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The Impact of Collaborative Innovation Network Embedding on the Innovation Performance of Specialized, Sophisticated, Special and New Enterprises: A Moderated Mediation Model

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Abstract: Based on the social network theory and knowledge-based theory, this paper deeply explores the impact of collaborative innovation network embedding on the innovation performance of specialized, sophisticated, special and new enterprises, and analyzes the mediating role of knowledge integration and the moderating role of government support. The research selects specialized, sophisticated, special and new enterprises in Jiangsu, Zhejiang and Shanghai as research samples, and conducts an empirical analysis by adopting methods such as hierarchical regression. The results show that collaborative innovation network embedding has a significant positive impact on the innovation performance of specialized, sophisticated, special and new enterprises, in which structural embedding is conducive to obtaining resource information and relational embedding promotes the flow of tacit knowledge; knowledge integration plays a significant mediating role between network embedding and innovation performance; government support positively moderates the relationship between network embedding and innovation performance, for example, subsidies lower the participation threshold and tax incentives amplify knowledge spillovers. This study expands the theoretical boundary of the collaborative innovation network, constructs an institutional synergy theory for the innovation of specialized, sophisticated, special and new enterprises, and provides useful references for enterprise innovation management and government policy-making.

Keywords: Collaborative Innovation Network Embedding; Specialized, Sophisticated, Special and New Enterprises; Innovation Performance; Knowledge Integration; Government Support.

1. Introduction

The Third Plenary Session of the 20th Central Committee of the Communist Party of China proposed to uphold consolidating the fundamentals and fostering new growth drivers, and promote theoretical innovation, practical innovation, institutional innovation, cultural innovation and all other types of innovation. Innovation has become the theme of the development of the times and the main content of competition in the world today. As a driving force for national economic growth, innovation is the key to enhancing a country's comprehensive national strength. The Party has regarded innovation as an important productive force and driving force for development in various development plans and goal-setting initiatives. General Secretary Xi Jinping pointed out in the report to the 20th National Congress of the Communist Party of China that "we must uphold science and technology as the primary productive force, talent as the primary resource, and innovation as the primary driving force, thoroughly implement the strategy of invigorating the country through science and education, the strategy of strengthening the country through talent, and the strategy of driving development through innovation, open up new fields and new tracks for development, and constantly foster new drivers and new advantages for development". Against this backdrop, domestic enterprises, as the main force of innovation, have begun to improve their innovation performance and carry out transformation and upgrading. Specialized, sophisticated, special and new enterprises, as the backbone in addressing the bottlenecks in key core technologies in China, play an important role in strengthening, extending and supplementing industrial chains. However, under the background of open innovation, the technological innovation of individual enterprises is facing increasing challenges. The closed-door innovation model makes it difficult for enterprises to obtain external resources, and "going it alone" can no longer adapt to the requirements of the current era. In addition, resource redundancy within enterprises also hinders the innovation process to a certain extent. The high-quality development of the economy and society requires the national economic system to be more dynamic and creative, and open collaborative innovation is increasingly becoming the mainstream model of innovation-driven development strategies in all countries. Universities and research institutes are important channels for enterprises to obtain knowledge resources (Yu et al., 2020).

Science and technology are the primary productive force. General Secretary Xi Jinping emphasized that we should accelerate the building of a world scientific and technological power and achieve a high level of scientific and technological self-reliance and self-improvement. China is currently facing the predicament of being constrained by other countries in key core technologies, and the insufficient innovation capacity of small and medium-sized enterprises is an important factor hindering the construction of China's innovation-driven development system. Therefore, it is necessary to clarify the dominant position of small and medium-sized enterprises in innovation and continuously enhance their independent innovation capacity. The Political Bureau Meeting of the Central Committee of the Communist Party of China, the Central Economic Work Conference and the 14th Five-Year Plan have repeatedly emphasized that specialized, sophisticated, special and new enterprises are the

key to solving the problem of technological bottlenecks. Nevertheless, such enterprises still face problems such as insufficient innovation capacity, weak sustainable innovation capacity and inadequate collaborative innovation capacity. Therefore, specialized, sophisticated, special and new enterprises need to seek external cooperation in technological innovation to achieve collaborative innovation. Collaborative innovation can not only effectively make up for the insufficient innovation capacity of individual enterprises, but also effectively promote cooperation among enterprises. A collaborative innovation network can bring abundant resources and information to enterprises, and enterprises' active embedding in the collaborative innovation network can create more output value and improve their innovation performance.

