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HOW KNOWLEDGE STRATEGY MATTERS IN FIRM PERFORMANCE: THE INTERACTION EFFECT OF KNOWLEDGE SPECIFICITY

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Abstract

What is the relationship between knowledge strategy and firm performance? The impact of the same knowledge strategy on firm performance is inconsistent. We identify two dimensions of knowledge strategy: knowledge newness and knowledge diversity which are the important factors of organizational knowledge. This study argue that the effect of knowledge strategy on firm performance is contingent on knowledge specificity defined as the extent of the specific nature of the knowledge in terms of its acquisition and application relative to other organizations. The objective of this study is, therefore, to explicate theoretically and test empirically the interaction effect of knowledge specificity on the knowledge strategy ? firm performance relationship. Based on 1998-2007 data from COMPUSTAT, USPTO, and WOS in biotechnology and pharmaceutical industry, we find increasing organizational knowledge diversity can enhance firm performance, whereas increasing knowledge newness cannot lead to an assured outcome. The empirical results show knowledge specificity will interact with knowledge diversity and knowledge newness that enhance firm performance collectively

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ABSTRACT

What is the relationship between knowledge strategy and firm performance? The impact of the same knowledge strategy on firm performance is inconsistent. We identify two dimensions of knowledge strategy: knowledge newness and knowledge diversity which are the important factors of organizational knowledge. This study argue that the effect of knowledge strategy on firm performance is contingent on knowledge specificity defined as the extent of the specific nature of the knowledge in terms of its acquisition and application relative to other organizations. The objective of this study is, therefore, to explicate theoretically and test empirically the interaction effect of knowledge specificity on the knowledge strategy – firm performance relationship. Based on 1998-2007 data from COMPUSTAT, USPTO, and WOS in biotechnology and pharmaceutical industry, we find increasing organizational knowledge diversity can enhance firm performance, whereas increasing knowledge newness cannot lead to an assured outcome. The empirical results show knowledge specificity will interact with knowledge diversity and knowledge newness that enhance firm performance collectively.

INTRODUCTION

Knowledge is extensively viewed as the most valuable strategic resource in today's business world. Many organizations make their efforts to manage their intellectual capitals and capabilities in order to keep these knowledge resources competitive. However, the most valuable knowledge resources is context-specific and tacit that embedded in complex organizational routines and developed from experience (Grant, 1996; Teece, Pisano, & Shuen, 1997). In addition, knowledge may be obsolesce in a period of time. Thus, firms need to update their existing knowledge base through acquiring and continuous learning new knowledge. Since knowledge has tacit and obsolesce attributes, deciding what knowledge organization should know and how to manage is not easy. Therefore, knowledge strategy is proposed and contains the set of choices that can guide firm to develop intellectual capitals for sustained competitiveness (Bierly & Chakrabarti, 1996; Bierly & Daly, 2007; Mitch Casselman & Samson, 2007) .

Despite the importance of knowledge strategy, the impact of the same knowledge strategy on firm performance is inconsistent. For example, in-house R&D investments can be regarded as the knowledge exploitation behavior which assist to create the specialized technological know-how within organization (Bierly & Chakrabarti, 1996). But empirical evidences demonstrate that the effects of R&D intensity on firm performance reflecting in the stock price is more significant in R&D active industries relative to other industries (Chan, Lakonishok, & Sougiannis, 2001). It is possible that knowledge strategy interacts with other variables to make these various consequences.

Due to the lack of empirical studies in investigating the interaction effects of knowledge strategy with other factors, we suggest that knowledge specificity might be an important factor interacting with knowledge strategy, then collectively influencing firm performance. Knowledge-based view is used as the inference of the relationship between knowledge strategy and firm performance, while resource-based view is used as the inference of the moderating effects on knowledge strategy and firm performance. The objective of this study is, therefore, to explicate theoretically and test empirically the interaction effect of knowledge specificity on the knowledge strategy – firm performance relationship. This analysis is guided by the following two research questions: (1) how does knowledge strategy influence firm performance? and (2) how does knowledge specificity moderate the relationship between knowledge strategy and firm performance?

