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Coupling Open Innovation: Network Position, Knowledge Integration Ability, and Innovation Performance

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Abstract
Taking some enterprises in the Yangtze River Delta of China as samples, this paper discusses the impact of coupling open innovation on innovation performance and the moderating role of network position and knowledge integration ability. The results show that there is a positive correlation between coupling open innovation and innovation performance. Both network centrality and structural holes positively regulate this relationship. In the knowledge integration ability, the two elements of socialization ability and cooperation-coordination ability also play a positive moderating role. The research results enrich the literature of coupling open innovation and help to provide theoretical reference for enterprises to implement coupling innovation.

Keywords Coupling open innovation · Network centrality · Structural holes · Knowledge integration capability · Innovation performance

Introduction

With the establishment of new production relations, the open innovation model has broken through the limitations of the previous process simply from outside to inside or from inside to outside and paid more attention to the interactive role between various subjects. Some scholars have found that although the two models of inbound open innovation and outbound open innovation are different in nature, they are not mutually exclusive. From the perspective of knowledge flow, they should be collaborative and complementary. Enterprises can engage in two activities at the same time to promote enterprise development in different ways (Cassiman & Valentini, 2016), which is the so called coupling open innovation. This kind of innovation practice should widely exist in the enterprise innovation strategy; exploring its value to the

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enterprise innovation performance is of great significance to expand the open innovation theory.

Coupling innovation involves extensive exchange of knowledge, and its smooth implementation is inseparable from the support of innovation network. Network is an important channel for enterprise information communication, resource exchange, the formation of new relationships and the consolidation of existing relationships. The concept of innovation network was first proposed by Free Man (Freeman et al., 1991). Scholars believe that innovation network is an association system of information exchange and mutual cooperation among organizations. The innovation network has the characteristics of loose and informal (Kale et al., 2000) and emphasizes the improvement of the innovation ability of the whole network through communication and cooperation among internal subjects. MvEvily classified innovation networks into organizational networks. He believes that enterprises exchange information through innovation networks to improve their innovation efficiency (MvEvily & Marcus, 2005).

The scale, quantity and type of resources that enterprises can allocate in the innovation network are largely affected by their embeddedness and position in the network. Network embeddedness is divided into relationship and structure embeddedness. Relationship embeddedness mainly shows the relationship characteristics between enterprises in the innovation network, such as connection strength and trust level (He-cheng et al., 2016; Zhuang & Chen, 2017; Wu et al., 2018). Structural embeddedness includes network density and scale. Scholars have found that network embeddedness has a positive impact on enterprise innovation capability (Feng-shu & Jing-han, 2018); structure embeddedness and relationship embeddedness will directly have a positive impact on enterprise innovation ability (Wu et al., 2021).

Burt believes that the position of an individual or organization in the network is more important than the strength of the relationship (Burt, 1992). The position in the network determines the information, resources and power of an individual or organization. Network centrality and structural holes are two common indicators of network position. Network centrality is used to measure the degree to which a node in the network is connected to all other nodes. The higher the network centrality of an enterprise, the more its connection with society. This connection can effectively reduce the information asymmetry between internal and external investors and accelerate investors' identification and response to enterprise investment opportunities (Ruo-sen & Xiaoli, 2017). The rich channel resources of network centrality make high-tech enterprises have obvious advantages in knowledge spillover and affect the ability of enterprises to approach and acquire knowledge. In addition, enterprises in the center of the network also occupy a better institutional position and can more actively respond to the regulatory institutional pressure from the government. The design of government policy content often fits the innovative demands of enterprises, and enterprises can obtain greater benefits directly through institutional capital (Bo & Jing, 2019). Structural holes are used to measure the criticality of a node in the network. Companies occupying structural holes have more non-redundant heterogeneous social relationships and can release companies from the pressure of redundant relationship management by virtue of information advantages and control advantages, greatly reducing financing management costs and having

more opportunities to obtain high-quality heterogeneous knowledge (Wan, 2019). Therefore, regardless of the strength of the relationship, if the enterprise is in the position of structural holes, it can connect the two subjects that are not directly connected to provide more services and returns for itself. In short, if the network position of an enterprise has advantages, the enterprise can realize the transformation from a passive "receiver" to a "controller" with resources to obtain initiative, so as to more easily realize high-quality knowledge flow and enhance innovation ability (Zhu et al., 2017). Therefore, if an organization wants to maintain its advantage in the competition, it must establish extensive contacts, ensure its high network centrality, occupy more structural holes, and master more information and resources (Karamanos, 2016). From the perspective of resource view theory, the innovation network position of an enterprise is one of the most important exogenous network resources for its product innovation and strategic choice. In view of this, it is of great practical and theoretical value to study how different innovation network position affects the coupling open innovation development and performance improvement of an enterprise.