An analysis of previous relevant studies shows that the importance of the collaborative innovation network is self-evident. Different scholars have explored the positive effect of the collaborative innovation network on enterprise innovation performance (Xie, 2010), but their research has mainly focused on the manufacturing industry. However, specialized, sophisticated, special and new enterprises are often not limited to a single industry, so the applicability of research results based on a single industry to such enterprises remains to be considered. In addition, scholars' research from the network perspective has paid more attention to the characteristics of certain aspects of the network, such as the relationship between network structure, network relations, network strength, network capability and enterprise performance (Soh, 2009), lacking research and analysis from the overall network perspective.

Based on this, from the perspective of social network theory, this paper summarizes the impact path of collaborative innovation network embedding on the innovation performance of specialized, sophisticated, special and new enterprises, clarifies the specific roles of knowledge integration and government support in it, and helps enterprises better control their own innovation network layout and innovation management decisions.

2. Theoretical Analysis and Research Hypotheses

2.1. The Impact of Collaborative Innovation Network Embedding on Enterprise Innovation Performance

According to the resource dependence theory, individual organizations generally face systematic challenges such as resource homogenization, limited knowledge reserves and a single capability structure in the development process, and it is urgent to achieve complementary advantages by establishing resource exchange channels with external subjects (Pfeffer & Salancik, 1978). Against this background, the collaborative innovation network provides a systematic solution for enterprises to break through innovation bottlenecks by building a multi-dimensional interaction platform: on the one hand, the network builds a reliable channel for enterprises to obtain scarce resources and heterogeneous knowledge by establishing a trust mechanism and support system; on the other hand, its extensive knowledge base can promote the cross-integration of background knowledge and complementary knowledge, and knowledge diversity plays a key moderating role in this process—when enterprises realize the reorganization of knowledge elements, knowledge capital can be effectively transformed into enterprises' technological innovation output (Yang, 2021; Cai et al., 2021). With the deepening of digital transformation, the dynamic characteristics of the collaborative innovation network show new trends. An empirical study by Wen et al. (2021) on 158 automobile enterprises in China shows that the density and breadth of the inter-firm R&D network are significantly positively correlated with enterprise innovation performance, verifying the role of the network synergy effect in technological innovation. Previous studies have shown that enterprises' embedding in the collaborative innovation network usually consists of structural embedding and relational embedding (Lyu et al., 2017). Structural embedding emphasizes the non-redundant information advantage brought by occupying the position of structural holes in the network (Burt, 1992), while relational embedding promotes the transfer of tacit knowledge and the formation of trust mechanisms through network relations (Yang et al., 2019). The two embedding mechanisms produce a synergetic effect on the network. The former enables enterprises to obtain diversified knowledge resources, and the latter guarantees the efficiency of resource transformation. Together, they form a dual path for enterprises to improve innovation performance in the digital economy era. While optimizing their network structure position to obtain information advantages, enterprises enhance inter-firm cooperative relations to activate knowledge potential, and finally form a synergistic innovation ecosystem in a dynamic competitive environment to realize value creation.

(1) Network Structural Embedding and Innovation Performance

Under the wave of digitalization, inter-organizational collaborative innovation has become the core paradigm of the knowledge economy era. As an important theoretical perspective in the research of collaborative innovation networks, network embedding presents a multi-dimensional and complex mechanism of action on enterprise innovation performance. Based on Granovetter's structural embedding theory, existing studies have revealed the impact mechanism of network structural characteristics on innovation capability: on the one hand, an organization's central position in the network and the density of heterogeneous connections directly affect innovation performance through knowledge integration and resource acquisition. For example, Xu et al. (2017) used a negative binomial regression model to confirm the inverted U-shaped relationship between network density and innovation output, and the collaborative innovation network model constructed by Chen's team (2009) shows that a moderate small-world characteristic can improve the efficiency of patent output by reducing the cost of knowledge transfer; on the other hand, different forms of network structure also have effects on enterprise innovation activities. An empirical study by Wu (2020) based on the RIS framework shows that structural embeddedness positively drives enterprise innovation performance by enhancing the coupling degree of innovation elements, and an empirical analysis by Ye et al. (2021) on the technology service industry further reveals that the richness of structural holes is significantly positively correlated with technological innovation capability, while Yang (2020) demonstrated the positive promoting effect of the synergetic effect of cooperative network scale and density on knowledge transfer. In addition, this network embedding effect has boundary

conditions. A study by Yu et al. (2018) found that structural holes may trigger the risk of knowledge fragmentation, indicating that enterprises need to balance the requirements of openness and management practice when building network platforms. These studies together construct a theoretical framework for the structural embedding of collaborative innovation networks, which not only provides practical enlightenment for enterprise network governance in digital transformation, such as topological structure optimization and knowledge flow management, but also points out the direction for subsequent research to explore moderating mechanisms and network evolution paths.

