The Influence of Knowledge Domain Coupling on Firm Innovation Performance

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Abstract. Promoting enterprise development with innovation is a positive response to the country's high-quality development. The improvement of innovation performance cannot be separated from the supporting role of knowledge, but the impact of changes in the knowledge base on innovation performance is not clear enough. Based on the knowledge base view, this paper explores the impact mechanism of knowledge domain coupling on innovation performance by utilizing the panel data of 249 manufacturing companies listed in China's A-share market from 2010 to 2022. The results show that existing knowledge domain coupling has a positive contribution to innovation performance, and there is an inverted "U-shaped" relationship between old and new knowledge domain coupling and innovation performance.

Keywords: Knowledge Domain Coupling, Innovation performance, Empirical Analysis

1 Introduction

Technological innovation is a key factor for enterprises to gain competitive advantage and an important driving force for economic and social development. However, on the whole, there is still a big gap between the innovation ability of Chinese enterprises and that of developed countries[1]. Since the reform and opening up, the technological progress of China's manufacturing enterprises has mainly relied on imitation innovation based on technology introduction and foreign capital technology overflow, which has led to China's manufacturing enterprises being caught in a long-term low-level cycle of "lagging behind-introducing-again lagging behind-introducing again". As a result, China's manufacturing enterprises have long been caught in the low-level cycle of "lagging behind-introducing-then lagging behind-introducing again", forming a path dependence on technology introduction. In the current context of China's economic development model is facing a substantial transformation, innovation has become the new driving force of economic development, which requires us to pay attention not only to the "quantity" of technological innovation, but also to the "quality" of technological innovation. If China's manufacturing enterprises cannot transform from simple material processing and low technology content to high value-added, inde-

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pendent intellectual property rights and independent brands, their development will be unsustainable.

Enterprise innovation capability is the basic quality of an enterprise to realize scientific and technological breakthroughs through the effective cooperation of external resource acquisition and internal resource utilization, so as to realize market value[2].Enterprise innovation activities are knowledge-based. The knowledge-based view emphasizes that knowledge is a strategic resource for enterprises to form their core competitiveness, and that valuable heterogeneous knowledge and the ability to utilize it are the key to maintaining competitive advantages. Therefore, the improvement of enterprise innovation performance cannot be separated from the effective utilization of knowledge resources. The enterprise knowledge base, as a network composed of knowledge elements in different fields and interconnections between knowledge elements, provides a knowledge base for the improvement of enterprise innovation performance. Activities such as the diffusion, accumulation and reorganization of knowledge resources can enrich the enterprise's knowledge base, thus improving the quality of enterprise innovation[3].Knowledge domain coupling, as a decision related to the dynamic reorganization of knowledge elements from different domains in the process of knowledge search by an organization[4], can change the knowledge base of a firm, which in turn affects the firm's innovation[5].When the knowledge in a single domain tends to be homogenized, and it is difficult to realize the facilitating effect of knowledge on the improvement of innovation performance, enterprises will cross the knowledge boundary, search for the knowledge in different domains, discover the dynamic interactive relationship between different types of knowledge, and absorb the heterogeneous knowledge to couple with the existing knowledge, so as to stimulate the new creativity of knowledge. Therefore, knowledge domain coupling has become an important way for enterprises to maintain their innovative power, and their innovative activities will give more prominence to the coupling role of cross-domain knowledge.

