A STUDY ON THE INFLUENCE OF KNOWLEDGE NETWORK STRUCTURE EMBEDDING ON ENTERPRISE INNOVATION PERFORMANCE: BASED ON THE MEDIATION EFFECT OF TECHNOLOGICAL DIVERSIFICATION

Wei Wang
Dhurakij Pundit University, Bangkok, Thailand

With the continuous changes in the environment and the gradual enhancement of market competitiveness, knowledge and information have become an important foundation for enterprise development, and knowledge elements have become important factors affecting enterprise innovation. The trend of knowledge networking is becoming increasingly evident. The knowledge network formed from this can break the traditional pattern of internal circular innovation, provide enterprises with many heterogeneous resources, and improve innovation performance. The cross integration of different technologies makes the knowledge network denser and more complex. How to continuously acquire and develop heterogeneous resources through knowledge networks? How to promote innovation performance of enterprises through rational allocation and utilization of technological diversification? The in-depth study of this series of issues has important theoretical and practical significance. This study will conduct a series of theoretical and empirical studies on the impact of knowledge network structure embedding on enterprise innovation performance. It will provide ideas and references for promoting sustainable innovation in enterprises.

Keywords: knowledge network; structure embedding; innovation performance; technology diversification

Introduction

With the development of the social economy and the acceleration of globalization, the importance of knowledge is gradually increasing, and competition within and between organizations is gradually shifting towards competition between knowledge.

In order to occupy an advantageous position in the constantly changing environment for a long time, enterprises will inevitably establish connections with other enterprises and organizations, complement each other's advantages, and form a knowledge network.

Wei Wang
PhD Graduate, International College, Dhurakij Pundit University, Bangkok, Thailand
Research interests: knowledge networks, innovativeness, technological management
E-mail: 305991834@qq.com
As an important knowledge management tool, knowledge networks have become a research hotspot today. In a challenging international environment, if enterprises rely too heavily on the utilization of existing resources, it will be difficult to establish a long-term foothold.

Therefore, enterprises need to continuously generate new capabilities and knowledge to gain market competitiveness, and the strategic position of innovation in various industries is increasingly prominent.

This study focuses on the following research questions:

1. Does the embedding of knowledge network structure affect the innovation performance of enterprises?
2. Does the embedding of knowledge network structure have an impact on technological diversification?
3. Does technological diversification play a mediating role between the embedding of knowledge network structure and enterprise innovation performance?

Research foundation

Knowledge network theory

For knowledge network theory, many experts in the economic field have studied it from different perspectives, but so far there has not been a unified definition.

This study believes that knowledge network embedding is generated based on network cooperation between enterprises.

This type of knowledge network embedding can achieve information exchange between enterprises, reduce information asymmetry between enterprises and internal departments, and promote stable growth of enterprises.

Regarding the constituent elements of knowledge networks, this study mainly focuses on computer, communication, and other electronic equipment manufacturing enterprises as the research subjects.

Embedding theory

Embedding is an emerging concept in the economic field in the context of the network era, and there are many definitions of network embeddedness in society.

Stanford University professor Mark Granovett was the first to classify embeddedness, which was mainly divided into two parts: "organizational embeddedness" and "relational embeddedness" (Ding & Chen, 2016; Mazzola et al., 2015).

Subsequently, economists further divided embeddedness into cultural embeddedness and political embeddedness based on the actual development of society at that time. So far, organizational embeddedness and relational embeddedness are the two most recognized and widely used dimensions.

For this study, referring to the binary classification method commonly used by experts, knowledge network embedding is divided into two dimensions: structural embedding and relational embedding.

This study will analyze from the perspective of structural embedding.
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Theoretical analysis and research hypotheses

Embedding knowledge network structure and innovation performance

The knowledge elements in a knowledge network are considered as network nodes, and structural embeddedness is achieved through connections between knowledge elements.

The view that structural embeddedness has an impact on the innovation performance of enterprises has been validated in a study by Wang & Wang (2018).

Structural embeddedness provides potential knowledge element combination paths for organizations, thereby helping to break path dependencies (Yang et al., 2019; Fang et al., 2016).

Overall, structural embeddedness brings more non-redundant heterogeneous resources to enterprises.

The more structural holes knowledge elements occupy, the higher the chance of directly connecting with these elements or forming connections with other knowledge elements (Wang et al., 2018). The structural embeddedness of knowledge networks provides a non-redundant "bridge" between different knowledge, while the knowledge elements at both ends of the structural hole provide untapped potential combination opportunities, which have exploitable innovative value (Guan & Liu, 2016).