Knowledge integration ability is the ability to synthesize and integrate knowledge from different sources, levels, structures and contents by using scientific methods and form a new knowledge system through knowledge reconstruction, integration and improvement (Li, 2016). It refers to the enterprise's ability to comprehensively use the existing and acquired knowledge. This ability is not only the use of tools (such as the use of databases), but also the knowledge possessed by the enterprise's employees or departments through mutual communication and coordination. Kogut and Zander pointed out that the knowledge of enterprises can be divided into two types: scattered knowledge and system knowledge (Grant, 1996; Kogut & Zander, 1992). The process of knowledge integration can be represented by three characteristics: the effectiveness of knowledge integration, the scope of knowledge integration and the flexibility of knowledge integration. The effectiveness of knowledge integration means that system knowledge can approach and utilize scattered knowledge. The scope of knowledge integration refers to the scope of the use of system knowledge to scattered knowledge. The flexibility of knowledge integration means that the system knowledge can approach the additional scattered knowledge and integrate the existing scattered knowledge. Boer et al. believes that knowledge integration ability is embodied in systematization ability, cooperation ability and socialization ability (Boer et al., 1999). Firstly, employees with different functions in the enterprise master different knowledge, and employees often only focus on their own work, which will cause some obstacles to the dissemination of knowledge. If the organization has strong socialization ability, its members have common values, norms or tacit understanding, and the direction of employees' efforts is more consistent; this obstacle can be broken, and the dissemination and transformation of knowledge can be promoted (Lee & Yang, 2000; Nonaka et al., 2001). Secondly, knowledge sharing and integration are realized in the process of enterprise employee cooperation and coordination. If enterprises have strong cooperation ability and departments often coordinate and support each other, knowledge with different attributes can be better combined and transformed in this interaction (Dougherty, 1992). Finally, in order to provide good products or services, enterprises need to integrate expertise in different

fields. This requires enterprises to have strong systematization ability, so as to condense these multifaceted and multi-level fragmented knowledge and form the new knowledge required for innovation (Grant, 1996; Verona & Ravasi, 2003). Innovation is the result of applying new knowledge. Therefore, as a key link of knowledge management, knowledge integration ability is very important to the acquisition of innovation ability (Qin et al., 2017).

To sum up, the existing research involves little in coupling open innovation. In fact, with the evolution and development of the enterprise's internal and external innovation environment and technology track, as an effective innovation way to avoid risks in the implementation of open innovation, coupling open innovation will become a third innovation type to replace the single inbound or outbound open innovation. How does it affect innovation performance? What factors will moderate this impact? These problems are worth exploring in depth. From the dual perspective of knowledge and network, taking the impact of coupling open innovation on innovation performance as the research content, this paper analyzes the moderating role of the network position of enterprises in the innovation network and the organization's knowledge integration ability, so as to explore the relationship between coupling open innovation and innovation performance, as well as the moderating effect of network position and knowledge integration ability on this relationship. The research results are expected to provide guidance for the smooth implementation of coupling innovation and improving innovation performance.

The rest of the paper is organized as follows. As the theoretical basis, the concept of coupling innovation and related theoretical assumptions are presented in "Theoretical background and hypotheses development". In "Sample and Methodology", the design of empirical research, including data collection, variable determination and data analysis methods, is introduced. The hypothesis test results are presented in "Results". Finally, the conclusions are summarized in "Discussion and Conclusions".

Theoretical Background and Hypotheses Development

Coupling Open Innovation and Innovation Performance

Coupling open innovation is a combination of inbound and outbound innovation and is the most open innovation model. Coupling open innovation is not a simple superposition process of inside-out and outside-in. On the contrary, it is a complementary process of stakeholders and an embodiment of social participation in the shared economy, which requires the equal promotion and participation of various complementary innovation partners. This innovation is a risk mitigation agent, which requires long-term partnership to provide continuous cost and risk sharing. It also needs to establish an active and strategic management alliance portfolio to interact more closely with partners (Ovuakporiea et al., 2021).

In this context, enterprises will not be bound by specific cooperation circles and have a high degree of independence and autonomy. Enterprises can freely participate in and exit different network systems according to their own needs or belong to

several intersecting or disjoint network circles at the same time. To some extent, the boundary between organizations has been replaced by the connection line between organizations and different social subjects and evolved into an invisible network. The more open the innovation background is, the more unstable the partners between organizations are. The whole society maintains its coordinated development through the interweaving of responsibilities among various subjects into a social innovation network. It can be seen that coupling open innovation is an innovative core concept that integrates into the lifeblood of the organization, penetrates into the organizational process and penetrates into the organizational business. Because the performance brought by open innovation has non-linear characteristics, coupling open innovation is by no means a simple superposition of two single innovation modes. It is bound to produce an innovation effect of "$1+1>2$", which greatly promotes the organization innovation performance (Zhao, 2021a, 2021b).

Huawei is a typical example of implementing coupled open innovation. By building a platform for developers to use, Huawei searches for good innovative ideas from all over the world and establishes an open innovation community jointly created by the government, scientific research institutions (universities), Internet platform companies and the public. At the same time, Huawei has strengthened the integration of internal and external innovation resources and commercialization channels to make the two-way flow of knowledge more complex and frequent, and the information communication has changed from linear to network. The acquisition of innovation resources has broken through the limitations of time, space and region and greatly stimulated the innovation performance of enterprises. As of June 2019, Huawei has won 46 5G commercial contracts in 30 countries around the world, with more than 100,000 5G base stations shipped, taking the lead in making a technological breakthrough in the communication network. In 2020, the company ranked first among China's top 500 private enterprises (Zhao, 2021a, 2021b).