Combing through the existing literature, it can be found that the existing discussions on the factors influencing innovation performance mainly focus on the knowledge management perspective, the national policy-oriented perspective, and the perspective of market participant subjects. In the era of digital economy, knowledge has gradually become a key resource for new enterprises[6].The improvement of enterprise innovation performance increasingly focuses on the interaction of knowledge, and the study of the relationship between knowledge and innovation has thus received extensive attention from scholars. Existing studies that cut through the knowledge management perspective mostly focus on the static characteristics of the knowledge base and the role of knowledge searching behaviors on innovation, e.g., Wang et al.[7] explored the relationship between open innovation, knowledge reorganization, and innovation performance by using the sample data of listed companies in China's manufacturing industry. Using fsQCA, Dong et al[8]. integrated antecedent conditions such as the three dimensions of knowledge integration capability and the two dimensions of open innovation and knowledge sharing, and discussed the multiple concurrent factors and causal complexity mechanisms that affect innovation performance. And unlike previous studies, knowledge domain coupling focuses on the dynamic changes

in the knowledge base and explores the influencing factors of innovation from a dynamic perspective. With the changes in the corporate knowledge base, new coupling or decoupling between knowledge domains may occur, resulting in changes in the mode and degree of knowledge domain coupling in the corporate knowledge base, which may have different impacts on innovation outcomes. Scholars have studied the important impact of knowledge domain coupling on enterprise innovation performance, binary innovation, green innovation, etc., but have not conducted an in-depth investigation of the relationship between knowledge domain coupling and enterprise innovation performance, and whether different types of knowledge domain coupling have a facilitating or inhibiting effect on enterprise innovation performance.

2 Hypothesis

2.1 Coupling Between Existing Knowledge Domains and Firm Innovation Performance

By changing the interactions between existing knowledge, firms can explore new combinations of existing knowledge. First, firms are familiar with existing knowledge and have a high level of expertise in using existing knowledge, so firms can reduce uncertainty and risk by exploring new combinations of knowledge in existing knowledge domains. Compared to new knowledge developers have a more in-depth understanding of the existing knowledge base, and through repeated and in-depth searches for knowledge in existing knowledge domains, firms have a greater likelihood of effective innovation.Second, the continuous reconfiguration of knowledge in a given knowledge domain can push the limits of original innovation[9].The coupling of existing knowledge can help companies to develop new combinations of knowledge, find new ways of solving problems, and avoid falling into the “familiarity trap” when solving problems. By trying new combinations of knowledge, it can provide new ideas for creating inventions and solving problems. Thirdly, the use of internal knowledge for R&D helps to enrich and perfect the knowledge base of the enterprise, improve the structure of the enterprise's knowledge base, and enhance the ability to utilize and absorb knowledge[10]. Deep integration and reorganization of knowledge elements in existing knowledge domains can, on the one hand, promote enterprises' awareness and utilization of existing knowledge to further explore new technologies and market opportunities, and on the other hand, stimulate enterprises to create new perspectives and improve the efficiency of knowledge utilization, which will lead to more creative inventions. Based on this, this paper proposes the following hypotheses:

H1:Coupling between existing knowledge domains positively contributes to innovation performance

2.2 Coupling Between New and Existing Knowledge Domains and Firm Innovation Performance

First, the effective combination of internal and external resources can promote value-added resources. Enterprises combine the existing knowledge base to launch the search for new knowledge, which helps enterprises to narrow the scope of knowledge coupling and reduce the uncertainty of knowledge combination, so that enterprises gradually obtain the ability to conduct R&D in new technology fields.Since this knowledge coupling method is to introduce new knowledge elements on the basis of the original technology field, the knowledge search activities of the enterprises are more effective and go beyond what can be generated from the original knowledge base innovation value. At the same time, this progressive approach is conducive to the elimination of old knowledge and the continuous improvement of the enterprise's products or services, so that the enterprise can gradually build up its research capability in new fields. Secondly, the combination of new and existing knowledge can expand the size of an enterprise's knowledge base and realize the dynamic accumulation of the knowledge base. It helps enterprises to deepen their knowledge in the innovation process, generate new ideas and create new technologies that are difficult for competitors to imitate. It has been pointed out that cross-domain search for new knowledge on the basis of existing knowledge is not only conducive to the introduction of new ideas, but also deepens the manufacturing enterprise's knowledge of existing knowledge domains and enables the enterprise to utilize its existing strengths to further explore new technologies and market opportunities. Third, when an enterprise expands its knowledge sources to new knowledge domains, it can discover natural interconnections between knowledge elements that it did not realize in the past, prompting it to discover valuable knowledge combinations in the process of integrating new and existing knowledge. The coupling between new and existing knowledge expands the knowledge search boundary of manufacturing enterprises, which can weaken the traditional cognitive inertia and provide new perspectives for enterprise independent innovation. Based on this, this paper proposes the following hypotheses:

H2:Coupling between new and existing knowledge domains positively affects innovation performance

In summary, the theoretical model of this paper is shown in Figure 1.

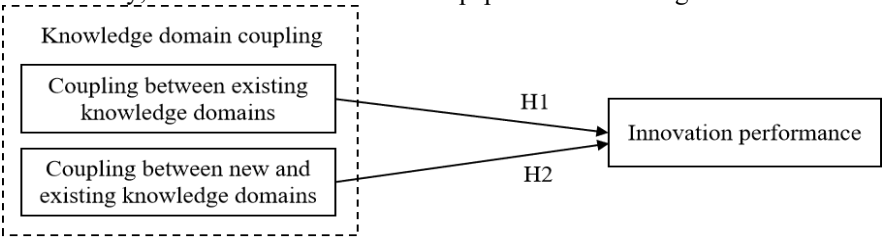

Fig. 1. Theoretical model.

3 Research Methods

3.1 Research Sample

The sample enterprises in this paper are from A-share listed manufacturing enterprises in Shanghai and Shenzhen from 2010 to 2022. Manufacturing firms are knowledge-intensive industries that emphasize the protection of intellectual property, which means that manufacturing firms value patent applications. In addition, the high technology iteration and knowledge updating speed enable us to examine the changes in knowledge coupling between different knowledge domains in a short period of time. The data needed for this study are divided into two categories: one is the basic data such as assets, profits, and R&D expenditures from the Cathay Pacific database; the other is the patent data from the State Intellectual Property Office (SIPO) patent database. Since this paper uses a time window to measure the explanatory variables, the patent data from 2010-2022 can only be obtained for seven measurement periods of the study, so the data other than the patent data are only collected from 2016-2022.

In order to ensure the reliability of the study, we try to eliminate the influence of undesirable factors when screening the samples: (1) select manufacturing enterprises according to the "Classification and Coding of Industries of China's National Economy" (GB/4754-2011); (2) eliminate sample enterprises marked with "ST" and "*ST" mark sample enterprises; (3) on this basis, eliminate the sample enterprises with seriously insufficient data; (4) in order to avoid the influence of extreme values, the main continuous variables are shrink-tailed. Finally, 239 valid sample enterprises were formed.

3.2 Measure of Varibles

Dependent variable. Innovation Performance. Patent is a visual reflection of the innovation performance of enterprises, this paper combines the existing research and adopts the number of patents granted that have been in force to indicate the innovation performance of enterprises[11].

Independent variable. Knowledge domain coupling. This study adopts the knowledge category of the enterprise to measure the knowledge coupling of the enterprise. Existing studies show that the first four digits of a patent's IPC number can well reflect the knowledge category to which the patent belongs, so knowledge coupling is reflected in the patent as a patent with two or more IPC numbers[12]. To minimize the impact of fluctuations in the number of patent applications, a three-year time window is used to measure the knowledge base of companies in the current year.