Based on this, the following hypothesis is proposed:

H1: The embedding of knowledge network structure positively affects the innovation performance of enterprises.

Embedding knowledge network structure and technological diversification

The embedding of knowledge network structure in enterprises has a positive impact on the expansion of technological diversification, with information and resource advantages playing a key role.

Firstly, the embedding of knowledge network structure brings information advantages to enterprises, which have a dual role: on the one hand, it enables enterprises to understand the changes in demand among various innovative entities earlier, thereby helping them seize opportunities in a timely manner, fully utilize their first mover advantages, integrate required resources, and promote technological diversification development.

On the other hand, the information advantage of enterprises reduces transaction costs, enabling them to obtain resources related to technological diversification at a lower cost. Secondly, the resource advantages embedded in the knowledge network structure of enterprises bring diverse resources and capabilities to the enterprise.

The accumulation of these heterogeneous resources and capabilities provides a solid foundation for technological diversification. By effectively integrating these heterogeneous resources and capabilities, enterprises can improve their level of technological diversification. This article believes that the embedding of knowledge network structure in enterprises has a positive promoting effect on the development of technological diversification. Based on this, the following hypothesis is proposed:

H2: The stronger the embedding of knowledge network structure, the higher the level of technological diversification.
Technological diversification and enterprise innovation performance

Technological diversification helps organizations combine existing and new technologies, thereby promoting breakthrough technological innovation achievements.

Previous studies have shown that controlling pre-conditions can stimulate innovation potential, and interdisciplinary knowledge based on diversified knowledge is an important source of enterprise innovation.

Provide prerequisites and conditions for enterprise innovation through the synergistic effect between diversified knowledge. Secondly, technological diversification helps organizations accumulate heterogeneous knowledge. Enterprises with technological diversification have accumulated more technology and knowledge from different fields, which provide a source of ideas for enterprise innovation (Wang et al., 2014).

Researchers typically attempt various possible combinations of innovation, and companies with richer knowledge reserves have more innovation combinations, resulting in better performance in exploratory innovation (Wang et al., 2014). Technological diversification helps companies embed their external networks and helps organizations access more external resources that are conducive to innovation (Huo et al., 2019).

The embedding of organizational knowledge networks reduces the cost of acquiring external knowledge and resources by expanding the scope of technological search and enhancing trust between organizations, thereby improving innovation performance of enterprises. Based on this, the following hypothesis is proposed:

H3: The level of technological diversification positively affects the innovation performance of enterprises.

The mediating effect of technological diversification

Technological diversification, as a manifestation of a company's breadth of technology and knowledge, has a significant impact on improving its absorptive capacity, reducing research and development costs, and reducing external dependence. The embedding of knowledge network structure in enterprises is likely to affect their innovation performance through technological diversification. Specifically, firstly, knowledge network embedding helps to enhance the absorptive capacity of enterprises by improving the level of technological diversification. Absorption capacity plays a crucial role in the creation of new knowledge and technological innovation within enterprises.

Secondly, technological diversification helps to reduce the R&D costs and risks of enterprises. Enterprises can balance their R&D capabilities through scope effects, thereby reducing innovation costs and R&D risks (Chen et al., 2005).

This further improves research and development efficiency, shortens the research and development cycle, and plays a key role in improving the innovation performance of the enterprise. In addition, by integrating knowledge network embedded resources, enterprises can promote technological diversification within the enterprise, extend product chains, reduce dependence on external resources, and thus improve innovation performance.

In summary, the embedding of knowledge network structure in enterprises has a positive impact on their innovation performance through technological diversification, which is reflected in enhancing absorption capacity, reducing research and development costs and risks, and reducing external dependence. Based on this, the following hypothesis is proposed:

H4: There is a mediating effect of technological diversification on the impact of knowledge network structure embedding on innovation performance.
Research design

Sample data collection
This study selected data from computer, communication, and other electronic equipment manufacturing enterprises from 2008 to 2020 as the research sample, excluding ST, * ST, and companies with incomplete information disclosure and issuance of A, B, and H cross shares. These companies must continue operating and not delisted between 2008 and 2020. Based on the above screening criteria, this article ultimately selected 553 companies as the sample companies for this study.

This study selected incoPat and CSMAR databases as patent data sources, excluding companies that only produced patents in a short time period and those that did not engage in continuous research and development during this period. Finally, 11127 patent data from 352 companies were retained.