(2) Network Relational Embedding and Innovation Performance

Uzzi (1997) pointed out that the relational embedding of the network is different from general market relations, and it shows more relational characteristics such as trust, commitment and reciprocity, which are conducive to promoting inter-organizational interaction and information sharing. Some scholars have proposed that the inter-organizational trust mechanism is related to the degree of enterprise relational embedding (Walker, 1997). Trust relations make enterprises draw more on the knowledge and technology of other enterprises in the R&D process, and gradually strengthen relations to form a strong relational network (Gilsing & Duysters, 2008). The strength of relational embedding in the collaborative innovation network refers to the closeness of interaction and communication between enterprise subjects and their level of resource input (Yang, 2016). Studies have shown that there is a significant correlation between the strength of network relational embedding and innovation performance. Ritter (2004) confirmed that enterprises can improve the success rate of innovation by strengthening external ties; Huang et al. (2017) further found that strong relational embedding has a positive impact on innovation performance by promoting the transfer of tacit knowledge; Freeman (1991) emphasized the key role of relationship quality (including trust level, knowledge base fit, etc.) in inter-organizational knowledge learning, a view supported by the empirical research of Zhan et al. (2020). It is worth noting that the innovation effect of the strength of relational embedding has a dual nature. When a stable cooperative relationship with high trust and continuous knowledge input is formed among innovation subjects, a dedicated channel for knowledge sharing can be built to improve the efficiency of innovation element integration. However, over-reliance on strong relations may lead to a network lock-in effect, manifested as innovation rigidity caused by path dependence, resource misallocation caused by information redundancy, and slow response to changes in the external environment. Therefore, enterprises need to build a dynamic adjustment mechanism, obtain key knowledge resources through strong relational embedding, and maintain moderate weak ties to obtain heterogeneous information at the same time, and finally realize the flexible configuration of network relations to provide double guarantees for the sustainable innovation of enterprises.

Based on the above analysis, the following hypotheses are proposed:H1a: The structural embedding of the collaborative innovation network has a positive impact on enterprise innovation performance.H1b: The relational embedding of the collaborative innovation network has a positive impact on enterprise innovation performance.

2.2. The Mediating Role of Knowledge Integration

The knowledge resources accumulated by enterprises are an important guarantee for improving their innovation capability, and the innovation network provides a good platform for enterprises to accumulate resources. In the collaborative innovation network, universities and research institutes act as aggregators of knowledge, providing enterprises with the required knowledge, while intermediary organizations provide enterprises with the required services, and can effectively reduce the cost of knowledge acquisition and help avoid certain risks to a certain extent. The collaborative innovation network enables specialized, sophisticated, special and new enterprises to break organizational boundaries and facilitate in-depth communication. On the one hand, as the scale of the network continues to expand, network subjects can connect with more enterprises, have more channels to obtain external knowledge, and can better generate a cluster learning effect to realize knowledge integration; on the other hand, enterprises that are not in direct contact often need to complete knowledge exchange through structural holes. Therefore, enterprises in the central position are more likely to access new technologies and new knowledge. Existing studies have shown that enterprises in the central position of the innovation network have more opportunities for knowledge sharing, thus effectively conducting inter-organizational learning (Tsai, 2001). Through research, Ganguly et al. (2019) found that the close relations formed by enterprises with members in the network can deepen the breadth and depth of cooperative communication, create conditions for the network to obtain knowledge resources, expand the scope of knowledge absorption, increase the external opportunities of subjects in the network, and thus promote the knowledge integration effect.