Different knowledge elements are coupled to form coupling pairs, and all coupling pairs and their interrelationships are assembled into the knowledge base of the enterprise. In order to distinguish between new knowledge and existing knowledge, this paper compares the knowledge matrix of the enterprise from stage t-1 to t-3 with the knowledge matrix from stage t-4 to t-6, and if the knowledge categories appearing in both time periods are existing knowledge, the knowledge categories appearing only in the first stage are new knowledge. In this way, the types of knowledge coupling are

divided into coupling between existing knowledge, coupling between new knowledge and existing knowledge, and coupling between new knowledge, and since the first two types of coupling account for nearly 70% of the research samples in this paper, this paper only investigates these two types of coupling. On this basis, identifying the number of IPC classification number types contained in various types of knowledge coupling and the number of IPC classification number types contained in all patents, the formula for calculating the value of knowledge coupling of company i in year t is:

$$EKC_{i,t} = \frac{QEKC_{i,t}}{QP_{i,t}} \tag{1}$$

$$NKC_{i,t} = \frac{QNKC_{i,t}}{QP_{i,t}} \tag{2}$$

Where EKC is the coupling between existing knowledge, NKC is the coupling between new and existing knowledge, QEKC is the number of types of knowledge categories involved in the coupling of existing knowledge, QNKC is the number of types of knowledge categories involved in the coupling of new and existing knowledge, and QP is the number of types of knowledge categories included in all patents.

Control Variables. Firm size. Research shows that firm size directly affects innovation performance and willingness to innovate. Large-scale firms have more advantages in resource utilization and risk resistance. This study uses the logarithm of total assets to measure firm size. R&D Intensity. The R&D intensity of a firm reflects the firm's investment in innovation, hence the need to control for this input measure. This study uses R&D expenditures over operating revenues to measure R&D intensity. Firm Performance. Because firm performance affects firms' knowledge search behavior, it will have an impact on firms' coupling selection behavior. This paper utilizes return on assets to measure firm performance. Firm Age. Firm age reflects, to some extent, the number of years a firm has been innovating and affects the firm's accumulation of knowledge about innovation. In this paper, the difference between the sample observation year minus the establishment year is used as a measure of firm age. Enterprise Growth. This paper uses the year-on-year growth rate of a firm's operating income as a measure of firm growth, calculated as the ratio of the current period's main operating income growth to the previous period's main operating income. Vummy Variables. Year dummy variables are included to control for time-dependent effects such as patent filings. A dummy variable for the nature of the firm is added to control for the effect of the firm's innovativeness as influenced by property rights.

4 Results

4.1 Main Analyses

In order to eliminate the effect of variable magnitude, before regression, this paper standardizes the independent variables and moderating variables. In order to test the hypotheses, this paper constructs the following model, and the specific regression results are shown in Table 1. Among them, model 1 contains only control variables.

The results show that most of the control variables are significantly correlated with the innovation performance of manufacturing companies, and these variables need to be controlled. Regarding the main effect test. Model 2 tests the direct effect of existing knowledge domain coupling on innovation performance, and the results show that the coefficient of existing knowledge domain coupling is 0.112, which is significant at the 1% level, and the hypothesis H1 is tested; Model 3 tests the direct effect of the coupling of new and existing knowledge domains on innovation performance, and the results show that the coefficient of the coupling of new and existing knowledge domains is 0.115, which is significant at the 1% level, and the hypothesis H2 is tested.

4.2 Robustness Check

The explanatory variables are lagged two periods. The explanatory variables are lagged by two periods, and the remaining variables are regressed using the current values, and the regression results are shown in Table 1.The results of Model4 and Model5 show that both types of knowledge coupling and innovation performance are positively significant, and the regression results are consistent with the basic regression results, and the basic conclusions have not been substantially changed.

5 Discussion and Conclusion

5.1 Conclusion

This paper takes A-share listed manufacturing enterprises as the research object, based on the knowledge base theory, empirically analyzes the impact of knowledge coupling on enterprise innovation performance, and obtains the following main conclusions:

The coupling of existing knowledge domains and the coupling of new and existing knowledge domains in manufacturing firms are both conducive to promoting firms' innovation performance. This conclusion extends Moorthy's[13]view that knowledge search and development based on existing knowledge bases can only avoid the “familiarity trap” by repeatedly experimenting with various combinations of knowledge in order to create new knowledge and technologies.

