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Moderating Effect of Structural Holes on Absorptive Capacity and Knowledge-Innovation Performance: Empirical Evidence from Chinese Firms

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Abstract: Under open innovation, the position of the innovation subject in the knowledge network plays a vital role. The purpose of this paper was to identify the role of structural holes in the relationship between the knowledge-absorption capacity and the innovation performance. Previous studies have ignored the role of structural holes in this relationship. Moreover, there are differences between structural-hole theory and weak-relationship theory on the mechanism of the network location on the innovation performance. A hierarchical regression model was applied to test the hypothesis. The findings from a study of 74 Chinese-listed integrated-circuit companies confirm the positive effect that the absorptive capacity has on the innovation performance, as well as the moderating role of structural holes in this relationship. By benefiting from the advantages of information and control, structural-hole spanners often have stronger knowledge-absorption abilities, and they thus achieve higher innovation performances. The results suggest that the synergy of structural holes should be taken seriously by those enterprises that are trying to strengthen their knowledge-absorption abilities to improve their innovation performances.

Keywords: structural holes; absorptive capacity; knowledge-innovation performance

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1. Introduction

The knowledge-innovation performance has long been considered to be directly and positively affected by the absorptive capacity [1,2]. However, the extent of this impact may have a boundary range [3]. There is no significant correlation or negative impact between them when the external-knowledge-acquisition cost of the enterprise is higher than its potential benefits [4].

In addition, the transmission and the sharing of information and knowledge are closely related to the position of the innovation subjects in the network [5]. Both structural-hole theory and weak-tie theory agree with this view [6,7]. Unfortunately, there are differences between the two theories on what kind of cooperation form and relationship between subjects is more conducive to knowledge transmission and sharing. The former emphasizes that, in the context of open innovation, closely connected knowledge subjects are widely distributed in the innovation network, but there are still third-party subjects who maintain close contact with two relatively loose knowledge subjects at the same time, so as to obtain resource acquisition and a competitive advantage through information and control advantages, which help these knowledge subjects in the position of the structural hole to improve the innovation performance [8,9]. However, the latter confirms that, in the context of network closure, the strong relationship between knowledge subjects can enhance mutual trust and emotional ties, which results in more cooperation opportunities and information exchange [10]. Furthermore, a kind of network weak tie can promote the absorption of heterogeneous knowledge, increase the exploration of potential innovation opportunities, and thus positively affect the innovation performance [6].

Therefore, we postulate that the research should consider structural holes to explain the relationship between the absorptive capacity and the performance because the acquisition, transformation, and application of information and knowledge are completed within the network, and even the network characteristics should be included among the factors that influence the innovation performance [11,12]. Although a few studies have studied knowledge innovation in the context of considering the network positions of knowledge subjects [13,14], there is no complete research framework to capture the potential significance of the interaction between structural holes and the absorptive capacity on the performance of network innovation. This is of great value for exploring innovative activities in knowledge networks.

To explore these problems, we analyzed 74 samples from listed Chinese-mainland integrated-circuit companies. These selected research samples highlight the knowledge innovation in commercial economic activities. On the basis of the existing literature, we measured the absorptive capacity, the structural holes, and the innovation performance. In order to estimate the impact of structural holes on the innovation performance while controlling the absorptive capacity and other variables, we used a hierarchical regression model; at the same time, it can also test the interaction between structural holes and the absorption capacity. The literature confirms the network position and the knowledge-innovation performance through the structural-hole spanners and the patent output, respectively. In our research framework, we explain the relationship between the absorptive capacity, structural holes, and performance. Specifically, we tested whether the absorptive capacity affects the performance of knowledge innovation, and we further tested the regulatory effect of structural-hole spanners. By answering the above questions, the results of the study contribute to the research on the performance of knowledge-innovation networks. Figure 1 illustrates the theoretical framework of this study.

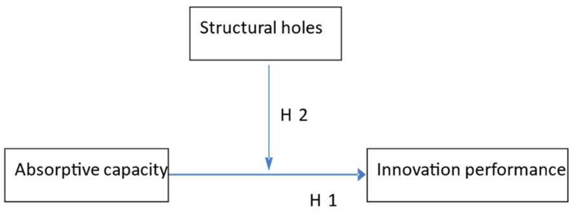

Figure 1. Theoretical framework.

