R&D MANAGEMENT

The effects of knowledge interaction for business innovation

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The objective of this paper is to examine the effects of knowledge interaction on different types of business innovation. We first identified three indicators that reflect on the quality of the interaction between customers and technological knowledge, and then classified business innovations as product innovation, problem-solving innovation, or general innovation capability. Hypotheses about the impact of different qualities of knowledge interaction on business innovations were tested by collecting data from 178 high-technology firms in Taiwan. The results revealed that product innovation requires both wide-ranging and deep interaction between customers and technological knowledge, that problem-solving innovation requires either wide-ranging or deeper interaction between customers and technological knowledge, and that wide-ranging knowledge interaction is the most important driver for building general innovation capability. The research results enhance our understanding of knowledge interaction, with a special focus on the content and quality of the knowledge interactions within an enterprise. It also helps business managers in allocating resources and facilitating interorganizational communications for different situations related to innovation.

1. Introduction

Knowledge interaction describes all types of direct and indirect personal and non-personal interactions between and among organizations and/or individuals. Through knowledge interactions among diverse knowledge components, firms develop combinative capabilities (Kogut and Zander, 1992) to synthesize and apply the exchanged knowledge within innovation processes (Schartinger et al., 2002), thus generating a variety of innovative activities such as new forms of production and service provisions (Spender, 1996). Because of the complexity of knowledge interaction and the various kinds of business innovation involved, our research aims to address the question: how do the different forms of knowledge interaction affect business innovation?

In order to understand the effects of knowledge interaction on business innovation, two things need to be clarified: (1) What do we know about the quality of knowledge interaction? (2) What kind of business innovations can be achieved? On the topic

of knowledge for innovation, studies in economics (Romer, 1986; Haussler, 2010) and strategic management (Leiponen and Helfat, 2010; Zhou and Li, 2012) tend to describe knowledge at generalized level as resources or information. However, knowledge in an organizational setting requires deeper scrutiny about content and context (Ahlstrom and Nair, 2000; Wang et al., 2008). Additionally, prior studies (Van de Ven, 1980; Griffin and Hauser, 1996; Moenaert and Souder, 1996; Schartinger et al., 2002; Todtling et al., 2009) have mostly examined knowledge interaction in the context of the interorganizational environment. The effects of knowledge interaction were measured through the frequency of communication (Griffin and Hauser, 1996; Moenaert and Souder, 1996), and diverse innovative results were examined in terms of product, customer service, or research development. Thus, a lack of understanding of innovation–knowledge interaction at the intraorganizational level exists as well as the quality of the knowledge being verified and classification of resultant innovations. This study attempts to explore the important and subtle distinctions of knowledge interaction by thoroughly examining the different sources of knowledge content under various innovation conditions within business.

Studies of knowledge management have analyzed cases concerning the importance of interactions among firms, universities, and research centers (Conceicao and Heitor, 2002; Nishida, 2002; He and Wong, 2009). Most of these empirical studies examined the patterns or results of knowledge interaction with external parties. None of the studies, however, addressed the content of interacted knowledge, nor can we find any examination of the quality.

Although some studies (e.g., Schartinger et al., 2002; Moorthy and Polley, 2010) have used reach and range to describe the contents of knowledge sharing, there is a lack of these indicators' practical measures for knowledge interaction. On the other hand, quite a few studies (e.g., Van de Ven, 1980; Griffin and Hauser, 1996; Moenaert and Souder, 1996) have emphasized the effectiveness of interorganizational knowledge interaction as measured by the frequency of communication between two parties. Overemphasizing the strength of knowledge interaction (Schartinger et al., 2002) can create a misleading focus on facilitating or guiding interaction activities to increased harmony among participants, but the involved parties may not share relevant knowledge for innovative activities.

In regard to knowledge interaction content within a firm, technological and customer knowledge have both been identified as crucial because of the direct contribution to a company's innovation (Diaz-Diaz et al., 2008) as well as competitive advantage (Su et al., 2006). Firms need to explore the demands of customers in the development of technological knowledge, and customer knowledge needs to be incorporated into technological insights to identify potential requirements and provide effective solutions.

Moving deeper to the various kinds of business innovations, existing studies have measured innovation from different perspectives. For example, quite a few studies have examined knowledge for innovation and have indicated that a knowledge exchange (Spithoven et al., 2011) – the knowledge-integration mechanism (Tsai et al., 2012) – and the knowledge flow (Zhang et al., 2009) can affect business innovation for both products and services. Other studies (Blazevic and Lievens, 2008; Liu and Hart, 2011) have considered whether a knowledge exchange may reduce uncertainties, provide solutions to customer problems, and help a firm to achieve innovation. Finally, another group of studies on business innovation (Liao et al., 2010; Kumar and Rose, 2011) has examined the relationship between knowledge sharing and a firm's ability to generate intellectual property for future development. The dependent variable of innovation studies has been described in various forms, from actively developing products and reactively solving problems to proactively building innovative capabilities in capturing technological and market opportunities.