THEORY AND HYPOTHESES

Theory Background

Knowledge strategy

Knowledge strategy or knowledge creation strategy derived from knowledge-based view, is built upon a firm's intellectual resources and capabilities such as specific know-how, trade secrets, patents, and R&D (Bierly & Chakrabarti, 1996; Mitch Casselman & Samson, 2007). According to Bierly and Daly (2007), knowledge strategy is defined as the set of strategic of choices addressing knowledge creation. This definition infers that different knowledge accumulation and development strategies result in diverse ways of value creation among firms. Hence, the vital purpose of knowledge strategy is the attainment of competitive advantages through understanding what knowledge organization should know and is strategic importance, as well as knowing how to manage this knowledge.

Draw upon organizational learning literatures, Bierly and Chakrabarti (1996) indicated that there are four different types of organizational generic knowledge strategies, that is: external or internal learning; radical or incremental learning; fast or slow learning speeds; the depth or breadth of knowledge. They argued there exist the trade-offs between the deployment of limited knowledge resources. For example, emphasizing incremental learning can enhance the short-term profits but that will sacrifice radical learning, thereby decreasing the long-term profits (March, 1991). Following the same research vein, Zack (2002) proposed a conceptual framework to evaluate organizational knowledge strategy and examine how different firms manage their resource and capabilities to make knowledge strategically valuable. The recent studies empirically verified other knowledge-related elements such as knowledge diversity (Lin, 2011; Miller, Fern, & Cardinal, 2007), knowledge newness (Clarysse, Wright, & Van de Velde, 2011), R&D activities (Phene, Fladmoe-Lindquist, & Marsh, 2006) that can

lead to different knowledge creation strategies through organizational learning, knowledge sourcing, generating, and integrating.

However, existing studies in knowledge strategy are fragmented (Mitch Casselman & Samson, 2007). The results of empirical investigation on the relationship between knowledge strategy and performance are not an assured outcome. It is possible that knowledge strategy interacts with other variables to make these various consequences. Clarysse et al. (2011) argued the source of knowledge may be the determinant. They found the university and corporate spin-off companies both have a broad technological knowledge scope and high tacit knowledge resulting divergent growth outcomes. Moreover, other scholars take into account contextual factors such as environmental dynamism and industrial technology that could moderate the relationship between knowledge creation strategy and firm performance (Bierly & Daly, 2007).

Although prior research have investigated the environmental context factors as moderators, the knowledge characteristic itself is seldom be considered as the important catalysis of knowledge strategy. The characteristics of the knowledge can be categorized along four dimensions: scope, newness, tacitness, and relatedness (Clarysse et al., 2011). The only knowledge characteristic that have been studied as a moderator is knowledge tacitness in the firm-level study (Bierly, Damanpour, & Santoro, 2009). In this research, therefore, we propose another knowledge characteristic—knowledge specificity could moderate the relationship between knowledge creation strategy and firm performance. That is, knowledge specificity is likely to interact with other knowledge creation elements to amplify the extent of value creation. In investigating the role of knowledge specificity, we are particularly interested in the fit between knowledge specificity and key knowledge strategy elements such as knowledge diversity and knowledge newness.

Knowledge specificity as catalysis of knowledge strategy

According to Choudhury and Sampler (1997), knowledge specificity could be distinguished between specificity in use and specificity in acquisition. In their definition, knowledge specificity in acquisition is "information that can be acquired only by someone with the required specific knowledge" while knowledge specificity in application is "information that can be effectively used only by someone with the required specific knowledge". Building on these definitions, in this research, we redefine knowledge specificity as the extent of the specific nature of the knowledge in terms of its acquisition and application relative to other organizations.

The concept of knowledge specificity have been considered in management research. The resourced based-view of the firm proposed that firms with value, rare, inimitable, and non-substitutability resources have potential to achieve better performance (Barney, 1991). Specificity of knowledge resource will be used as the 'isolating mechanisms' that protect the firm's valuable and rare resources from imitation by rivals to achieve

sustained competitive advantages (Grant, 1996; Kogut & Zander, 1992; Rumelt, 1984). Knowledge specificity is hard to be replicated by others because firms with specific knowledge have the unique know-how to absorb and apply firm-specific knowledge (Wang, He, & Mahoney, 2009).