2. Theories and Hypotheses

2.1. Absorptive Capacity and Innovation Performance

The knowledge-absorptive capacity, or the ability to understand, to acquire, to use, and to ultimately take advantage of knowledge that is available outside of the organization, has long been considered an important factor that affects the innovation performance [2,15–17]. However, the search for and the acquisition of knowledge from external networks is only a small step for firms that achieve high performances. Knowledge management plays an important role in mediating the impact of the external embeddedness on the enterprise ambidexterity and, thus, it improves the innovation performance [18,19]. Knowledge-management practice plays a moderating role in the relationship between knowledge-based leadership and innovation performance [20], which suggests that knowledge management is an important way to improve the performance of knowledge innovation.

The absorptive capacity usually helps enterprises to transform external knowledge into environmental innovation, which is weakened by the internal innovation capacity and the socialization mechanism [21]. Subsidiaries with superior knowledge-management capabilities are more effective at using external R&D, which augments the magnitude of their external sources of knowledge and, consequently, improves their innovative performances [22]. External knowledge sharing was more strongly associated with performance when the work groups were more structurally diverse [23,24]. Ferraris et al. [25] found a positive relationship between R&D internationalization and innovation performance, which is positively moderated by knowledge-management orientation. The development of the internal-knowledge-management capacity promotes the exploitation of internal and external flows of knowledge, which, in turn, increases the innovation capacity [26]. External knowledge acquisition has a positive impact on the open-innovation performances of enterprises, and it further leads to innovation performance [27,28].

Knowledge-innovation practices influence open innovation, which, in turn, influences the organizational performance [29]. The impact of the absorptive capacity on the relationship between cooperation and the new product performance varies with the enterprise size and with the industry type [14]. Enterprises that increasingly rely on external R&D activities have better innovation performances to a certain extent. Beyond this threshold, external R&D activities will reduce the innovation performances of enterprises. To maintain a wide R&D boundary, enterprises with high knowledge stocks need to pay higher opportunity costs [3].

According to Easterby et al. [30], the knowledge-absorptive capacity includes external-knowledge acquisition and internal-knowledge learning, which correspond to knowledge management [31,32] and organizational learning [33,34], respectively. Moreover, these two dimensions jointly promote knowledge-innovation activities and improve enterprise performances. First of all, enterprises with certain knowledge bases have strong knowledge-absorption abilities and can act on new ideas and information [16,35]. Enterprises that can assimilate new knowledge will strengthen organizational learning and improve efficiency, which will contribute to the innovation and creation of new products and, thus, to improved performance [36,37]. Knowledge resources that can explore and discover opportunities are positively correlated with enterprise performance [38]. The theoretical assumption is that enterprises can continue to maintain their competitiveness in this field only by expanding their knowledge bases [23]. Secondly, the transformation and application of new knowledge may bring certain benefits to enterprises, but not long-term benefits [39]. On the one hand, the way for enterprises to acquire new knowledge needs to cost a certain price. The benefits become unworthy when the cost cannot expand the knowledge base [15]. On the other hand, it is difficult for enterprises to realize the benefits of this dimension when the new knowledge that is acquired and absorbed cannot be applied to the expansion of the knowledge base [40,41]. Therefore, the absorptive capacity positively influences the innovation performances of companies [1,42]. Although the above analysis shows that the existing literature has tested the positive effect of the knowledge-absorptive capacity on the innovation performance, it is still necessary to reverify this relationship in order to further discuss the role of structural holes in this relationship. Thus, we put forward the following assumptions:

Hypothesis 1. *The knowledge-absorptive capacity has a positive impact on the knowledge-innovation performance.*

2.2. Structural Holes as a Moderator

The knowledge network provides firms access to diversified knowledge for new product development and improvement [43,44]; however, the effectiveness and the efficiency of the knowledge transfer and integration will be affected by the network location and the network structure [45]. Structural holes realize information advantages and control benefits through the provision of early access authorization, which enhances the control advantage of the firm in information transmission [7]. Network closure helps to enhance the trust and cooperation among knowledge subjects, which can improve the motivation for knowledge sharing and the efficiency of the knowledge absorption [46,47]. The nonredundant relationship among knowledge subjects interferes with the willingness to share knowledge and the knowledge-absorption abilities of partners, which has an impact on the innovation performances of knowledge networks. The following arguments support this view.