To build a constructive understanding of knowledge interaction with respect to business innovation and effectively leverage the results of knowledge interaction for different aspects of business innovation, we need to engage in a deep examination of how technological knowledge interacts with customer knowledge within a firm to achieve innovation. To achieve this goal, this study first reviews and consolidates concepts of knowledge interaction between customers and technological knowledge. Then, indicators reflecting the quality of knowledge interaction – namely the scope, depth, and strength of the interaction between customer knowledge and technological knowledge – are proposed and operationalized. We then form hypotheses about the effects of different levels of scope and depth of knowledge interaction on three types of business innovation (product innovation, problem solving, and innovation capability) and conduct a thorough testing of the knowledge interaction effects on business innovation. The results of the empirical test are discussed in the next section, and the paper concludes with implications drawn from the study.

This paper contributes to the field of knowledge management and business innovation with a finely

drawn exploration of the dynamic interplay between knowledge interaction and business innovation. It situates knowledge interaction in the context of intrafirm environment with a focus on content level that delineates the scope and depth of knowledge based on major sources of organizational knowledge. The results would provide a practical and enriched base for studies in knowledge management and innovation. The proposed variables and relationships may ultimately benefit strategic planners and business managers in their attempt to cope with the challenges of building a cooperative and innovative culture within an organization.

2. Concepts and hypotheses of knowledge interaction for business innovation

A firm's knowledge can be viewed as collective knowledge (Nonaka, 1994) that includes solutions, referrals, problem reformulation, validation, and legitimation (Cross, 2004). This knowledge is embedded in employees, invested in practice, validated in use, and rooted in the tasks at hand (Grant, 1996). Enterprises integrate diverse knowledge to develop products and services to satisfy customers quickly in today's fast-changing environment (De Boer et al., 1999). Technological knowledge and customer knowledge are the two major, distinctive types of enterprise knowledge based on their contributions to innovation (Diaz-Diaz et al., 2008) and to financial performance (Su et al., 2006).

2.1. Technological knowledge

Technological knowledge refers to knowledge associated with products, technologies, and processes (Burgers et al., 2008), and it is usually systemized in order to achieve a technological change objective that can be understood by investigating the development of knowledge (Diaz-Diaz et al., 2008).

Technological knowledge can be divided into three categories: fundamental design concepts, technological operational knowledge, and technological application knowledge. Fundamental design concepts include knowledge about operational principles and normal configurations (Gupta et al., 1986; Song and Dyer, 1995). Technological operational knowledge emphasizes how to implement products or services from fundamental design concepts (Utterback, 1994). Technological application knowledge is accumulated from experience in design, learning from accidents, and rules of thumb to meet customer requirements (Howells et al., 2003).

Through a product-development process, firms meet the demand for exploration of customer knowledge (Burgers et al., 2008) in the development of technological knowledge. When technological knowledge lacks a customer orientation, it may cause products that are not suitable for a market.

2.2. Customer knowledge

Customer-specific knowledge as outlined by Desouza and Awazu (2005), Salomann et al. (2005), and Su et al. (2006) that include 'about the customer', 'to/for the customer', and 'from the customer', this study organizes business concerns of customer-related knowledge into the categories of customer demand knowledge, customer operation knowledge, and customer application knowledge. Customer demand knowledge is the knowledge *about* customers' backgrounds, motivations, expectations, and preferences for products or services. This kind of knowledge helps organizations to understand customers' demands and to target their needs effectively (Su et al., 2006). Customer operation knowledge is the knowledge learned *from* or provided by customers that emphasizes the use of the product during the value chain process, including customers' operational patterns or the consumption experience of products/services (Su et al., 2006). Some customer operation knowledge is generated by businesses in the form of product documentation, troubleshooting guides, repair manuals, and other types of support knowledge that assist customers in the use of a firm's products and/or services (Gupta et al., 1986; Song and Dyer, 1995). Customer application knowledge is knowledge generated *to* support customers in utilizing products and services, which in turn creates value for the business. This knowledge includes ideas, thoughts, and information about customer application of the products and services that generate profits and help the firm to pursue future trends and opportunities (Su et al., 2006). Customer knowledge can help an enterprise to achieve a better sense of market opportunities, examine new combinations of customer needs, and identify chances for innovation (Prahalad, 2004).

2.3. Interaction between customer and technological knowledge

The interaction philosophy emphasizes communication and transaction and establishes information flow between departments (Kahn, 1996). Interaction, therefore, has a structural nature of cross-departmental activities. Because knowledge is mainly embedded in people who perform related

functions within a department, coordinated activities between knowledge carriers is the visible form of knowledge interaction. This study defines knowledge interaction as the information flows among two or more parties that mutually influence one another within the innovation process. It is in contrast to previous studies (Kahn, 1996; Haas and Hansen, 2007), which have examined knowledge interaction mainly on the basis of mechanisms and coordinated interaction activities such as routine meetings, teleconferencing, conference calls, telephone calls, memoranda, e-mail, faxes, and the flow of standard documentation. Only by understanding the quality of knowledge interaction studies on knowledge management can we uncover insights of organizational interaction so that firms can design and manage these kinds of strategic moves effectively.