In the era of the knowledge economy, knowledge elements have become the core driving force for enterprise technological innovation. Scholars generally believe that knowledge integration, as a key capability for enterprises to reorganize internal and external knowledge resources and create new knowledge, is essentially to generate breakthrough solutions through the integration of new and old knowledge (Song, 2020). Studies have shown that this dynamic process includes multiple dimensions such as knowledge acquisition, sharing, flow and reconstruction (Elena Revilla et al., 2012; Guo et al., 2019). By developing tacit knowledge and building a unique knowledge network (Wang, 2025), enterprises can not only improve the efficiency of core technology breakthroughs (Xie et al., 2022), but also form an irreplicable competitive advantage (Ritala et al., 2013). Within the organization, knowledge integration accelerates knowledge dissemination and diffusion, and promotes the improvement of team innovation performance (Tsai et al., 2014); in external collaboration, enterprises achieve technological innovation by acquiring knowledge provided by universities, leading institutions, etc. (Verganti et al., 2013) and combining it with their own knowledge base (Zhou & Li, 2012). It is worth noting that the practice of manufacturing enterprises has verified the significant promoting effect of knowledge integration on servitization transformation (Wang et al., 2023). In-depth knowledge reorganization (Cheng et al., 2023) is not a simple accumulation of knowledge, but requires enterprises to continuously improve their knowledge processing

capabilities, as well as their ability to absorb professional knowledge and accurately identify potential knowledge combinations (Yang et al., 2020), and finally form a sustainable improvement mechanism for innovation performance. This positive correlation has reached a consensus in academic circles (Yu et al., 2018; Apak & Tuncer, 2012).

Based on the above analysis, the following hypotheses are proposed:H2a: The structural embedding of the collaborative innovation network has a positive impact on knowledge integration.H2b: The relational embedding of the collaborative innovation network has a positive impact on knowledge integration.H2c: Knowledge integration has a positive impact on enterprise innovation performance.

2.3. The Moderating Role of Government Support

At this stage, to solve the predicament of being constrained by other countries in key technologies in China, the state has formulated a series of policies and scientific research innovation projects. Traditional organizations also need to accelerate transformation and upgrading and actively change their organizational forms to better undertake major scientific research projects. Government financial support and the formulation of relevant policies are crucial to enterprise technological innovation. In the current era of increasingly severe international competition, all countries are actively formulating relevant policies to promote cooperation between enterprises and other organizations, thereby accelerating the enterprise innovation process. Through research, Liu and Qian (2016) found that government support such as government innovation subsidies can effectively promote the innovation organizational form of enterprises, and the government's funding for enterprise cooperation can improve the innovation efficiency of enterprise cooperation (Fan et al., 2012). When enterprises cooperate with other organizations to form a collaborative innovation network, continuous R&D investment may put enterprises in a situation of shortage of R&D funds (Zhang, 2022), and at this time, the government's substantial innovation funds can be used as the enterprise's R&D funds to ensure the sustainable operation of all subjects in the network (Yan, 2020). In addition, government support can provide enterprises with a strong "government endorsement", helping enterprises obtain more innovation resources (Hottenrott, 2020), thereby enhancing their innovation capability. Biggs and Shah (2006) also proposed that there is a close relationship between the government and the innovation performance of small and medium-sized enterprises. However, the research of Cooke (2000) and Doloreux (2004) shows that in practice, the government's promoting effect on small and medium-sized enterprises is far smaller than expected. In general, as a public sector, the government promotes the connection between enterprises and universities, research institutions, intermediaries, etc. by formulating relevant policies that can promote enterprise innovation, thus having a positive impact on the innovation of small and medium-sized enterprises.

Based on this, the following hypothesis is proposed:H3: Government support plays a moderating role between collaborative innovation network embedding and the innovation performance of specialized, sophisticated, special and new enterprises.

As can be seen from the above analysis, collaborative innovation network embedding includes two dimensions: structural embedding and relational embedding, both of which have an impact on the innovation performance of specialized, sophisticated, special and new enterprises. Among them, knowledge integration plays a mediating role between collaborative innovation network embedding and the innovation performance of specialized, sophisticated, special and new enterprises, and government support plays a moderating role in it. Based on this, a conceptual model is constructed as shown in Figure 1.