Firstly, the willingness to transfer and share knowledge among the knowledge subjects in the network is very important [48], and especially for partners with competitive relationships [47]. From the perspective of information transmission, a structural-hole spanner, as a key node, maximizes the information flow in the knowledge network [49,50]. In this case, structural holes alleviate information asymmetry and opportunistic behavior, which improves the willingness to transfer knowledge among knowledge subjects [51]. In such a wide and diversified knowledge network, innovation subjects may benefit from lower knowledge absorption and transformation costs.

Secondly, as an innovation resource, diversified knowledge has an impact on the innovation activities of firms, which must meet a prerequisite; that is, the innovation subject transforms and absorbs external knowledge combined with internal knowledge [48]. Knowledge diversity increases the difficulty of enterprises in the coordination and application of various types of complex knowledge [52,53], which means that a partnership without effective communication may lose many potential innovation opportunities, and especially in the transformation and understanding of tacit knowledge [54]. From the perspective of the network position, the structural-hole spanner is the central node in the network structure that links a large number of surrounding subjects [55–58]. The external information that is received by the knowledge subjects is related to the network position, which has an impact on the integration of internal and external knowledge into innovation activities, and thus affects the innovation performance [6,7]. The network structure plays a vital role in the realization and growth of innovation in social networks. Therefore, the characteristics of the social-network structure should be fully considered in the research on new product performances [5]. Focal firms that bridged otherwise disconnected firms in their ego networks enjoyed higher levels of innovation [59]. Whittington et al. [13] found evidence that regional agglomeration and network centrality have complementary effects on organizational innovation. The moderating effect of structural holes shows that the existence of structural holes is expected to complement the diversity of knowledge in network knowledge [60]. In this scenario, the innovation subject controls the link relationship between the nodes in the local network, which interferes with knowledge sharing, transformation, and absorption, and thus affects the innovation performance. The interaction between the absorptive capacity and the network position has significant positive effects on business-unit innovation and performance [61]. Given these concerns, we predict:

Hypothesis 2. *Structural holes play a positive regulatory role in the relationship between the knowledge-absorptive capacity and the knowledge-innovation performance.*

The theoretical analysis and hypotheses for this paper are as follows: First of all, they disclose the relationship between the knowledge-absorptive capacity and the knowledge-innovation performance by theoretical analysis. Next, they try to investigate the role that is played by the structural holes between the knowledge-absorptive capacity and the knowledge-innovation performance through theoretical elaboration.

3. Methodology

3.1. Research Setting

This paper studies the relationship between knowledge absorption and the knowledge-innovation performance by using the hierarchical regression model, and it tests the moderating effect of structural holes. The main reason for using hierarchical regression is that it can estimate and test the impact of the absorptive capacity on the innovation performance under the control of other variables. Firstly, Standard Regression Model 1 is constructed to test the impact of the control variables on the innovation performance. Secondly, Model 2 examines the impact of the knowledge-absorptive capacity on the innovation performance when controlling other variables. The same method is used for Models 3 to 6. Finally, a comparison of the R-square difference between Model 1 and Model 2 shows whether the absorptive capacity can significantly affect the innovation performance when controlling other variables and by considering the knowledge-absorptive capacity. The same method applies to Models 3 to 6 for an analysis of the effect of structural holes.

3.2. Data Collection

This paper selected the relevant data of the integrated-circuit industry on the Chinese mainland for empirical analysis. The reasons are as follows. Firstly, Gordon Moore, the founder of Intel Corp, proposed, in 1965, that the number of crystals that can be accommodated on integrated circuits will double every 18 to 24 months. This prediction was confirmed by the chip-manufacturing industry. It is still considered to be valid, and it later became known as Moore's law. More importantly, Moore's law summarizes the intensive and active knowledge-innovation activities in the integrated-circuit industry. Secondly, the selection of Chinese IC-listed companies as research samples was also based on the accessibility of the statistics. The China IC Industry Association provided the list and the quantity of the registered members of the listed integrated-circuit companies on the Chinese mainland. This was convenient for us to collect more complete data from the China Stock Market and Accounting Research database so as to complete the research work of this paper. Finally, the development of the integrated-circuit industries in many developing countries lags significantly behind those in the United States and Europe. In the process of exploring the development of the integrated-circuit industry, these countries urgently need to clarify the relationship between the knowledge-absorption capacity, structural holes, and the innovation performance so as to make policy decisions scientifically and reasonably.