Building a knowledge network
The specific steps for constructing a knowledge network are as follows: first, divide the period 2008-2020 into 10 rolling time windows based on a 4-year time window span, and construct a knowledge network window by window based on the collected patent data; Secondly, the first four digits of the IPC classification code in patent data are extracted as identifiers for knowledge element categories. If there is a correlation between two knowledge element categories, it indicates that these two knowledge elements have co-occurrence, and the connection coefficient is 1.

If they do not co-occur, the connection coefficient is 0, generating a relational adjacency matrix. This article constructs a total of 10 relational adjacency matrices, with the largest matrix size being 229 * 229. The specific time window information is shown in Tab. 1.

<table>
<thead>
<tr>
<th>Time Window/Year</th>
<th>Number of enterprises/units</th>
<th>Number of patents/pieces</th>
<th>Size of receiving matrix (rows and columns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-2011</td>
<td>286</td>
<td>8276</td>
<td>172*172</td>
</tr>
<tr>
<td>2009-2012</td>
<td>306</td>
<td>12232</td>
<td>185*185</td>
</tr>
<tr>
<td>2010-2013</td>
<td>322</td>
<td>16051</td>
<td>195*195</td>
</tr>
<tr>
<td>2011-2014</td>
<td>330</td>
<td>18996</td>
<td>191*191</td>
</tr>
<tr>
<td>2012-2015</td>
<td>331</td>
<td>22186</td>
<td>196*196</td>
</tr>
<tr>
<td>2013-2016</td>
<td>334</td>
<td>25286</td>
<td>197*197</td>
</tr>
<tr>
<td>2014-2017</td>
<td>336</td>
<td>29078</td>
<td>200*200</td>
</tr>
<tr>
<td>2015-2018</td>
<td>340</td>
<td>33815</td>
<td>220*220</td>
</tr>
<tr>
<td>2016-2019</td>
<td>339</td>
<td>38505</td>
<td>217*217</td>
</tr>
<tr>
<td>2017-2020</td>
<td>350</td>
<td>39210</td>
<td>229*229</td>
</tr>
</tbody>
</table>
**Variable measurement**

The dependent variable is the innovation performance of enterprises. According to the definition of Chinese patent law, among invention patents, utility model patents, and design patents, invention patents have the highest technological content, which can better measure the quantity and quality of enterprise innovation performance.

Therefore, this article selects the number of invention patent authorizations to measure the innovation performance of enterprises.

The explanatory variable is structural embedding, and this article uses structural hole network indicators to measure structural embedding. Select the structural hole efficiency index to measure the embedding of knowledge network structures (Yang et al., 2019). The calculation method is as follows:

\[
EFF_i = \frac{\sum_j (1 - \sum_q \frac{p_{ij}m_{jq}}{D_i(1)})}{D_i(1)}
\]

In equation (1), i is the target node within each time window, j represents other elements connected to knowledge element i, and q is the third knowledge element in the network except for i and j. \(P_{ij}\) is the proportional strength of the connection relationship between knowledge element i and q, \(m_{jq}\) is the marginal strength of the relationship between knowledge elements j and q (Liu Jun, 2009). \(D_i\) is the actual network size of knowledge element i.

The mediator variable is technological diversification, and this study follows the commonly used entropy index method in international literature (Chen et al., 2012) to measure technological diversification. This study distinguishes technology diversification based on the types of technologies that enterprises are involved in, and measures the technical fields that organizations are involved in based on the four international patent numbers (IPC-4) involved in the patents owned by enterprises.

Control variables: Referring to existing research findings on the influencing factors of enterprise innovation performance, this article selects four control variables, as follows: enterprise age (age), return on total assets (ROA), and enterprise size (insize).

**Empirical analysis**

**Correlation statistical analysis**

This article uses Pearson correlation coefficient analysis to test the correlation between observed variables, and the test results are shown in Tab. 2.

From the correlation analysis results between variables, there is a positive correlation between the embedding of knowledge network structure and enterprise innovation performance, which preliminarily verifies hypothesis H1.

There is a significant positive correlation between technological diversification and corporate innovation performance, which preliminarily validates hypothesis H3.

