlenecks in the transformation of scientific and technological achievements.

5. Research Limitations and Future Directions

5.1. Limitations

Although this paper has examined the conceptual evolution, organisational structure and operational mechanisms of innovation consortia, it nevertheless has the following limitations:

Firstly, the research perspective focuses predominantly on macro-level institutional and structural analysis, with insufficient examination of micro-level dynamic processes. Much of the existing literature focuses on structural dimensions such as the composition of participants, formation models and operational mechanisms, but lacks an in-depth portrayal of micro-level dynamic processes within the consortia, such as knowledge flow pathways, power dynamics and the evolution of trust. Consequently, it is difficult to fully unveil the "black box" of innovation consortia's operations. Secondly, existing research is predominantly qualitative, relying on case studies and theoretical exposition, and lacks large-scale empirical testing. Most studies depend on inductive analysis of single or multiple cases, whilst quantitative research—such as the quantitative assessment of innovation consortia performance and statistical inference regarding influencing factors—is relatively scarce. Consequently, the generalisability of some conclusions remains to be verified. Thirdly, there is insufficient attention paid to the dynamic evolutionary patterns of innovation consortia. Existing research is predominantly static cross-sectional analysis, with few longitudinal studies exploring the full lifecycle evolution of consortia from formation and operation to iterative upgrading. Furthermore, such research has failed to adequately address the impact of contextual changes—such as external policies, market competition and technological change—on the adaptability of these consortia.

5.2. Future Directions

In light of the aforementioned limitations, and taking into account existing re-

search findings and current challenges, this paper proposes the following three areas for future research to further advance the theoretical development and practical application of innovation consortia:

First, to deepen research into the classification of innovation consortia and their dynamic monitoring. Innovation consortia exhibit diverse organisational models across multiple levels; however, existing research lacks sufficient focus on different types of consortia and has yet to establish universally accepted classification criteria. Future research could combine multi-case comparisons with longitudinal tracking studies to identify differences in the characteristics of innovation consortia under various contexts (such as technological fields, regional endowments, and types of lead entities), thereby constructing a more explanatory theoretical framework and practical classification guidelines. Second, strengthen micro-level research into the mechanisms of enterprise leadership. How enterprises within consortia exert their influence in technological innovation decision-making, R&D investment, innovation organisation and the commercialisation of results, thereby leading the integrated development of diverse innovation actors, is a matter requiring urgent and in-depth examination. Future research could adopt perspectives such as process studies and actor-network theory, focusing on internal corporate mechanisms for strategy formulation, resource allocation and organisational learning, to reveal the intrinsic logic and boundary conditions of enterprise leadership. Third, expand systematic research into the mechanisms of government policy influence. As the practice of innovation consortia continues to expand, how to foster a favourable institutional environment throughout the entire process—from top-level policy design to implementation—along with the pathways and conditions for achieving this, will become a key research direction. Future research could integrate policy instrument theory and institutional theory, employing methods such as quasi-natural experiments and comparative case studies to systematically evaluate the differentiated impacts of various policy instruments (such as fiscal incentives, intellectual property protection and platform development) on the operational performance of innovation consortia, thereby providing empirical evidence for policy optimisation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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