According to the statistics of the China IC Industry Association, there are 673 large-scale registered entities on the Chinese mainland. By excluding the listed companies with delisting and incomplete data, we selected 74 listed companies from 2010 to 2019 as the research sample. We obtained the relevant information on these listed companies from the China Stock Market and Accounting Research database and from the Soo Pat patent database. Finally, we obtained a total of 25,483 patent records from 74 listed companies, and we built a knowledge-innovation network by using 2745 patents with patent citation relationships. Furthermore, we used the software UCINET to calculate the centrality and the structural-hole index in this knowledge-innovation network.

3.3. Dependent Variable

The knowledge-innovation performance is an index that is used to measure the output levels of knowledge subjects in knowledge-innovation activities. The innovation-performance variable is measured through questionnaire interviews with subjects participating in knowledge-innovation activities, and it is based on a designed scale [2,24,25]. However, this study does not use this method to measure the innovation performance. We are concerned that the selection area and the object differences of the questionnaire interviewees may affect the robustness of the research conclusions. As a proxy variable of the knowledge-innovation performance, the number of patent applications can be publicly obtained from the national patent office. More importantly, the number of patent applications reflects the development ability of enterprises in the future, which is suitable for empirical research that investigates the output levels of enterprises in knowledge-innovation activities [11,60]. When the knowledge subject submits a patent application, it indicates that the knowledge-innovation activity has been completed; the authorization stage is only a procedural process. Therefore, this study takes the number of patent applications as the proxy variable of the knowledge-innovation performance.

3.4. Independent Variable

The absorptive capacity is measured by the R&D costs. In the process of knowledge absorption, knowledge subjects need to consume innovative resources in order to understand and transform external knowledge. Therefore, the R&D expenditure is regarded as a key determinant of the knowledge-absorption capacity [15]. In this sense, it is reasonable for R&D costs to be used as a proxy variable of the knowledge-absorptive capacity [14,61].

3.5. Moderator Variable

In a network with a large number of connections, a node that is not directly connected to other surrounding nodes looks like a hole from the perspective of the network structure. Structural holes are usually understood by the constraint index [7–9]. Constraints describe the conditions and restrictions of the network subject in the position of the structural hole to bargain with other surrounding subjects. The term C_{ij} measures the constraint and it is described in the formula below:

$$C_{ij} = \left(p_{ij} + \sum p_{iq}p_{qj}\right)^2,\ q \neq i, j \tag{1}$$

The term p_{ij} reflects the status of i's resources that are devoted to Subject j. Subject q controls the flow of resources between i and j in the dense network of common third-party ties. By considering redundant connections, the constraint ranges in value from 0 to 1. The abundance of structural holes is negatively correlated with the constraint index. Consequently, the term SH_i is described in the formula below:

$$SH_i = 1 - \sum_j C_{ij} \tag{2}$$

3.6. Control Variables

According to previous studies [15,19,39,59], we control several factors that may provide some explanation for the hypothesis of the relationship between structural holes, the knowledge-absorption capacity, and the knowledge-innovation performance. We explain the differences in the development degrees of different knowledge subjects by controlling the size of the innovation subjects. We use a dummy variable year to identify the development time of the innovation subjects to control the possible impact of the enterprise-survival time on the performance. We also explain the differences in the different network positions by controlling the centrality-degree index of the social network. In addition, we control the knowledge stock to explain the possible impact of the historical knowledge storage on the knowledge-innovation performance. Table 1 provides an overview of the model constructs and the variables mentioned above.

Table 1. Constructs and variables.

Variables	Variable Symbols	Variable Calculations	Sources
Dependent variable Knowledge-innovation performance	KIP	Number of patent outputs	[11,60]
Independent variable Knowledge-absorptive capacity	KA	R&D expenses	[14,15,61]
Moderator variable Structural holes	SH	$SH_i = 1 - C_{ij}$	[7–9]
Control variables Centrality degree Size Year Knowledge stock	DC S Y KS	$C(N_i) = \sum_{j=1} x_{ij}, i \neq j$ Number of employees Survival year of the enterprise Number of patents in the past 24 months	[15,19,39,59]

This study applies the hierarchical regression model to carry out an empirical analysis, and it utilizes 74 listed companies (from 2010 to 2019) of the integrated-circuit industry on the Chinese mainland as the research sample. Meanwhile, the reasons for the selection of the various variable indicators of the study are explained and are also presented in Table 1 above. The empirical analysis results are presented in the next section.