For transaction cost theorist, firm-specific knowledge is the driver of opportunism behaviors between buyer and supplier. They argue that the one who possesses firm-specific knowledge will sacrifice the others benefits due to the asymmetry of knowledge resource applied information (Williamson, 1985). For example, in the job market, employees with specific knowledge rationally expect that their firm may hold them up in the future, this expectation will have a direct negative effect on their current incentives to make a specific human capital investments (Hart, 1995; Williamson, 1981). Besides, in network related literatures, knowledge specificity is applied to express the heterogeneous and specific knowledge exchanging and flowing between firms and individuals within network. For example, Sammarra and Biggiero (2008) studied the exchange of market, technological, and managerial knowledge, stressing the process of exchange is knowledge-specific which require access to and recombination of diverse knowledge. The literatures discussed above depict two attributes of knowledge specificity: (1) the specific or unique of knowledge within individuals depends on the comparison with others and (2) it is concerning the knowledge flows.

Despite the importance of roles in organizational knowledge specificity, the empirical studies still lack a comprehensive measurement to know what the extent the knowledge is specific to firms in acquisition and application, especially for comparison with counterparts. As noted by Choudhury & Sampler (1997, p.44), they mentioned “the primary challenge in this regard may be operationalizing the construct of knowledge specificity of information.” It is not clear that the effects of knowledge specificity on the relationship between knowledge strategy and performance. Patent citation provide direct evidence of knowledge flow and knowledge spillover, since each technological innovation explicitly identifies several others. Using the patent citation information as the measurement of knowledge specificity, this study may recognize that the difference of knowledge specificity extent could be strategically important in terms of knowledge acquired and applied ways and we concern the interaction effect of knowledge specificity on firm performance.

Hypotheses

Knowledge diversity

Prior studies have showed that the most valuable knowledge comes from the outside of organizational boundary and is transformed into an innovation while integrated with existing knowledge (Fleming, 2001; Phene et al., 2006; Schumpeter, 1939). In order to effectively source and recombine the knowledge acquired externally, a firm would diversify their knowledge through expanding the extent of its knowledge scope

(Carnabuci & Operti, 2013; Lin, 2011; Miller, 2006). A diverse knowledge background provides a learning foundation for a firm to increase the prospect of incoming information relating to what the firm has already known (Cohen & Levinthal, 1990). In other words, knowledge diversity is the necessity of proactively identifying and exploiting new available knowledge in the external environment.

Another important benefit from knowledge diversity proposed in the literatures is the synergistic effect through economies of scope (Granstrand, 1998; Lin, 2011; Miller, 2006). After acquiring knowledge from external sources, firms building up knowledge in multiple fields can create new inventions and functionalities from recombining and cross-fertilizing different kinds of technologies, thereby improving product and process performance (Granstrand, 1998). Economies of scope are greater when knowledge and know-how can be used across various business operations. For example, Miller et al. (2007) in their empirical study have confirmed that firms sharing their broad range of technological knowledge across business units could increase their financial performance with respect to manufacturing a product spans multiple domains. Based on the benefits of identifying, exploiting, and creating knowledge brought from knowledge diversity, the following hypothesis is proposed:

Hypothesis 1. Knowledge diversity has a positive impact on firm performance.

Knowledge newness

Knowledge newness refers to the cutting-edge technologies and new market application which are incorporated in a firm's innovation. When a firm has a high level of technological knowledge newness in product portfolio, it will benefit from first-mover advantages (Simon, Elango, Houghton, & Savelli, 2002). In the literatures, the first- mover advantages mainly from a firm’s technological progress could be attributed to two mechanisms: patenting and learning (Lieberman & Montgomery, 1988). Firms can take advantage of preemptive patenting, the first mechanism, to protect their technologies from imitating by competitors (Teece, 1986). Leveraging patents may drive out competitors and create market exclusivity for several years (Leask & Parker, 2007). For example, Shapiro (2001) indicate that an overlapping set of patenting related technologies keep some new products from commercialization in semiconductors, biotechnology, computer software, and the Internet industries.

The second mechanism, learning, emphasizes that a firm can reduce its unit production costs through learning experiences (Wernerfelt, 1984). In general, the leader will have higher returns than the follower because the later should take time to accumulate the same experiences without any knowledge spillovers. Empirical cases present that DuPont Corporation and Procter & Gamble utilize this preemptive learning strategy to develop their products, thereby gaining sustained profits and market share in distinct industries (Lieberman &

Montgomery, 1988). According to Bierly and Chakrabarti (1996), the firms learning fast can rapidly integrate state-of-the-art technologies into their new product or process. Due to a firm's faster learning speed, even if by the time an innovation is copied, the innovator would have gained plenty of rent or moved on to the next innovation. Accordingly, this study predict that knowledge newness may increase firm performance by first-mover advantages.