Therefore, this paper puts forward the hypothesis:

H1: There is a positive relationship between coupling open innovation and innovation performance.

The Moderating Effect of Network Position in Innovation Network on the Relationship Between Coupling Open Innovation and Innovation Performance

The rapid development of information technology and artificial intelligence has led to drastic changes in the innovation mode of enterprises. The previous "closed innovation" relying solely on the internal R&D of enterprises has been difficult to meet the needs of enterprise development and competition. With the help of innovation network, integrating internal and external resources and capabilities to carry open innovation has become the inevitable choice of enterprise (Abril et al., 2015). From the perspective of innovation network, enterprises in different network position have obvious differences in resources and constraints, resulting in different quantities, quality and types of innovation resources that can be obtained and allocated, which

will have different effects on innovation methods and innovation performance. This paper selects two important factors of network centrality and structural holes in network construction to explore the mechanism of network position in the relationship between coupling open innovation and innovation performance.

Moderating Role of Network Centrality

External network has the characteristics of resource value, scarcity, difficult to imitate and irreplaceable. It is one of the advantages of sustainable competition. Network centrality refers to the degree to which enterprises are in a dominant and core position in the innovation network. It is found that enterprises with higher network centrality usually have the following characteristics: first, compared with other network members, they have higher industry status and network reputation and master more information, knowledge and resources, that is, they can obtain the knowledge and technology needed for innovation more timely and effectively than other enterprises. Second, they can choose their partners in a wider range, so as to build a more efficient and perfect innovation network system. Third, they have stronger scale advantages and economies of scope, which greatly increases their business initiative. Obviously, such enterprises are easier to obtain knowledge from the outside, improve their innovation ability and have more opportunities to promote the commercialization of their own knowledge, so as to smoothly implement coupled open innovation, and finally lay a tangible and intangible resource foundation for enterprise innovation performance. Therefore, whether from the innovative resources, information and knowledge base, or from the innovative network capability, the higher the network centrality, the more the enterprise can make a breakthrough from technological innovation, and then promote the improvement of innovation performance.

Therefore, this paper puts forward the hypothesis:

H2A: Network centrality plays a positive moderating role between coupling open innovation and innovation performance.

The Moderating Effect of Structural Hole

The concept of structural hole was put forward by Burt (Burt, 1992) in the book "Structural Holes: The Social Structure of Competition". It refers to the gaps in the social network, that is, some or a certain individual in the social network is directly connected with other individuals, but there is no direct contact with another individual. From the perspective of the network as a whole, it seems that a cave has appeared in the network structure (as shown in Fig. 1). This phenomenon generally appears in the networked social system under the internet economic system.

According to the structural hole theory, the existence of structural holes in the innovation network will dilute the connection density of the whole network, thereby creating more opportunities for enterprises to seek rent and find gaps in the market. If an enterprise is connected with many network members who are not connected to each other, this network structure is very beneficial to the enterprise itself, and if

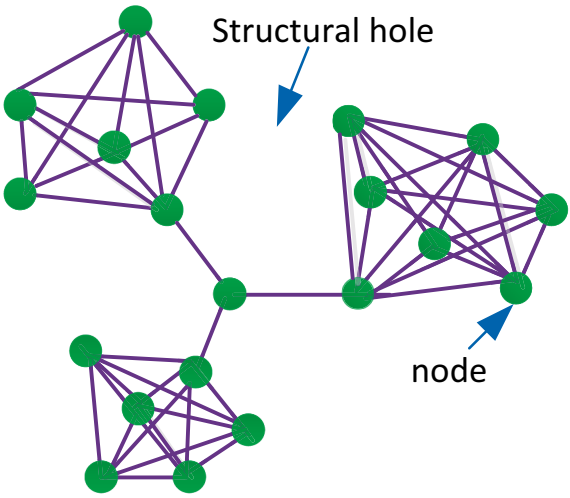

Fig. 1 Structural holes

an enterprise acts as a bridge between two unrelated groups, the benefits brought by this structure will be further amplified to a great extent (Uzzi, 1997). By occupying holes in the network structure, enterprises can act as "middlemen" for other network members to contact each other and objectively play a "bridging" role between other partners. The fact that the enterprise has structural holes indicates that the enterprise controls the important information channels in the network and occupies a favorable position to obtain the benefits from information control. Thus, additional information and knowledge can be obtained to provide a resource base for the implementation of coupling open innovation. At the same time, the enterprise also has more innovation opportunities and the possibility of success than that without the advantage of structural holes. Therefore, the structural hole plays a great role in promoting enterprises to grasp the opportunity of innovation and improve the quality and efficiency of innovation.

Based on this, we propose the hypothesis:

H2B: Structural holes play a positive moderating role between coupling open innovation and innovation performance.