4. Results

4.1. Diagnostic Test

The descriptive statistics and the correlation coefficients are presented in Table 2.

Table 2. Descriptive statistics and correlations.

Variables	Means	SDs	Maximums	Minimums	*t*-Test Values	Tolerances	VIFs
1. S_A	2.891	1.381	1.000	1.000	−10.948 **	0.221	4.527
S_B	1.000	0.000	8.000	2.000			
2. Y_A	17.891	5.730	35.000	8.000	−0.864	0.986	1.015
Y_B	17.018	5.276	34.000	8.000			
3. DC_A	1.426	0.989	3.810	0.149	−4.403 **	0.253	3.959
DC_B	0.737	0.711	4.087	0.299			
4. KA_A	3.618	5.208	13.225	0.108	−1.422	0.955	1.047
KA_B	2.527	3.009	26.915	0.308			
5. KS_A	0.064	0.039	0.143	0.012	−5.373 **	0.238	4.200
KS_B	0.032	0.024	0.212	0.013			
6. KIP_A	19.830	22.111	124.500	2.000	−2.195 *	-	-
KIP_B	11.575	18.917	90.700	1.400			

* $p < 0.05$; ** $p < 0.01$.

In order to clearly identify the data differences, we set up two data groups: Group A, in the presence of structural holes, and Group B, in the absence of structural holes. The mean of the knowledge-innovation performance and the knowledge-absorption capacity in Group A is higher. The standard deviation of these variables in Group B is smaller. On the whole, the sample data characteristics of the two groups have obvious differences between different groups. As expected, the results of the *t*-test show that there are significant differences in the innovation performances of the two types of knowledge subjects in the case of structural-hole grouping (the significance level of the innovation performance is less than 0.05). Meanwhile, the results of the multicollinearity diagnosis show that the variance expansion factor (VIF) of all the variables is less than 5, which indicates that there is no obvious collinearity between the variables. Therefore, it is reasonable to use the regression analysis model to deal with these research variables.

4.2. Hypothesis Test

We use the hierarchical regression model to deal with the control variables and the regulatory variables. Table 3 shows the results of the regression model. Firstly, we consider the impact of the control variables on the knowledge-innovation performance. The results of Model 1 show that the centrality degree has a positive impact on the knowledge-innovation performance ($p < 0.001$), which indicates that the key knowledge subjects in the innovation network may have better innovation performances. The positive impact of the knowledge stock on the innovation performance shows that having a wider knowledge storage may help to achieve a higher level of innovation performance. We test the positive impact of the knowledge-absorption ability that is proposed by Hypothesis 1 on the knowledge-innovation performance through Model 2. The R-square change in Model 2 compared to Model 1 is 29.8%, which shows that the prediction of the innovation performance through the incorporation of the knowledge-absorption capacity is statistically significant; that is, the independent variable explains 29.8% of the difference in the knowledge-innovation performance. The analysis yields a significant positive impact of the absorption ability on the knowledge-innovation performance ($\beta KA = 0.285$, $p < 0.001$), which suggests that innovation subjects with strong knowledge-absorption abilities have greater potential to achieve higher levels of knowledge-innovation performances. Therefore, Hypothesis 1 is fully supported.

Table 3. Hypothesis test results.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Size	0.307 * (6.867)	−0.071 (−0.824)	−0.035 (−0.383)	−0.123 (−1.079)	−0.123 (−1.100)	−0.119 (−1.111)
Year	−0.079 (−1.077)	−0.037 (-0.665)	−0.035 (−0.383)	−0.052 (−0.724)	−0.044 (−0.628)	−0.031 (−0.461)
Centrality degree	0.220 *** (4.330)	0.136 ** (2.359)	0.174 * (1.887)	0.129 * (1.722)	0.282 * (2.370)	0.260 * (2.275)
Knowledge stock	0.310 *** (7.124)	0.610 *** (8.215)	0.794 *** (6.515)	0.463 *** (4.654)	0.483 *** (4.937)	0.562 *** (5.662)
Knowledge-absorptive capacity (KA)		0.285 *** (3.251)	0.154 (1.231)	0.501 *** (3.704)	0.473 *** (3.555)	0.373 ** (2.788)
Structural holes (SH)					−0.163 (−1.448)	−0.185 (−1.709)
Interaction term: KA × SH						0.296 * (2.430)
Adjusted R^2	0.358	0.656	0.556	0.711	0.724	0.747

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. The *t*-test value is indicated in brackets.