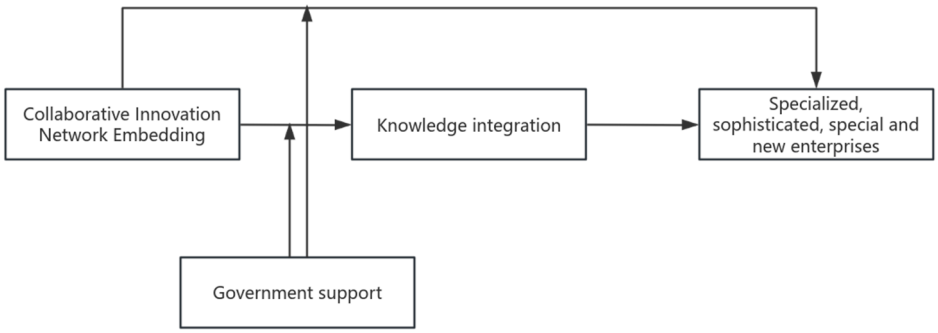


Figure 1. Conceptual Model

3. Research Design

3.1. Data Collection

In the current economic development pattern, specialized, sophisticated, special and new enterprises have become an important force driving innovation and economic growth, showing strong innovation vitality and development potential. The Yangtze River Delta region, as a frontier of China's economic development, is a gathering highland for specialized, sophisticated, special and new enterprises. Among them, Jiangsu, Zhejiang and Shanghai are the key engines of economic development in this region, gathering a large number of specialized, sophisticated, special and new enterprises, and having significant advantages in innovation resources and industrial supporting facilities. In view of this, the research samples of this paper are selected from specialized, sophisticated, special and new enterprises in Jiangsu, Zhejiang and Shanghai.

In the pre-investigation stage, on the basis of drawing on mature scales at home and abroad, field visits were made to a number of specialized, sophisticated, special and new small and medium-sized enterprises in Jiangsu for investigation, and the investigation items were appropriately adjusted according to the investigation results and expert opinions, initially forming the investigation items.

In the formal investigation stage, a total of 348 questionnaires were distributed by a combination of on-site distribution and e-mail. After excluding invalid questionnaires with serious missing data, 312 valid questionnaires were finally obtained.

Among all valid questionnaires, in terms of enterprise scale: 5.77% have less than 50 employees, 13.78% have 51-100 employees, 25.32% have 101-200 employees, 22.76% have 201-500 employees, 26.28% have 501-1000 employees, and 6.09% have more than 1000 employees; in terms of enterprise industry type: 18.19% are in the manufacturing industry, 3.53% in the software and information technology service industry, 21.79% in the construction industry, 19.87% in the power, water supply and gas supply industry, 16.99% in the wholesale and retail industry, and 18.91% in the logistics industry.

3.2. Variable Measurement

All variables in this study refer to mature scales at home and abroad and are appropriately adjusted in combination with the research content of this paper. Except for control variables, all variables are measured using a 5-point Likert scale.

(1) Dependent variable: Innovation performance of specialized, sophisticated, special and new enterprises. It mainly refers to the scale of Xie (2020), including four items such as "Compared with other enterprises, our enterprise can often launch new products or services faster" and "Compared with other enterprises, our enterprise can develop and introduce brand-new technologies and processes faster".

(2) Independent variable: Embeddedness in the collaborative innovation network. It includes two dimensions: network structural embedding and network relational embedding. It is mainly measured with reference to the scales of Uzzi (1997) and Xie (2020), including eight items such as "There are a large number of other enterprises or institutions in contact with our enterprise", "Other enterprises or institutions often contact other enterprises through our enterprise", and "The cooperative relationship with other enterprises or institutions is close".

(3) Mediating variable: Knowledge integration. It is mainly measured by drawing on the scale of Wang (2023), including four items such as "Our enterprise has a process of transferring external knowledge to the internal of the enterprise" and "Our enterprise has a process of applying knowledge to the development of new products or services".

(4) Moderating variable: Government support. It is mainly measured by drawing on the scale of Wang (2023), including four items such as "The local government has provided policies and projects conducive to the development of our enterprise", "The local government has provided necessary information and technical support for our enterprise", and "The local government has provided direct fiscal policies for our enterprise, including taxes and government subsidies".

(5) Control variables: Studies have found that enterprise scale and enterprise industry will have an impact on the innovation performance of specialized, sophisticated, special and new enterprises. To better explore the relationship between variables, this study takes enterprise scale and industry as control variables, and measures enterprise scale by the number of employees.