In addition, for the purpose of regression analysis in the following text, this study analyzed the variance inflation factor (VIF) of each variable, and the results showed that the VIF values of each variable were all less than the upper threshold of 10, indicating that there was no significant multicollinearity problem between the variables.
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Table 1 - Correlation analysis
(made by the author)

<table>
<thead>
<tr>
<th></th>
<th>innovation</th>
<th>efficient</th>
<th>TD</th>
<th>age</th>
<th>Kr</th>
<th>roa</th>
<th>Lnsize</th>
</tr>
</thead>
<tbody>
<tr>
<td>innovation</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>efficient</td>
<td>0.011***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TD</td>
<td>0.371***</td>
<td>0.018**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>age</td>
<td>0.232***</td>
<td>0.066***</td>
<td>0.088***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>kr</td>
<td>0.505***</td>
<td>0.036*</td>
<td>0.557***</td>
<td>0.107***</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>roa</td>
<td>-0.01**</td>
<td>-0.006</td>
<td>-0.0130</td>
<td>-0.109***</td>
<td>-0.01</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lnsize</td>
<td>0.276***</td>
<td>0.087***</td>
<td>0.203***</td>
<td>0.181***</td>
<td>0.213***</td>
<td>0.009</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: ***, **, * respectively represent significant levels at 1%, 5%, and 10% significance levels;

**Multiple regression analysis**

Empirical Analysis of the Impact of Knowledge Network Structure Embedding on Enterprise Innovation Performance

This article first examines the impact of knowledge network structure embedding on enterprise innovation performance, and the regression analysis results are shown in Tab. 3.

In model (1), without controlling for any factors, the regression coefficient of knowledge network structure embedding is 1.861, which is significant at the 5% level, indicating that knowledge network structure embedding has a significant positive effect on enterprise innovation performance.

In model (2), factors such as the age and size of the enterprise that may affect the innovation performance of the enterprise were controlled for, and the regression coefficient of efficiency remained significantly positive (regression coefficient 1.844).

Based on the above regression results, whether controlling for factors such as enterprise size or not, the embedding of knowledge network structure significantly positively affects the innovation performance of enterprises. Hypothesis H1 is validated.

Empirical analysis of the impact of knowledge network structure embedding on technological diversification

This study first examined the impact of knowledge network structure embedding on technological diversification, and the regression analysis results are shown in Tab. 3.

In model (3), without controlling for any factors, the regression coefficient of knowledge network structure embedding (efficient) is 0.004 and significant at the 1% level, indicating that knowledge network structure embedding has a significant impact on technological diversification.

In model (4), factors such as age and size of enterprises that may affect technological diversification were controlled for, and the regression coefficient of efficiency was 0.005, which was significant at the 1% level. Based on the above regression results, whether controlling for factors such as enterprise size or not, the embedding of knowledge network structure has a significant impact on technological diversification.

Hypothesis H2 is validated.
Empirical analysis of the impact of technological diversification on innovation performance of enterprises

In model (5), without controlling for any factors, the regression coefficient of technological diversification (TD) is 6.614, which is significant at the 1% level, indicating that technological diversification has a significant positive impact on enterprise innovation performance.

In model (6), factors such as age and size of enterprises that may affect innovation performance were controlled for, and the regression coefficient of technological diversification (TD) remained significantly positive (regression coefficient 9.593). Based on the above regression results, regardless of controlling for factors such as enterprise size at the enterprise level, technological diversification has a significant positive impact on enterprise innovation performance. This indicates that the higher the level of technological diversification, the higher the innovation performance of the enterprise. Hypothesis H3 is validated.

Empirical analysis of the mediation effect of technological diversification

Model (7) tests the mediating effect of technological diversification on the impact of knowledge network structure embedding on innovation performance, and the effect of technological diversification is significant. After controlling for factors such as age and size that may affect innovation performance, the regression coefficient of technological diversification (TD) remains significantly positive, assuming that H4 is validated.

Table 3 - Regression results of main and mediating effects
(made by the author)