The Moderating Effect of Knowledge Integration Ability on the Relationship Between Coupling Open Innovation and Innovation Performance

Knowledge includes not only explicit knowledge but also tacit knowledge. Enterprises need to integrate this knowledge, especially the integration of knowledge within or between departments, in order to promote the enterprise to gain a competitive advantage, rather than simply owning knowledge. Coupling open innovation not only emphasizes the integration and utilization of external knowledge and internal knowledge, but also pays attention to the commercial spillover of internal knowledge. It has higher requirements for the novelty of knowledge and

needs stronger knowledge integration ability, so as to integrate internal knowledge and external knowledge to form new knowledge. As for the constituent factors of knowledge integration ability, Boer et al. believes that knowledge integration ability is embodied in three aspects: systematization ability, cooperation ability and socialization ability (Boer et al., 1999). Kogut and Van et al. deconstructed it from three aspects: systematization ability, socialization ability and coordination ability (Kogut & Zander, 1992; Van Den Bosch et al., 1999). Xie Hongming et al. believe that socialization ability and cooperation ability are the main factors constituting knowledge integration ability (Xie et al., 2008). Referring to the above arguments, this paper analyzes the role of knowledge integration ability on coupling open innovation and innovation performance from the two main elements of socialization ability, coordination-cooperation ability.

The Role of Socialization Ability in Coupling Open Innovation and Innovation Performance

Socialization capability is the ability of an organization to integrate tacit knowledge into new knowledge by promoting corporate culture, values and beliefs. Tsai and Ghoshallls believe that the establishment of common goals, cognition and behavioral norms among members of the internal network can promote all departments of the enterprise to become one (Tsai & Ghoshal, 1998). The stronger the members of different departments identify with the corporate culture, values and beliefs, and the higher the acceptance of the corporate system and code of conduct, the closer the communication and contact within the organization, the better the adaptability and coordination of organization members and the more efficient the dissemination of knowledge, creativity and thinking within the organization. Thus, it can remove the obstacles caused by different cultures and systems to knowledge circulation and integration, form a common spiritual language of knowledge sharers and enhance the effect of enterprise knowledge integration and the ability to transform creativity and thinking into innovation opportunities.

Therefore, this paper puts forward the hypothesis:

H3A: Socialization ability plays a positive moderating role between coupling open innovation and innovation performance.

The Role of Coordination-Cooperation Ability in Coupling Open Innovation and Innovation Performance

Cooperation ability is the ability of members in an organization to integrate explicit complex or tacit knowledge into new knowledge through interaction and communication with internal and external units. Zack believes that the organization must organize, integrate and share the knowledge that has spread throughout the organization in order to play the role of knowledge (Zack, 1999). The diffusion, integration and sharing of knowledge are realized in the process of cooperation and coordination among employees. New methods are developed to improve the relationship of knowledge sharers, thereby improving the efficiency of knowledge circulation and

integration. The stronger the company's ability to cooperate, the closer the relationship between the knowledge sharers. Frequent knowledge dissemination, reconciliation and synthesis among members will strongly promote the efficiency and effect of knowledge integration, so as to effectively play the role of knowledge and promote the development of new products. At the same time, the coordination between R & D department and marketing and manufacturing department is very important for the effective development of new products. Coordination behavior promotes effective interaction between departments. Close partnership can enable both parties to jointly carry out the integration planning of knowledge activities, reach a consensus, promote the standardization of information and maintain the consistency of process, increase the mutual recognition among members and facilitate the mutual communication and cooperation between internal and external members of the enterprise. The stronger the cooperation ability of the enterprise, the higher the coordination degree of each department of the company, and the easier it is for employees to get the support of other departments and personnel when needed. This will make knowledge spread and applied among members and make tacit knowledge explicit, so as to enhance the coupling open innovation ability of enterprises.

Therefore, this paper puts forward the hypothesis:

H3B: Coordination-cooperation ability plays a positive moderating role between coupling open innovation and innovation performance.

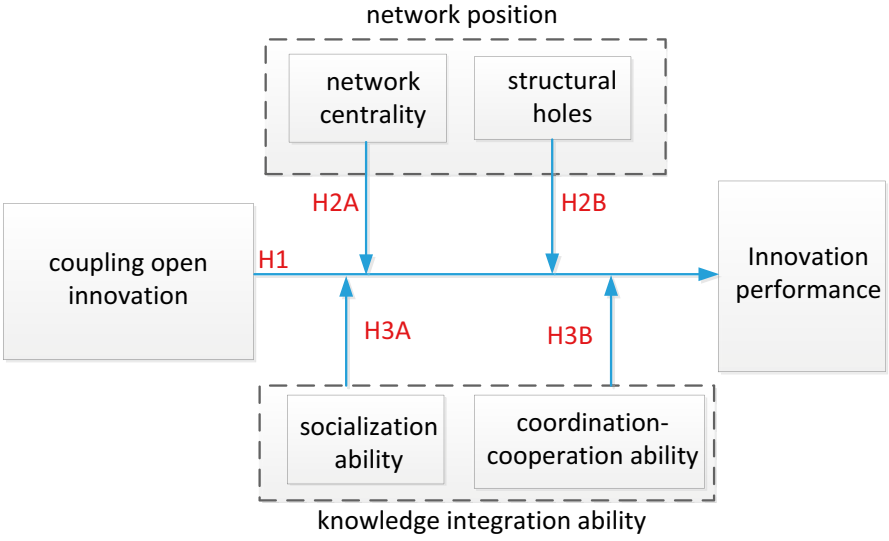

Fig. 2 Theoretical model

Theoretical Model

According to the research hypothesis, a theoretical model of the relationship between coupling open innovation, network position, knowledge integration ability and the innovation performance is constructed, as shown in Fig. 2.