Hypothesis 2. Knowledge newness has a positive impact on firm performance.

Interaction between knowledge diversity and knowledge specificity

Knowledge diversity could increase the probability of discovering novel linkages, promoting creativity, innovation, and even the economies of scope. However, the major challenge is whether the knowledge acquired from the outside of organizational boundary and recombined internally through different technology fields is suitable for organization existing operations. In this situation, the resource or human assigned to knowledge acquired or applied could suffer certain loss. The resource-based view of the firm suggests that a high level of firm specificity of innovative knowledge can help the firm appropriate a greater share of innovation value (Barney, 1991; Dierickx & Cool, 1989; Wernerfelt, 1984). On the one hand, a high level of knowledge specificity implies the knowledge involve tacit knowledge that can be acquired or applied by employees who own this domain know-how (Choudhury & Sampler, 1997). On the other hand, when the diversified knowledge is highly firm-specific, employees can more easily leverage their existing collaborative efforts and communication language to the new knowledge acquired (Teece et al., 1997). Therefore, this study predict that firms with a high level of knowledge specificity could lead to diversified knowledge acquired and applied more effectively through the tacit of domain know-how and existing work routines.

Hypothesis 3. The interaction between knowledge diversity and knowledge specificity has a positive impact on firm performance.

Interaction between knowledge newness and knowledge specificity

Knowledge newness could bring the first-mover advantages in the product market through patent protection and fast learning speed. The newness of technological knowledge also reflects the new market opportunities which could be exploited (Bierly et al., 2009). However, being the forefront of innovation cannot guarantee the highest profits in the industry since how many profits gained from product market depends on the extent of product differentiation relative to competitors. According to Mosakowski (1993), firms holding unique or specialized resources can be more easily in adopting the differentiation strategy which refers to the way in which firms make their products from those of competing firms. Following his logic, we argue a firm with a high level of knowledge specificity could target a market by offering its differentiation products. By offering a

product or set of products that differ from competitors, a firm can increase its likelihood of gaining a competitive advantage, thereby obtaining more profits from the market (Porter, 1980). Therefore, the knowledge specificity could interact with knowledge newness, then enhancing firm performance collectively. Thus, the following hypothesis is proposed:

Hypothesis 4. The interaction between knowledge newness and knowledge specificity has a positive impact on firm performance.

Figure 1. depicts the research framework of our study, which illustrates the linkage among proposed hypotheses.

METHODS

Empirical context, sample and data collection

Empirical context

The research setting for this study is the North American biotechnology industry. As an emerging industry, biotechnology and pharmaceutical industry is not part of the standard industrial classification (SIC) system that is consistent in all research. Following previous research (Guo, Lev, & Zhou, 2005; Toole, 2003), we take a broadly definition of this industry to increase the generality of this research. Therefore, the sample used in this study consists of biotechnology companies in four-digit SIC codes: 2833 (Medicinal Chemicals and Botanical Products), 2834 (Pharmaceutical Preparations), 2835 (In Vitro and In Vivo Diagnostic Sub stances), 2836 (Biological Products, Except Diagnostic Substances) and 8731 (Commercial Physical and Biological Research).

We chose this context for two reasons. First, prior research shows that a string link exists between firm's knowledge strategy and performance in the biotechnology and pharmaceutical industry (Bierly & Chakrabarti, 1996). For the purpose of continuously developing higher quality innovations, firms is this industry not only take advantage of R&D investments to accumulate their knowledge stocks, but also collaborate with university scientists and research centers to introduce new ideas. Patent citations information provides valuable data concerning the flow of knowledge to a firm from external sources. Second, firms in a knowledge intensive industry have a high propensity to issue patents compared with other industries (Phene et al., 2006). Biotechnology and pharmaceutical firms are relatively used to patenting their new innovations that provides us more available and representative information for analysis.