4. Empirical Analysis

4.1. Reliability and Validity Test of the Questionnaire

Table 1. Measurement Items of Variables and Test Results of Reliability and Validity

Variables	Items	Factor Load	α Value	AVE
Structural embedding of collaborative innovation network	There are a large number of other enterprises or institutions in contact with our enterprise	0.749	0.857	0.6097
	Other enterprises or institutions often contact other enterprises through our enterprise	0.769		
	The number of cooperative enterprises or institutions with our enterprise changes infrequently	0.809		
	Our enterprise has structural advantages in key resources such as information and technology	0.795		
Relational embedding of collaborative innovation network	The frequency of contact with other enterprises or institutions is very high	0.776	0.852	0.5913
	The scope of cooperation with other enterprises or institutions is extensive	0.835		
	The cooperative relationship with other enterprises or institutions is close	0.703		
	The cooperative relationship with other enterprises or institutions lasts for a long time	0.756		
Knowledge integration	Our enterprise has a process of transferring external knowledge to the internal of the enterprise	0.717	0.806	0.551
	Our enterprise has measures to promote information and knowledge sharing with other teams	0.717		
	Our enterprise has a process of applying knowledge to the development of new products or services	0.721		
	Our enterprise improves efficiency through the application of knowledge	0.81		
Enterprise innovation performance	Compared with other enterprises, our enterprise can often launch new products or services faster	0.738	0.858	0.5878
	Compared with other enterprises, our enterprise can develop and introduce brand-new technologies and processes faster	0.799		
	Compared with other enterprises, our enterprise's products contain first-class advanced technologies and processes	0.744		
	Compared with other enterprises, our enterprise has a higher success rate in developing new products	0.784		
Government support	The local government has provided policies and projects conducive to the development of our enterprise	0.788	0.836	0.6102
	The local government has provided necessary information and technical support for our enterprise	0.76		
	The local government has provided great help for our enterprise to introduce technologies and equipment	0.773		

To reduce the problem of common method bias in the sample collection process, this study uses the test methods of SPSS27.0 and Amos to test the samples. The results show that the variance explanation rate of the first principal component factor is 37.736%, lower than 40%, so there is no obvious common method bias in the sample data of this paper.

This study tests the reliability and validity of all variables by using SPSS27.0, and the specific data analysis results are shown in Table 1. It can be found from the results that the Cronbach's α values of variables such as the structural embedding of the collaborative innovation network, the relational embedding of the collaborative innovation network, knowledge integration, government support and the innovation performance of specialized, sophisticated, special and new enterprises are all higher than 0.8, indicating that the internal consistency of the research scale is high. Moreover, since the scales used all refer to mature scales at home and abroad, the factor load of each item is greater than 0.6, the average variance extracted (AVE) of each variable is above 0.5, and the composite reliability (CR) is above 0.8, so the convergent validity passes the test. In addition, it can be seen from Table 1 that the square root of the AVE of each variable is higher than the correlation coefficient between variables, so the discriminant validity also passes the test.

4.2. Correlation Analysis

Table 2 presents the descriptive statistical results of each research variable, the square root of the average variance extracted (AVE) and the correlation coefficient matrix. The data structure shows that the structural embedding of the collaborative innovation network, the relational embedding of the collaborative innovation network, knowledge integration, government support and the innovation performance of specialized, sophisticated, special and new enterprises are all significantly correlated at the 1% significance level, and the correlation coefficients do not exceed the critical value of 0.7, which provides preliminary data support for the subsequent model construction and hypothesis testing. Further multicollinearity diagnosis found that the variance inflation factor (VIF) value of each variable is significantly lower than the warning threshold of 10, indicating that there is no significant multicollinearity problem between variables.

Table 2. Descriptive Statistics and Square Root of AVE of Each Variable

Variables	Enterprise Scale	Enterprise Industry	Structural Embedding	Relational Embedding	Knowledge Integration	Innovation Performance	Government Support
Enterprise Scale	—						
Enterprise Industry	-0.079	—					
Structural Embedding	0.077	-0.021	0.78083				
Relational Embedding	-0.008	-0.041	0.469**	0.76890			
Knowledge Integration	-0.001	-0.041	0.374**	0.408**	0.9231		
Innovation Performance	-0.047	0.002	0.495**	0.515**	0.449**	0.9223	
Government Support	0.008	-0.069	0.370**	0.342**	0.425**	0.335**	0.9286
Mean	3.6827	3.4904	3.7059	3.609	3.9143	3.5689	3.9311
Standard Deviation	1.3172	1.79672	1.06833	1.0769	0.88193	1.11806	0.92486