Table 1. Regression analyses testing Hypotheses 1-2.

	main effects test			robustness check	
	Model1	model2	model3	Model4	Model5
EKC		0.115***		0.064**	
		(0.024)		(0.032)	
NKC			0.128***		0.164***
			(0.023)		(0.031)
Firm size	0.417***	0.388***	0.407***	0.419***	0.430***
	(0.019)	(0.025)	(0.024)	(0.033)	(0.031)
R&D intensity	0.178***	0.123***	0.148***	0.101***	0.115***

	(0.018)	(0.025)	(0.024)	(0.031)	(0.031)
Firm Performance	0.026	0.023	0.023	0.028	0.031
	(0.019)	(0.025)	(0.024)	(0.035)	(0.032)
Firm Growth	-0.014	-0.039	-0.028	-0.061	-0.049
	(0.019)	(0.026)	(0.025)	(0.037)	(0.035)
Firm age	0.099***	0.096***	0.076***	0.095***	0.068**
	(0.022)	(0.026)	(0.026)	(0.035)	(0.034)
Year dummy	Y	Y	Y	Y	Y
Enterprise nature dummy	Y	Y	Y	Y	Y
_cons	0.095	0.132*	0.125*	0.069	0.126
	(0.061)	(0.072)	(0.069)	(0.083)	(0.077)
N	2380	1397	1479	919	972
adj. R2	0.1895	0.1885	0.1944	0.1744	0.1980

Note: Standard error in brackets, *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.

5.2 Theoretical Contribution

The knowledge domain coupling perspective provides new ideas for research on the impact of corporate innovation performance. Enterprises are often constrained by limited resources, so strengthening knowledge management and improving resource utilization efficiency are particularly important for enterprise innovation. This paper clarifies the relationship between different types of knowledge domain coupling and corporate innovation performance, and shifts the focus of research from the static perspective of knowledge management to the dynamic perspective. This paper defines the concept of knowledge-domain coupling and the classification of types by combing related literature, and clarifies the impact of different types of knowledge-domain coupling on innovation performance from the time dimension of knowledge. In the knowledge-innovation path, for the study of the driving factors of innovation performance, the existing literature focuses more on the static perspective of knowledge management, such as knowledge depth, knowledge width, etc., and few studies have paid attention to the impact of dynamic interactions between enterprise knowledge elements on innovation performance. The concept of coupling enables knowledge management research to cross from the level of knowledge elements to the level of knowledge base, which not only focuses on the basic attributes of knowledge elements, but also emphasizes more on the interaction relationship between knowledge elements, which provides a new path for enterprises to improve their innovation performance, and enriches the theoretical results of the cross-study of knowledge management and innovation.

5.3 Implications

The findings of this paper have the following implications for corporate innovation performance improvement:

The development of manufacturing enterprises relies heavily on technological innovation, which is a complex process that requires coupling multi-domain knowledge for knowledge utilization and technology development. Therefore, in order to improve the quality of innovation, firms usually invest a lot of resources to develop new knowledge. Knowledge domain coupling focuses on the connection between knowledge elements, which means that new knowledge combinations can be generated without new knowledge enterprises, which provides a new path for the knowledge utilization of the organization, from creating knowledge to reshaping knowledge. Manufacturing enterprises should continuously expand their knowledge base, strengthen the interaction and integration of different domains of knowledge, avoid knowledge isolation, and explore new connections between knowledge elements. On the one hand, managers should encourage employees to share knowledge, recognize the interdependence of existing domain knowledge elements, conduct in-depth search and reconfiguration of existing knowledge, and provide rich knowledge resources for improving innovation performance; on the other hand, managers should actively use the social network of manufacturing enterprises to absorb external heterogeneous knowledge resources coupled with the existing knowledge of the enterprise, and to create new knowledge that is difficult to be imitated,. Thus improving the efficiency of independent innovation.

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