Sample and data collection

This study utilizes three secondary data sources. First, using the SIC code mentioned before as an identifier, we collect 10 years (1998-2007) financial data of these companies from Standard & Poor's COMPUSTAT North America Industrial Annual Dataset, which include 699 publicly-traded firms. Second, we collect patent data of these firms from the United States Patent and Trademark Office (USPTO) database. To find out which patent belongs to whom, the patent data is matched with COMPUSTAT data by using the latest NBER Patent Citation Data File which include US patent and citation information during the period of 1976 to 2006 (Hall, Jaffe, & Trajtenberg, 2001). Due to NBER patent data ended in 2006, we exhaustedly expand our data to 2007 by matching COMPUSTAT company name to USPTO assignee name. Then, each scientific article reference of our sample patent is extracted from 'Other Reference' part in the patent documents. Third, we take a long time inquiring information about scientific articles citied by patents in the ISI Web of Science (WOS) database operated by Thomson Reuters. Research journal articles indexed in the WOS database are good indicators of successfully depicting major research streams because the database covers a large proportion of the scientific journal literature in various scientific disciplines (Tijssen & Van Leeuwen, 2006). After eliminating some missing data in the COMPUSTAT database, there are 2139 firm-year observations for 427 firms remained in the final data set. To decrease annual fluctuations and adequately capture the lagged strategic effects, a 3-year observation window is used to calculate a focal firm's strategies. All data that will be used for subsequent regression analysis and testing the hypotheses. The generalised linear model will be conducted to analysis data and test hypotheses.

Measures

Dependent variable

Firm Performance. We adopt Tobin's Q as our measure of firm performance. Tobin' Q refers to the capital market value of the firm divided by the replacement value of its assets and is a widely used measure of long-term financial performance in strategic management and finance literatures (Berger & Ofek, 1995; Miller, 2004). Chung and Pruitt (1994) established an approximate Tobin's q formula, which requires only basic and readily available financial data from COMPUSTAT database, and this measure was operationally defined by Lee and Tompkins (1999). We use their formula to calculate the approximate Tobin's q ratio with the data obtained from COMPUSTAT database. We take one year lag of firm performance to enhance casual inference between dependent variable and independent variable.

Independent variables

Knowledge Specificity. Knowledge specificity, a characteristic of organizational knowledge emphasizing its scientific parts, is proposed in this study and defined as the degree of a firm's knowledge combination being

rare or unique relative to its counterparts. Specificity of a firm's knowledge is operationalized by the specificity indicator introduced in this research. We calculate the specificity indicator as the average weighed value of scientific articles references citied by a patent portfolio, thereby revealing a distinct scientific link between an invention and scientific knowledge which it built on. The greater specificity indicator value of a firm, the scientific knowledge which the firm depends on are more rarely used and unique within the firm's industry. For example, assume a patent A cites two scientific articles: article x was citied twice in all sample patent, and article y was citied four times in all sample patent. The weighted value of article x is 0.5 and that of article y is 0.25. Therefore, the specificity indicator value of patent A is 0.375 from the average value of 0.5 and 0.25.

Knowledge Diversity. Knowledge diversity refers to the extent of diversification of a firm's technology scope in a firm's patent portfolio (Lin, 2011). We use the Herfindahl-index to measure the extent of diversification of a firm's technology base. We calculate the number of patents in a firm's patent portfolio that belong to the five technology fields (Xi, i= 1 to 5): electrical engineering, instruments, chemistry, mechanical engineering, and other fields according to the ISI-OST-INPI classification (Schmoch, 2008). Follow the formulation of prior research (Leten, Belderbos, & Van Looy, 2007), knowledge diversity is then defined as follows:

$$\text{Knowledge diversity} = 1 \Big/ \sum_{i=1}^{5} \left(\frac{x_i}{\sum x_i} \right)^2$$

Knowledge Newness. Knowledge newness is measured by technology cycle time (TCT) indicator that reflects the age of the technological knowledge which a new invention is built on (Kayal & Waters, 1999; Park & Park, 2006). TCT indicator is calculated by the mean of all backward citation lag for a specific patent. Backward patent citation lags, representing the knowledge flow between the citing patent and cited patent, is the time between the year in which a citied patent was granted and the year in which a citing patent was granted. Due to the shorter the age of the technological knowledge constructing an innovation, the technological progress goes further advanced. Therefore, we take the inverse of the TCT to calculate the knowledge newness.