Sample and Methodology

Sample

In order to fully reflect that the coupling open innovation is different from the single inward or outward open innovation, this paper selects the data of five categories of enterprises in China's Yangtze River Delta (three provinces and one city: Shanghai, Jiangsu, Zhejiang and Anhui), including manufacturing industry, new energy and new materials, metal products and medical devices, electronic information, power grid and Internet, textile and so on. The main reasons for the choice are first, the Yangtze River Delta is one of the regions with strong scientific and technological strength and complete industrial categories in China. After years of development and integration, enterprises in the region are gradually embedded in the global value chain and initially form an external innovation environment for regional industrial clusters. Second, the integrated development of the Yangtze River Delta has a foundation for many years. The regional industrial clusters have not only industry leading enterprises, but also a large number of private small- and medium-sized enterprises, forming a relatively developed production technology network and the premise of carrying out coupling open innovation. Third, the region is rich in scientific, technological and educational resources. Universities, scientific research institutions and industries have formed a rooted regional innovation system. At the same time, the national strategic background of Yangtze River Delta integration proposed by the government will further promote the construction of regional innovation community.

Data Collection

The data sources of enterprises investigated in this paper are mainly obtained in the form of on-site questionnaire and electronic questionnaire. The respondents are relevant technical and management personnel who are engaged in innovation activities or have a certain understanding of innovation activities. A total of 850 questionnaires were distributed, and 753 were actually recovered, with a recovery rate of 88.6%. After excluding the questionnaires with more missing values, 632 valid questionnaires were obtained, with a recovery rate of 74.4%. See Table 1 and Fig. 3 for the basic information of samples.

Table 1 Analysis of sample characteristics ($N=632$)

Feature	Category	Number	Rate (%)	Feature	Category	Number	Rate (%)
Position	Middle manager	474	75	Staff size (person)	1–99	155	24.5
	Senior manager	158	25		100–499	363	57.4
Duration time (year)	< 5	149	23.6		500–999	74	11.7
	5–10	205	32.4		> 1000	40	6.4
	11–15	172	27.2	Development stage	Start-up	107	16.9
	16–20	84	13.3		Growing	263	41.6
	> 20	22	3.5		Mature	209	33.1
					Transition	53	8.4

Variables and Calculations

Dependent Variable

This paper takes innovation performance (*ip*) as the dependent variable. Due to the innovation differences and complexity in different industries and different positions of the industrial chain, the measurement methods of innovation performance are not unified. Referring to the research results of Zhang Huiying and Wang Beifen (Zhang & Wang, 2019), this paper uses three items to measure, namely (1) Proportion of successful new products on the market (*ip1*); (2) proportion of new product sales in total sales (*ip2*); (3) proportion of new product profit in total profit (*ip3*).

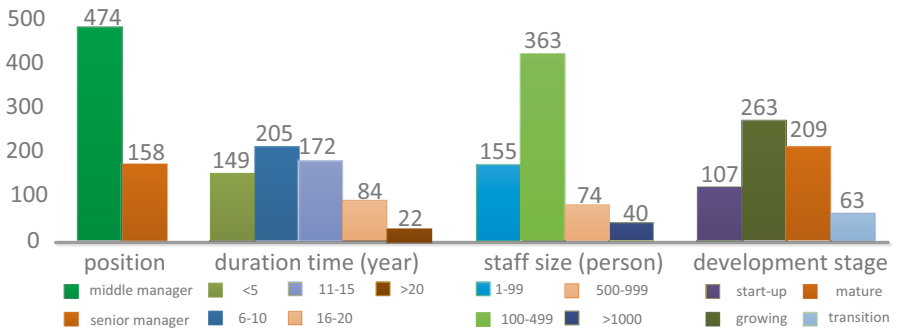

Fig. 3 Sample characteristics

Independent Variable

In this paper, coupling open innovation (*ci*) is selected as an independent variable, which is measured by four items: (1) frequently introduce external technology and information by scanning the external environment (*ci1*); (2) actively purchase intellectual property rights from R&D institutions of other corporates and universities for internal new product or technology research and development (*ci2*); (3) enterprise often sell technical knowledge and intellectual property (*ci3*); (4) enterprise has a dedicated department to commercialize its internal knowledge assets (*ci4*). The score of each item is determined by Likert 5 scale. 1 ~ 5 points represent "completely disagree" to "fully agree".