On the basis of the results above, we further tested Hypothesis 2, which assumes that structural holes play a positive regulatory role in the relationship between the knowledge-absorptive capacity and the knowledge-innovation performance. We tested the impact of the knowledge-absorptive capacity on the knowledge-innovation performance in the presence and absence of structural holes through Model 3 and Model 4, respectively. Model 4 shows a significant positive relationship between the knowledge-absorptive capacity and the knowledge-innovation performance in the presence of structural holes, while Model 3 shows that the impact of the knowledge-absorptive capacity on the knowledge-innovation performance becomes insignificant in the absence of structural holes. At the same time, the impact of the knowledge-absorptive capacity on the knowledge-innovation performance is insignificant (Model 5). In general, the results show that structural holes play a regulatory role in the relationship between the knowledge-absorptive capacity and the knowledge-innovation performance. Furthermore, we investigated the regulatory effect of structural holes. We introduce an interaction term between the knowledge-absorptive capacity and structural holes (Model 6). The results show that the interaction term has a positive effect on the knowledge-innovation performance (βKA*SH = 0.296, $p < 0.05$), while the main effects of the knowledge-absorptive capacity are still significant ($p < 0.05$). This suggests that structural holes can effectively promote the positive impact of the knowledge-absorption capacity on the innovation performance, and that innovation subjects can benefit from the cooperativity of structural holes, which supports Hypothesis 2.

In order to understand the interactions comprehensively, we plotted the moderated relationships according to the parameters in Model 6, as illustrated in Figure 2. The low-structural-holes line is upward, while the high-structural-holes line is steeper. Consequently, we interpret the positive moderating effects as the cooperativity of the structural holes.

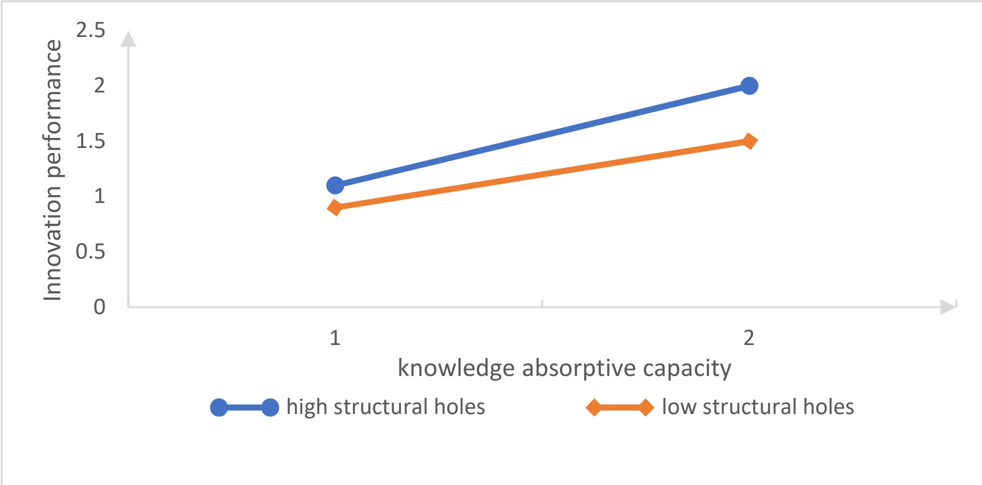

Figure 2. Moderating effects of structural holes.

5. Discussion and Conclusions

This study discusses knowledge-innovation activities against the background of open innovation. We believe that the knowledge-absorptive capacity will improve the innovation activities and enhance the competitiveness of enterprises by integrating the acquired external knowledge with internal knowledge. Furthermore, the position of the innovation subject in the knowledge network will affect the transmission and the sharing of information and knowledge among enterprises, and will thus affect the performance of the knowledge innovation. The results show that the knowledge-absorptive capacity has a positive impact on the innovation performance, and that structural holes have a positive regulatory effect on this relationship. Enterprises should pay attention to the potential of structural-hole spanners in information and knowledge acquisition, transformation, and application, which is very important to improving the innovation performance.