Control Variables. This study controls for several potential sources of heterogeneity across observations that might influence firm's strategic decision and performance. *Ten-year dummy variables*, Y1998 through Y2007, are introduced to account for the variances of general environmental conditions. Following the traditional studies concerning firm strategy, we also control *firm size* (measured as the logarithm of total assets), *firm age* (measured as the age of firm's operations), *slack resources* (measured as the debt-to-debt-plus-equity ratio), and *R&D intensity* (measured as the R&D expenses divided by total assets).

RESULTS

Table 1 provides the descriptive statistics and correlations for our sample. Prior to the procedure of regression analysis, both independent and moderating variables are mean-centered to reduce the potential problem of multicollinearity (Aiken & West, 1991). All correlation coefficients are under 0.6, revealing that multicollinearity is not a problem. We also calculated the values of variance inflation factors (VIFs) associated with each of the predictors in our model. The value of VIFs ranged from 1.00 to 2.22, with a mean of 1.37, suggesting that multicollinearity is of little concern.

Table 2 displays the results of the regression analysis examining the impacts of knowledge diversity and knowledge newness, as well as their interaction effects with knowledge specificity on firm performance. Model 1 is the base model that includes the nine year dummy control variables and four strategy-related control variables: firm size, firm age, slack resources, and R&D intensity. Firm size has negative significant effects on firm performance while firm age has positive significant effects on firm performance. Slack resources do not have significant and direct effects on firm performance. R&D intensity has strongly positive significant effects on firm performance. Model 1 indicates smaller firms in biotechnology and pharmaceutical industry have better performance than larger firms, but older firms have better performance than younger firms. Investing in R&D is beneficial to both small and large firms.

Model 2 is significant at the $p<0.001$ level ($F=30.072$, Adj $R2=0.179$). It captures the direct effects of diversity, newness, and R&D intensity on firm performance. Hypothesis 1 postulates knowledge diversity has a positive impact on firm performance. The coefficient of diversity in Model 2 is positive and statistically significant ($\beta = 0.486$; $p<0.05$), supporting the hypothesis 1. Hypothesis 2 predicts knowledge newness has a positive impact on firm performance. However, the coefficient of newness in biotechnology and pharmaceutical firms Model 2 and Model 3 are both insignificant. Thus, Hypothesis 2 is not supported. These findings suggest that increasing organizational knowledge diversity can enhance firm performance. However, the insignificant of knowledge newness on firm performance implies that technological or knowledge newness in bio- and pharm- firms might not be able to enhance competitive advantage solely by incorporating the cutting-edge technologies in innovations.

Model 3 is significant at the $p<0.001$ level ($F=27.132$, Adj $R2=0.180$). Model 3 tests our three hypotheses regarding the interaction effects between uniqueness and three independent variables: diversity, newness, as well as R&D intensity. Hypothesis 4 states that the interaction between diversity and uniqueness has a positive impact on firm performance. The coefficient of the interaction term between knowledge diversity and knowledge specificity is positive and statistically significant ($\beta = 0.447$; $p<0.1$), suggesting that knowledge diversity is more positively associated with firm performance when knowledge specificity is high. Hence,

Hypothesis 3 is supported. Hypothesis 4 states that the interaction between knowledge newness and knowledge specificity has a positive impact on firm performance. The coefficient of the interaction term between knowledge newness and knowledge specificity is positive and statistically significant (β = 6.686; p<0.1), suggesting that knowledge newness is more positively associated with firm performance when knowledge specificity is high. Hence, Hypothesis 4 is supported.

To see the pattern of the interaction effects, we plotted the trends showing the relationship between firm performance and three independent variables: diversity, newness, as well as R&D intensity at both high and low levels of uniqueness. We define high- and low-level uniqueness based on one standard deviation above and below the mean of the uniqueness variable, respectively. Figure 2 and 3 present the interaction plots, indicating uniqueness definitely a critical moderating variable that influences the relationship between firm performance and three variables: diversity, newness, and R&D intensity. As shown in Figure 2, we find that when knowledge specificity is high the knowledge diversity-performance is positive, and when knowledge specificity is low the knowledge diversity-performance is negative. Although knowledge newness has the negative relationship with performance in Figure 3, firms with high knowledge specificity perform better than with low knowledge specificity, especially in the low level of knowledge newness. Figure 2 and 3 shows a consistent pattern with our predictions.