Moderating Variables

1. Network centrality (*nc*)

In this paper, the commonly used name generator is used to measure the network centrality. The specific process is that in the questionnaire survey, the surveyed enterprises are required to fill in more than 3 network members who have close ties with the enterprises, and finally get 1587 enterprise names, which are encoded by dummy variables according to whether there is a cooperative relationship between them. The code of cooperative relationship is 1, and the code of non-cooperative relationship is 0, so as to form a 0–1 matrix of 1587 × 1587, then, use UCINET6.0 to calculate and obtain the relevant index of network location. Freeman proposed three forms of network centrality: degree centrality, intermediary centrality and proximity centrality (Freeman, 1991). Degree centrality reflects the degree of direct connection between actors and other individuals in the network, proximity centrality reflects the ease of actors to other individuals in the network, and intermediary centrality reflects the ability to control the connection between other actors in the network. Among the three centralities, degree centrality is the most widely used and the most intuitive measurement of network position centrality. Therefore, this paper takes the degree centrality as the index of enterprise network centrality. The calculation formula is:

$$D_i = \frac{\sum_{j \neq i} \delta(i,j)}{n-1} \tag{1}$$

where $\delta(i,j)$ indicates whether enterprise i has a cooperative relationship with enterprise j. n is the total number of enterprises in the network.

2. Structural holes (*sh*)

According to the structural holes theory, there are four methods to measure the structural hole, namely, effective scale, efficiency, restriction degree and level. Among them, the use of restriction degree is more extensive (Qian et al., 2010). Therefore, this

paper uses the restriction degree to measure the richness of structural holes, which is calculated by (2):

$$R_i = \sum_{j \neq i} \left[p_{ij} + \sum_{k \neq i, j} \left(p_{ik} p_{kj} \right) \right]^2 \tag{2}$$

where $p_{ij} = 1/\mathrm{M}$ indicates the strength of the direct dependence of enterprise i on enterprise j (M is the total number of enterprises in the network that has a direct cooperative relationship with enterprise i. When enterprise i has no direct cooperative relationship with enterprise j, $p_{ij} = 0$. R_i represents the total restriction of enterprise i in the network. The less restricted an enterprise is, the richer its network structure holes is. Therefore, according to the method of Zaheer and Bell (2005), this paper uses $1 - R_i$ to represent the size of the structural holes of an enterprise i.

3. Socialization ability (*sa*)

Referring to the research results of Boer et al., Kogut and Zander etc., socialization ability is measured by four measurement items (Boer et al., 1999; Kogut & Zander, 1992). (1) Employees recognize the business philosophy of the enterprise (sa1). (2) Employees are willing to work together to achieve organizational goals (sa2). (3) Employees are willing to accept the established organizational culture (sa3). (4) The enterprise system can only be implemented after the joint discussion of all employees (sa4). The score of each item is determined by liker 5 scale.

4. Coordination-cooperation ability (*ca*)

Referring to the research of Van et al. and Xie Hongming et al., the coordination-cooperation ability is measured by five items (Van Den Bosch et al., 1999; Xie et al., 2008): (1) various departments of the enterprise often communicate (*ca1*); (2) the company's products need the cooperation of various personnel to complete (*ca2*); (3) create an atmosphere of interactive learning and exchange within the enterprise (*ca3*); (4) the adaptation time required for enterprise employees to move to a new department is very short (*ca4*); (5) employees' willingness to cooperate with others will increase with the increase of job rotation (*ca5*). The score of each item is also determined by liker 5 scale.

Control Variables

In order to effectively eliminate the interference of other factors on the research results, this paper selects the age of the enterprise (*ag*), the size of the enterprise (*sz*) and the nature of ownership (*ow*) as the control variables. Among them, the age of the company is measured by 2020 minus the time the company was established and taken the natural logarithm. Enterprise size is measured by the natural logarithm of the number of employees referring to the research of Sandulli et al. (2012). The nature of ownership is divided into state-owned enterprises, private enterprises and foreign-funded enterprises according to the information of registrants whose registered capital is greater than 50%

Table 2 Reliability test

Variable	*Cronbach's α*	Variable	*Cronbach's α*
ip	**0.702**	*sa*	**0.736**
ci	**0.725**	*ca*	**0.812**

and is measured by dummy variables (state-owned enterprise = 0, private enterprise = 1, foreign enterprise = 2).

Sample Validity Verification

Using SPSS21.0 to calculate the Cronbach α of each variable, the results are shown in Table 2. It can be seen that the Cronbach α value of each variable is greater than 0.7, indicating that the variables have good reliability.

Table 3 and Table 4 show the results of confirmatory factor analysis (CFA) calculated by SPSSAU. It can be seen that the factor loading of each measurement item is greater than 0.6, and the average variance extracted (AVE) value of each variable is greater than 50%; the composite reliability (CR) value of each variable is greater than the standard value of 0.7, so the variables have high aggregation validity. At the same time, it can be known from Table 4 that the square root value of AVE of each variable (bold italics on the diagonal in the table) is greater than the correlation coefficients of its row and column, which indicates that the variable has a good discrimination validity.