5.1. Theoretical Contributions

This study has some implications for the structural-hole research on the knowledge-innovation performance. The first research problem is solved through the empirical evidence of the positive relationship between the knowledge-absorptive capacity and the knowledge-innovation performance. The research results show that knowledge subjects with strong knowledge-absorption abilities have greater opportunities to engage in knowledge-innovation activities, and to use these products to improve the performances of their knowledge innovation, although Volberda et al. [4] believe that enterprises that focus too much on knowledge acquisition and assimilation may not obtain benefits because of the impact of the cost, because it will interfere with the cognition of the novelty value, and because it is difficult to explore novel ideas. Our results support the view of Forés and Camisón [1], who show that the knowledge-absorptive capacity has a positive impact on the performances of innovation networks. Therefore, this study adds to the literature by clarifying the recent view that the improvement in the knowledge-innovation performances of enterprises can benefit from high absorptive capacities.

The second research problem is addressed through the evidence of the positive linkage between the interaction term and the knowledge-innovation performance. The results support that structural holes play a regulatory role in the positive impact of the knowledge-absorption capacity on the knowledge-innovation performance, which suggests that structural-hole optimization is an important way to improve the innovation performance. Our results show that structural-hole spanners can significantly enhance the positive impact of the absorptive capacity on the innovation performance, which is consistent with the research conclusions of Wen et al. [9] and Ozer and Zhang [8]. Thus, this study integrates the concepts of structural holes and the knowledge-absorptive capacity into the knowledge-innovation-performance research, which is helpful for the expansion of the existing literature.

5.2. Practical Implications

The research provides two potential implications for managers. The behavior of the knowledge transfer and sharing among knowledge subjects is based on the motivation to obtain high innovation output. The assumption of this motivation is that the knowledge subject can effectively integrate external knowledge into knowledge-innovation activities. However, our findings show that the absorptive capacity of knowledge subjects can effectively promote the improvement in the knowledge-innovation performance. Therefore, managers are encouraged to actively participate in knowledge transfer and sharing, and to strengthen their absorptive capacities in order to improve the output of knowledge innovation.

Furthermore, there is no denying that the positive impact of the knowledge-absorptive capacity on the knowledge-innovation performance is not simple and direct because the knowledge-absorption ability of the innovation subject is affected by its position in the network. Structural holes have consistency and synergy between the knowledge-absorptive capacity and the knowledge-innovation performance. Our findings indicate that the improvement in the knowledge-innovation performance benefits from the strengthening of the knowledge-absorption capacity, and structural holes play an important role in this process. We emphasize the importance of structural-hole optimization for improving the performance of knowledge innovation. Managers who aim to improve their innovation performance by optimizing structural holes can use our research for focused interventions. The research legalizes the optimization of structural holes.

5.3. Limitations and Future Research Suggestions

Although we provide new insights into the role of structural holes and the knowledge-absorptive capacity on the innovation performance, this study still has some limitations. First of all, the research sample is listed integrated-circuit companies, which may be different from other innovation subjects. We tried to solve this problem by collecting the innovation-output data of universities and scientific research institutions. However, because of the imperfection of the information-disclosure system, the relevant data of most colleges and universities cannot be obtained completely. We suggest that future researchers collect data from universities and scientific research institutions as much as possible in order to avoid bias in the sample selection.

Secondly, the research result is based on a hierarchical regression analysis, which is essentially a correlation. Exploring a more rigorous causality requires that managers make empirical judgments in combination with practical situations. In addition, the research method of the construction of the knowledge-innovation network through the patent citation relationship in a certain time cycle is a static dimension. However, in a more general situation, the knowledge-innovation network is in a changing state, and we cannot guarantee that the research findings are still valid, which is worthy of further exploration by future researchers.

Finally, since the sample only includes Chinese-listed IC enterprises, we cannot guarantee that the results will hold when applied to cases from countries with different systems and industrial backgrounds. Therefore, it is necessary to validate our framework across other national and industrial settings. Future research may consider the control of the social system and the industrial environment.

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