<table>
<thead>
<tr>
<th></th>
<th>Model 1 innovation</th>
<th>Model 2 innovation</th>
<th>Model 3 innovation</th>
<th>Model 4 innovation</th>
<th>Model 5 innovation</th>
<th>Model 6 innovation</th>
<th>Model 11 innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TD</td>
<td>6.614***</td>
<td>9.593***</td>
<td>6.626***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( 4.863 )</td>
<td>( 2.045 )</td>
<td>( 1.165 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>efficient</td>
<td>1.861**</td>
<td>1.844**</td>
<td>0.004***</td>
<td>0.005***</td>
<td></td>
<td></td>
<td>1.300**</td>
</tr>
<tr>
<td></td>
<td>( 0.868 )</td>
<td>( 0.862 )</td>
<td>( 0.001 )</td>
<td>( 0.001 )</td>
<td></td>
<td></td>
<td>( 0.997 )</td>
</tr>
<tr>
<td>age</td>
<td>-22.122</td>
<td>0.007***</td>
<td>16.984***</td>
<td>17.119***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( 14.561 )</td>
<td>( 0.002 )</td>
<td>( 1.785 )</td>
<td>( 1.788 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kr</td>
<td>0.101</td>
<td>0.000</td>
<td>0.335***</td>
<td>0.335***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( 0.113 )</td>
<td>( 0.000 )</td>
<td>( 0.012 )</td>
<td>( 0.012 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>roa</td>
<td>29.269</td>
<td>-0.103</td>
<td>69.840</td>
<td>69.385</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( 101.490 )</td>
<td>( 0.077 )</td>
<td>( 87.667 )</td>
<td>( 87.657 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insize</td>
<td>29.394***</td>
<td>0.035***</td>
<td>57.041***</td>
<td>57.752***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( 4.325 )</td>
<td>( 0.006 )</td>
<td>( 6.505 )</td>
<td>( 6.527 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>11.656</td>
<td>6.816***</td>
<td>0.916***</td>
<td>0.075</td>
<td>29.869</td>
<td>23.237***</td>
<td>17.406***</td>
</tr>
<tr>
<td></td>
<td>( 15.185 )</td>
<td>( 4.333 )</td>
<td>( 0.017 )</td>
<td>( 0.121 )</td>
<td>( 24.359 )</td>
<td>( 17.370 )</td>
<td>( 13.427 )</td>
</tr>
<tr>
<td>Observations</td>
<td>2884</td>
<td>2884</td>
<td>2884</td>
<td>2884</td>
<td>2884</td>
<td>2884</td>
<td>2884</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.004</td>
<td>0.053</td>
<td>0.008</td>
<td>0.035</td>
<td>0.019</td>
<td>0.315</td>
<td>0.394</td>
</tr>
</tbody>
</table>

Note: The parentheses indicate standard errors, ** * p<0.01, * * p<0.05, * p<0.1
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Conclusion

This study is based on the perspective of knowledge network embedding, focusing on the impact of knowledge network structure embedding and technological diversification on the performance of enterprise technological innovation. The study concludes that firstly, the embedding of knowledge network structure has a significant positive impact on the innovation performance of enterprises. Structural embedding means that enterprises occupy a critical position in the knowledge network, with more connections and touch points. This makes it easier for knowledge to flow and share between different departments, organizations, or individuals. This knowledge flow and sharing promote the dissemination and exchange of innovative ideas, helping to accelerate the progress of innovation activities. Structural embedding enables enterprises to access diverse knowledge resources. Not only can we obtain knowledge from different fields and sources, but we can also obtain information on cutting-edge technologies and the latest trends.

Secondly, there is a mediating pathway in the impact of technological diversification on innovation performance through the embedding of knowledge networks. Technological diversification helps companies embed their external networks, helps organizations access more innovative new resources, reduces innovation costs, and improves innovation performance.

The research conclusion also has important implications for enterprise practice and management. Firstly, at the industry level, for the computer, communication, and other electronic equipment manufacturing industries, knowledge network embedding provides guidance for enterprises to find advantageous knowledge elements and technological fields. Although structural embedding has a positive impact on enterprise innovation, enterprises in the industry should carefully choose technological competition fields and avoid blindly pursuing diversification.

Enterprises can enhance the centrality and number of structural holes of their own knowledge elements, use patent data to construct a knowledge network, and based on the analysis of the knowledge network, set technological development goals in the process of innovation management to improve the success rate of innovation. Secondly, develop a strategy for technological diversification to enhance the company's technological diversification capabilities. Technological diversification is an important component and core of a company's diversification strategy. Only by mastering diversified technologies can a company remain invincible in competition in different fields.

To this end, enterprises should actively invest in research and development, search for new technological growth points in the knowledge network, and expand the level of technological diversification; on the other hand, in the process of cooperating with other innovation entities, by means of mergers and acquisitions, investments, etc., the company expands its business scope, converts network embedding resources into its own technological capabilities, reduces network embedding dependence, and improves innovation performance. The mediating role between new performance actors.

This study has two shortcomings: firstly, the research content and dimensions of knowledge network embedding are limited. Due to space limitations, this study only analyzes and measures the structural framework.
Secondly, there are many factors that affect innovation performance. This study mainly focuses on variables such as knowledge network structure embedding and technological diversification, which may lead to bias and universality in research conclusions. Therefore, in future research, the research content will be further enriched and expanded in terms of research data. These issues will be gradually addressed in subsequent research.

References


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