The Harman single-factor test was carried out for the recovered questionnaire. The results showed that the explained variance of the first principal component accounted

Table 3 Results of CFA

Variable	Measurement items	Factor loading	CR	AVE
ip	*ip1*	**0.680**	**0.812**	**0.562**
	ip2	**0.713**		
	ip3	**0.728**		
ci	*ci1*	**0.658**	**0.783**	**0.515**
	ci2	**0.622**		
	ci3	**0.736**		
	ci4	**0.871**		
sa	*sa1*	**0.715**	**0.822**	**0.546**
	sa2	**0.672**		
	sa3	**0.684**		
	sa4	**0.716**		
ca	*ca1*	**0.788**	**0.782**	**0.537**
	ca2	**0.752**		
	ca3	**0.659**		
	ca4	**0.718**		
	ca5	**0.633**		

Table 4 Correlation coefficient

Variable	1	2	3	4	5	6	7	8	9
1. *sz*									
2. *ag*	0.012								
3. *ow*	−0.004	0.005							
4. *nc*	0.001	−0.007	0.017						
5. *sh*	0.015	0.026	0.032	0.525					
6. *ip*	0.011	0.101	0.105	0.426	0.501	***0.750***			
7. *ci*	0.006	0.119	0.020	0.419	0.487	0.561	***0.718***		
8. *sa*	0.012	0.114	−0.001	0.272	0.253	0.487	0.459	***0.739***	
9. *ca*	−0.001	0.128	0.103	0.289	0.341	0.374	0.317	0.304	***0.733***
Mean	1.801	0.921	1.013	0.003	0.137	0.415	2.321	2.627	2.216
Std	1.136	1.408	0.421	0.018	0.976	0.612	4.754	4.179	3.325

Bold italics are the square root of the corresponding variable AVE

for less than 50% of the total variance, indicating that there was no serious homology deviation.

In Table 4, the correlation coefficient between variables is lower than 0.7; Table 5 shows that the maximum value of the variance inflation factor (VIF) between each model variable is 4.326, far lower than the critical value of 10, indicating that there is no serious multicollinearity problem between variables.

Results

Regression model

In this study, using the hierarchical regression analysis method, the control variables, independent variables and regulatory variables will be added to each model to test each hypothesis. The regression results are shown in Table 5. Model 1 is the basic model that contains only control variables. Model 2 adds "coupling open innovation" as independent variable on the basis of the basic model. On the basis of Model 2, the variables of "product of network centrality and coupling open innovation" and "product of structural holes and coupling open innovation" are added to model 3 and model 4 respectively to verify the moderating role of network position, and the variables of "product of socialization ability and coupling open innovation" and "product of coordination-cooperation ability and coupling open innovation" are added to model 5 and model 6 respectively to test the moderating role of knowledge integration ability. Observing the regression results, it can be seen that after increasing variables, R^2 has increased, indicating that the added variables have impact on the model.

Table 5 Regression results

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
sz	0.002 (0.805)	0.001 (0.877)	0.002* (1.613)	0.003* (1.652)	0.002 (0.683)	0.003 (0.835)
ag	0.011 (1.102)	0.012 (1.214)	0.015* (1.642)	0.013 (0.965)	0.012 (1.126)	0.011* (1.671)
ow	−0.001 (1.417)	0.004 (1.151)	0.003 (0.767)	−0.002* (1.692)	0.001 (1.312)	0.002* (1.584)
ci		0.222** (2.482)	0.231** (2.519)	0.225*** (3.267)	0.219** (2.338)	0.221** (2.401)
nc × *ci*			0.224*** (3.207)			
sh × *ci*				0.191*** (3.328)		
sa × *ci*					0.263*** (3.221)	
ca × *ci*						0.209*** (3.183)
R^2	0.339	0.402	0.461	0.453	0.475	0.471
Adjusted R^2	0.278	0.394	0.421	0.407	0.432	0.428
F	3.516	3.658*	3.607**	3.712**	4.324*	3.593
VIF average	2.446	2.524	1.951	2.314	1.811	1.688
VIF maximum	3.545	4.326	3.037	2.658	2.013	1.971

The value in brackets is *t* value

*$p<0.05$; **$p<0.01$; ***$p<0.001$

Regression Results and Analysis

The regression results of model 2 show that the regression coefficient of coupling open innovation is positive and significant ($\beta = 0.222$, $p < 0.01$), which shows that the coupling open innovation is positively correlated with innovation performance, so H1 is supported. In the era of internet economy, compared with single open innovation model, coupling open innovation can more effectively promote the flow and integration of innovation elements, so it is easier to achieve innovation success and greater innovation performance.