*p<0.1, **p<0.05, ***p<0.01

4.3. Hypothesis Testing

(1) Main effect test. This paper mainly adopts the hierarchical regression method to test the structural embedding, relational embedding, knowledge integration, government support of the collaborative innovation network and the innovation performance of specialized, sophisticated, special and new enterprises. When studying the impact of collaborative innovation network embedding on the innovation performance of specialized, sophisticated, special and new enterprises, the control variables of enterprise scale and enterprise industry are first included in the model, and the results are shown in Table 3. It can be seen from Model 2 that both the structural embedding of the collaborative innovation network (β=0.347, p<0.001) and the relational embedding of the collaborative innovation network (β=0.374, p<0.001) have a significant positive impact on the innovation performance of specialized, sophisticated, special and new enterprises, so Hypotheses H1a and H1b are established.

(2) Mediating effect test. To explore whether knowledge integration plays a mediating role between the collaborative innovation network and the overall enterprise innovation performance, this paper adopts the stepwise test method for testing, and the results are shown in Table 3. It can be seen from Model 3 that after adding the mediating variable of knowledge integration, the impact coefficient of structural embedding on specialized, sophisticated, special and new enterprises decreases from the original 0.347 to 0.291, but it is still significant (p<0.001), and the impact coefficient of relational embedding on specialized, sophisticated, special and new enterprises decreases from the original 0.374 to 0.304, but it is still significant (p<0.001), indicating that knowledge integration plays a mediating role between collaborative innovation network embedding and the innovation performance of specialized, sophisticated, special and new enterprises. Therefore, Hypotheses H2a, H2b and H2c pass the test.

(3) Moderating effect test. To test the moderating role of government support, the relevant variables are first standardized to avoid the problem of multicollinearity, and the results are shown in Table 4. Government support positively moderates the relationship between the structural embedding of the collaborative innovation network and knowledge integration (β=0.281, p<0.001), government support positively moderates the relationship between the relational embedding of the collaborative innovation network and knowledge integration (β=0.297, p<0.001), and

government support positively moderates the relationship between knowledge integration and the innovation performance of specialized, sophisticated, special and new enterprises (β=0.268, p<0.001). Hypothesis H3 is verified.

Table 3. Test Results of Main Effect and Mediating Effect

Variables	Model 1	Model 2	Model 3
Control Variables			
Enterprise Scale	-0.04	-0.058	-0.055
Enterprise Industry	-0.001	0.011	0.015
Independent Variables			
Structural Embedding		0.347***	0.291***
Relational Embedding		0.374***	0.304***
Mediating Variable			
Knowledge Integration			0.287***
R^2	0.002***	0.353***	0.393***
ΔR^2	-0.004***	0.344***	0.383***
F	0.347***	83.151***	20.446***

*p<0.1, **p<0.05, ***p<0.01

Table 4. Regression Results of Moderating Effect

Variables	Model 4	Model 5
Control Variables		
Enterprise Scale	-0.055	-0.054
Enterprise Industry	0.015	0.016
Independent Variables		
Structural Embedding	0.291***	0.281***
Relational Embedding	0.304***	0.297***
Mediating Variable		
Knowledge Integration	0.287***	0.268***
Moderating Variable		
Government Support		0.061***
R^2	0.393***	0.395***
ΔR^2	0.383***	0.383***
F	39.683***	0.965***

*p<0.1, **p<0.05, ***p<0.01

5. Research Conclusion and Implications

5.1. Research Conclusion

Based on the social network theory and knowledge-based theory, this paper explores and verifies the impact path of collaborative innovation network embedding and knowledge integration on the innovation performance of specialized, sophisticated, special and new enterprises, and analyzes the moderating role of the government in it, drawing the following conclusions:

(1) Collaborative innovation network embedding has a significant positive driving effect on the innovation performance of specialized, sophisticated, special and new enterprises. By deconstructing the two-dimensional mechanism of collaborative innovation network embedding, it is found that: in the dimension of structural embedding, enterprises effectively obtain complementary technical resources and market information by occupying the core nodes of the network, providing an element foundation for breakthrough innovation; in the dimension of relational embedding, enterprises rely on social capital such as trust commitment and reciprocity norms to deeply activate the flow of tacit knowledge and joint R&D activities among network members. The empirical results confirm that enterprise innovation behavior has significant characteristics of relational resource dependence.