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Table 1. Descriptive statistics and correlations

	Mean	Std.	1	2	3	4	5	6	7	VIF
1 Tobin's Q	3.76	7.93								
2 Firm size	2.21	0.98	-0.19 **							2.22
3 Firm age	11.67	7.83	0.02	0.50 **						1.41
4 Slack resources	0.27	1.28	0.03	0.01 *	0.05 *					1.00
5 R&D intensity	0.34	0.43	0.39 **	-0.47 **	-0.15 **	0.03				1.31
6 Knowledge specificity	-0.11	0.89	0.06 *	-0.16	-0.02	-0.03	0.05 *			1.05
7 Knowledge diversity	1.88	0.87	-0.05 *	0.58 **	0.38 **	0.00	-0.21 **	-0.15 **		1.56
8 Knowledge newness	0.12	0.04	0.03	-0.08 **	-0.15 **	-0.04	0.05 *	0.08 **	-0.07 **	1.03

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

Table 2. Regression results

Independent variables	Firm performance (Tobin's Q)		
	Model 1	Model 2	Model 3
Intercept	-0.387	-0.543	-0.492
Y1998	0.984	0.833	0.956
Y1999	3.153 ***	3.042 ***	3.180 ***
Y2000	3.450 **	3.428 ***	3.526 ***
Y2001	2.083 +	2.067 **	2.170 **
Y2002	-0.290	-0.319	-0.242
Y2003	1.400	1.377 +	1.452 +
Y2004	1.811	1.778 *	1.809 *
Y2005	1.484	1.445 *	1.496 +
Y2006	1.315 +	1.277 +	1.310
Firm size	-0.580 **	-0.769 **	-0.717 **
Firm age	0.124 ***	0.114 ***	0.113 ***
Slack resources	0.143	0.150	0.143
R&D intensity	7.055 ***	7.022 ***	7.053 ***
Knowledge specificity		0.273	-1.285 ***
Knowledge diversity		0.486 *	0.488 *
Knowledge newness		-1.162	-2.758
Knowledge specificity * Knowledge diversity			0.447 +
Knowledge specificity * Knowledge newness			6.686 +
Number of observations	2139	2139	2139
F-value	36.442 ***	30.072 ***	27.132 ***
R^2	0.182	0.185	0.187
Adjusted R^2	0.177	0.179	0.180