In model 3, the regression coefficient of "product of network centrality and coupling open innovation" ($nc \times ci$) is positive and significant ($\beta = 0.224$, $p < 0.001$), shows that network centrality has a positive moderating effect on the relationship between coupling open innovation and innovation performance. H2A is supported by data. At the same time, the results of model 4 show that the regression coefficient of "product of structural holes and coupling open innovation" ($sh \times ci$) is positive and significant ($\beta = 0.191$, $p < 0.001$), so the structural holes play positive moderating role between coupling innovation and innovation performance, and H2B is also supported. These two empirical results show that the network position has a great impact on the implementation of coupling open innovation. Because the coupling open innovation is produced in the social network, the position of enterprises in the network determines the amount, difficulty and quality of enterprises' access to innovation resources to a certain extent; the coupling open innovation of enterprises in the center of the network and with rich structural holes is easier to succeed.

In model 5, the regression coefficients of "product of socialization ability and coupling open innovation" ($sa \times ci$) and "product of coordination-cooperation ability and coupling open innovation" ($ca \times ci$) are all positive and significant (The regression results are $\beta = 0.263$, $p < 0.001$; $\beta = 0.209$, $p < 0.001$, respectively), indicating that both socialization ability and coordination and cooperation ability positively moderate the relationship between coupling open innovation and innovation performance, so knowledge integration ability plays a positive moderating role between coupling open innovation and innovation performance. In other words, it is not enough for an enterprise to possess a large amount of knowledge. It must also enhance its connotation and enhance its own knowledge integration capabilities to make knowledge resources truly effective.

Discussion and Conclusions

Theoretical Implications

This paper investigates the relationship between coupling open innovation and innovation performance, as well as the moderating effect of network position and knowledge integration ability. The main theoretical significance of the research includes:

1. Taking coupling open innovation as a new model of open innovation, this paper studies the relationship between coupling open innovation and innovation per-

formance. The empirical results show that coupling open innovation can greatly promote innovation performance. On the one hand, coupling open innovation can improve its innovation ability by introducing heterogeneous knowledge; on the other hand, it can also accelerate the commercialization of innovative technology through the output of intellectual property rights, so that it can not only gradually establish competitive advantage, but also obtain better innovation performance and ensure the sustainable development of innovation activities. This study enriches the literature related to open innovation.

2. From the two dimensions of network centrality and structural holes, this paper studies the moderating effect of enterprise's network position. The results show that both network centrality and structural holes positively moderate the relationship between coupling open innovation and innovation performance. As a derivative of social network, the effectiveness of coupling open innovation must also be transmitted through social network. Therefore, this research will help to reveal the external mechanism of coupling open innovation and provide theoretical support for enterprises to build innovation networks.
3. From the two dimensions of socialization ability and coordination-cooperation ability, this paper studies the moderating effect of enterprise's knowledge integration ability. The results show that both socialization ability and coordination-cooperation ability positively moderate the relationship between coupling open innovation and innovation performance. The characteristics of coupling open innovation put forward high requirements for the uniqueness and novelty of knowledge. On the one hand, enterprises need to effectively integrate the resources obtained from the external network to enhance their innovation ability; on the other hand, they also need to integrate the innovation achievements to enhance their commercialization ability. In a sense, the ability of knowledge integration is more important. Therefore, this study helps to reveal the internal mechanism of coupling open innovation and point out the direction for corporate governance.

Managerial Implications

Through theoretical research and empirical test, the following management enlightenment is obtained:

1. In the era of rapid changes in knowledge and technology, enterprises should actively implement coupling open innovation to gain competitive advantage. The development of Internet technology provides great convenience for the implementation of coupled open innovation. It enables enterprises to break through the limitations of time and space and technology, build a social network with a certain depth and breadth and promote the rapid flow of innovation elements. Enterprises should seize the opportunity, follow the trend, vigorously implement coupling innovation and gain a firm foothold in the fierce market competition.
2. In order to successfully implement the coupling open innovation, enterprises should actively seize and build a favorable network position. On the one hand, enterprises should deeply cultivate their own industry, strive to establish a social

network covering the whole industrial chain, make ourselves in the center of the network and lay the foundation for extensive access to knowledge. On the other hand, they should also actively expand the social network across the industrial chain, establish contacts with knowledge and information far away from technology, enrich their own structural holes and prepare conditions for obtaining heterogeneous knowledge.

3. Good network location makes it possible for the implementation of coupling innovation. However, to turn this possibility into reality, enterprises also need to have good knowledge integration ability. Only in this way can enterprises remove the turnip from a large number of complex knowledge, excavate and produce new knowledge, and improve knowledge utilization efficiency and innovation ability. Therefore, in order to successfully implement coupling innovation, the organizational structure of enterprises should break the traditional division between departments and establish a department linkage mechanism with knowledge mining as the core.

Limitations and Future Research

Some valuable conclusions have been obtained in this study, but there are the following limitations: first, the empirical samples of this paper are concentrated in the eastern economically developed areas of China, and the representativeness of the research conclusions still needs to be tested in practice. For example, coupling open innovations with different degrees of coupling should have different effects on companies at different growth stages. However, because the representativeness of the sample is not comprehensive, this has not been fully proved in this study. Secondly, the influencing factors of network location have not been fully demonstrated. In fact, this is very important because it involves how to effectively improve the network location of the enterprise. This is also one of the interests we will continue to study in the future.

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Declarations

Competing Interests The author declares no competing interests.

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