(2) Knowledge integration plays a significant mediating role between specialized, sophisticated, special and new enterprises' embedding in the collaborative innovation network and the improvement of innovation performance. Empirical research shows that after enterprises realize the agglomeration of knowledge elements by embedding in the inter-organizational collaboration network, the improvement of their innovation efficiency essentially stems from the systematic integration and reconstruction of heterogeneous knowledge resources, and then through the establishment of an organizational learning mechanism for knowledge absorption, transformation and reorganization, these knowledge are transformed into innovative capital with strategic value, and finally drive the continuous output of breakthrough innovation results.

(3) Government support plays a moderating role in the relationship between collaborative innovation network embedding and the innovation performance of specialized, sophisticated, special and new enterprises. Empirical research shows that the government has significantly enhanced the intensity of the effect of network embedding on innovation performance by constructing a series of policy supports. The research results show that the government's special subsidies have effectively lowered the threshold for enterprises to participate in the innovation network, improving the synergetic effect of relational embedding; the leverage effect of tax incentive policies has amplified the knowledge spillovers of structural embedding, prompting enterprises to increase their R&D intensity.

5.2. Theoretical Contributions

(1) Expanding the theoretical boundary of the collaborative innovation network. On the basis of the traditional network embedding theory, it innovatively reveals the impact mechanism of government support as a moderating variable on the network embedding efficiency. It breaks through the theoretical presupposition of existing research that regards network embedding as a spontaneous market behavior, proposes a new paradigm of policy embedding, clarifies the mechanism of the government reconstructing the network structure and knowledge flow path through institutions, and provides a new theoretical perspective for understanding the interactive effect of the institutional environment and the market network.

(2) Constructing an institutional synergy theory for the innovation of specialized, sophisticated, special and new enterprises. Aiming at the characteristics of specialized, sophisticated, special and new enterprises, a dual-path moderating framework of structural-relational is proposed. At the theoretical level, it deconstructs the differentiated impact mechanism of government support on different dimensions of network embedding: in the dimension of structural embedding, policy tools reduce the cost of network connection through the optimization of factor allocation; in the dimension of relational embedding, institutional trust strengthens the depth of knowledge sharing. It provides a new explanation of the institutional synergy theory for small and medium-sized enterprises to break through the "innovation resource curse", and enriches the theoretical map of innovation policy research in the context of emerging economies.

5.3. Management Implications

This paper can provide the following implications for the innovation process of specialized, sophisticated, special and new enterprises and the government's promotion of enterprise technological innovation:

First, specialized, sophisticated, special and new

enterprises should attach importance to the network formed in the innovation process. On the one hand, they should actively strengthen cooperation with universities, research institutions and other organizations. Enterprises need to establish a multi-level network embedding system, and systematically promote the coordinated development of relational networks, structural positions and cognitive capabilities. By strengthening strategic cooperation with heterogeneous subjects such as universities and research institutions, build an innovation alliance with the deep integration of industry, university and research.

Second, specialized, sophisticated, special and new enterprises should rationally utilize the knowledge in the network. Establish a closed-loop management system covering knowledge identification, transformation and value realization. Use digital tools to realize real-time tracking and intelligent matching of network knowledge, focus on breaking the institutional and institutional obstacles to the transfer of tacit knowledge, and transform knowledge flow into sustainable innovation momentum through institutional design.

Third, the government should continuously improve the policy support for specialized, sophisticated, special and new enterprises. Build a composite support system of "policy toolbox + digital governance platform", and improve the accuracy of policy response through data sharing mechanisms. Explore institutional breakthroughs in cross-border innovation collaboration, and establish special policy zones for offshore R&D and cross-border technology transfer. Improve the innovation risk sharing mechanism, and build a risk buffer system guided by the government and participated by multiple subjects.

5.4. Research Limitations and Prospects

This paper still has certain deficiencies: first, due to the limitations of research conditions, the research samples only select some specialized, sophisticated, special and new enterprises in Jiangsu, Zhejiang and Shanghai, and the research scope needs to be further expanded in the future. Second, the research scale of this paper draws on existing mature scales at home and abroad, which cannot accurately reflect the time lag of innovation performance. Follow-up research should adopt a more up-to-date research design.

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