+ < 0.1; * p < 0.05; ** p < 0.01; *** p < 0.001

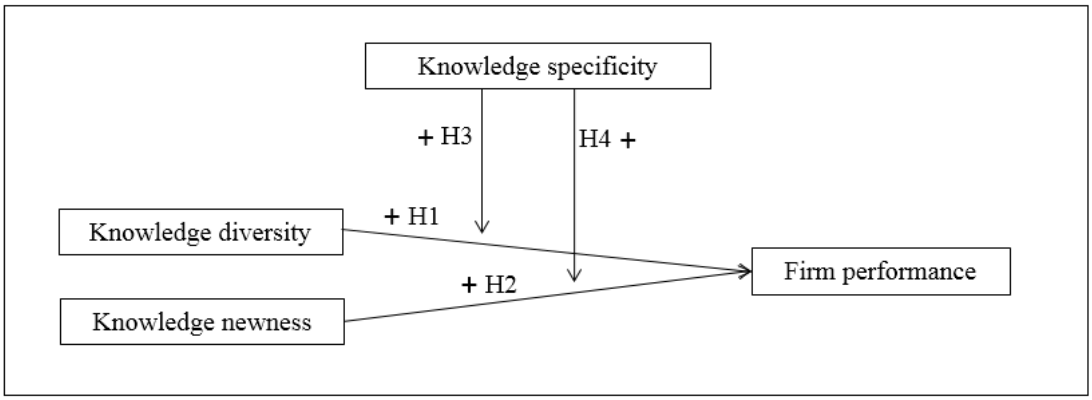

Figure 1. The Research framework and proposed hypotheses

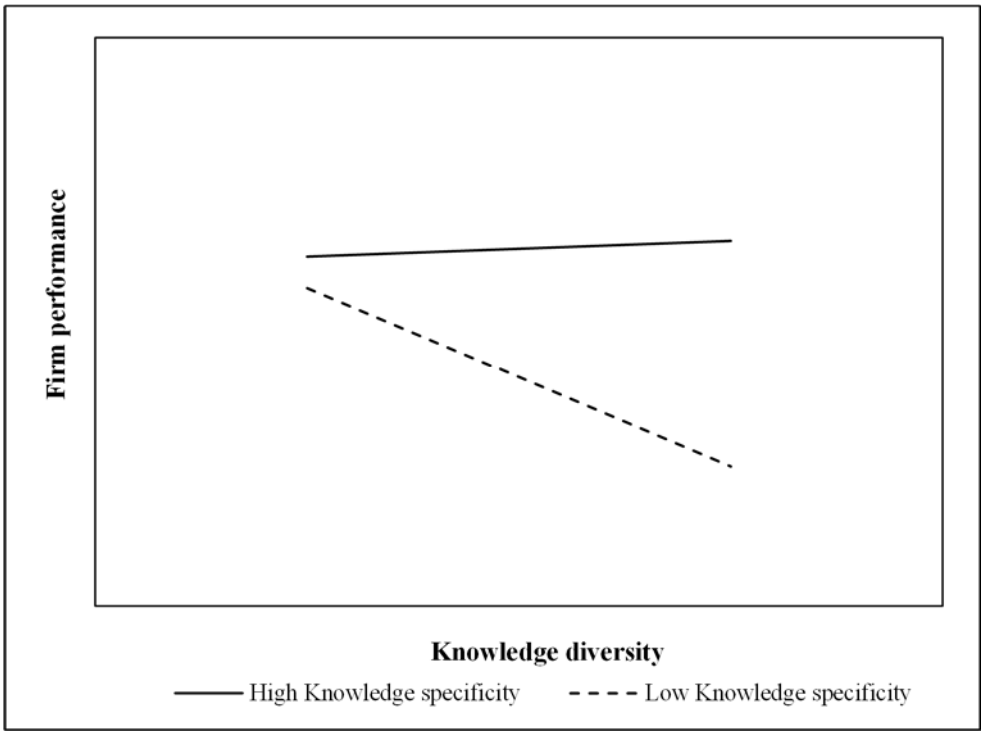

Figure 2. The moderating effect of knowledge specificity on the knowledge diversity and firm performance relationship

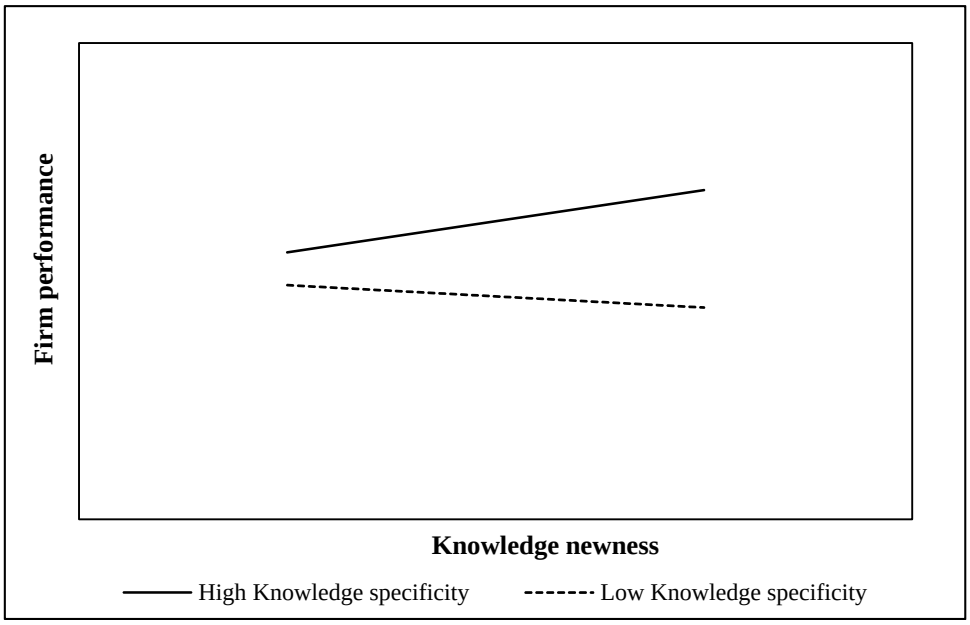

Figure 3. The moderating effect of knowledge specificity on the knowledge newness and firm performance relationship