2.4. Quality of knowledge interaction

Previous studies (Kahn, 1996; Weill, 1998; Sambamurthy, 2003) have used the concepts of scope and depth to reflect the value of knowledge flow. Studies of knowledge interaction (e.g., Schartinger et al., 2002) acknowledge that this type of activity involves quite a large amount of knowledge exchanged between agents, although the exact extent, quality, and effect of this knowledge remain uncertain. Another line of research on knowledge interaction has considered the frequency of directly facing or making contact among people for business objectives (Lagace et al., 1991), which is another aspect of understanding the strength of knowledge interaction. Because knowledge interaction involves a great amount of knowledge exchange between different sources of knowledge, we examine the quality of knowledge interaction from three aspects: the scope of knowledge interaction, the depth of knowledge interaction, and the strength of knowledge interaction.

2.5. Scope of knowledge interaction

In organizational practice, the scope of knowledge for interaction can be described as the types of messages sent and transactions processed between parties (Weill, 1998). It represents the spread of different knowledge areas existing in an organization, which can be increased by learning in different areas (Sousa, 2006). A wide range of knowledge interaction may bring out different ideas, instances of creativity, and new perspectives, and thus may produce opportunities for innovation (Sousa, 2006). In this study, we consider the scope of knowledge interaction as the range of knowledge exchange and business activities that can be completed between two knowledge carriers to achieve specific organizational objectives.

In a wide breadth of knowledge interaction for business innovation, business innovators would need to absorb both customer and technological knowledge from technological concepts, operations, and applications to customer demands.

2.6. Depth of knowledge interaction

The depth of knowledge interaction indicates the richness of interactions among individuals for knowledge transfer and sharing (Sambamurthy, 2003). Knowledge depth is reflected in the level of understanding and experience existing in an organization in a specific knowledge area and can be increased by learning within existing areas (Sousa, 2006). This study considers the depth of knowledge interaction for accomplishing innovation as the extent of knowledge sharing, transference, and creation between two parties to address the insufficiency of knowledge for achieving specific goals.

For different extents of knowledge interaction, this study divides knowledge interaction into four levels: (1) factual knowledge, (2) conceptual knowledge, (3) procedural knowledge, and (4) causal knowledge. Factual knowledge includes terms, elements, details, facts, or data that result from direct observation and research (Sussane, 2009). Conceptual knowledge includes classifications, categories, principles, theories, models, and information-observational data in a usable form. The descriptions include information about the who, what, when, where, and how of specific products or services a firm produces (Quinn et al., 1996). Procedure knowledge is a description of how to do something (Kogut and Zander, 1992) and the sequence of operations to complete business tasks (Santhanam et al., 2007). It is the accumulated practical skill or expertise that allows one to do something smoothly and efficiently (Von Hippel, 1998). Finally, causal knowledge is the in-depth knowledge of cause-and-effect relationships (Quinn et al., 1996) – knowing why certain functions must be utilized and how these can be adapted to business needs (Santhanam et al., 2007). Professionals should possess highly trained intuition so that they can anticipate unintended interactions and results and move beyond the execution of tasks to solving large, complex problems and create extraordinary value (Quinn et al., 1996).

2.7. Strength of knowledge interaction

Interaction strength means the frequency of directly facing or contacting people for business objectives

(Lagace et al., 1991). It is similar to communication frequency, which means the intensity of information flow between or among managers via meetings, reports, or conversations (Van de Ven, 1980; Moenaert and Souder, 1996). Interaction strength can maintain and enhance the relationship between firms and customers (Lagace et al., 1991). Tie strength characterizes the closeness and interaction frequency of a relationship between two parties (Hansen, 1999).

2.8. Business innovation

Many studies (e.g., Betz, 1993; Dosi, 1988; Elmquist and Le Masson, 2009) define business innovation from different aspects. Based on the scope of changes of products and services, research studies (Subramaniam and Youndt, 2005; Chiang and Hung, 2010) have classified innovation as radical or incremental and have analyzed interorganizational exploitation and exploration of knowledge exchange. Distinguished by front and back office operations, many studies (Maine et al., 2012; Bauer and Leker, 2013) have defined business innovations as product and process innovation and have studied knowledge management as concentrated on either customer demands (Chua and Banerjee, 2013) or technological enablement (Handzic, 2011). On the basis of customer needs and requirements (Linder et al., 2003) and for the purpose of satisfying customers with innovative approaches, interorganizational knowledge interaction can contribute to business innovation in three areas: product innovation so as to actively deliver new products and services to customers, problem-solving innovation so as to reactively solve problems for customers, and innovation capability so as to proactively capture opportunities in the market and in technologies for satisfying future customer needs.

'Product innovation' is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses (Betz, 1993) that meet emerging customer demands (Damanpour, 1990). In general, the term 'product innovation' has often been used to refer to perceived newness, novelty, originality, or uniqueness of products or services delivered (Wang and Ahmed, 2004). Recognized innovative approaches include significant improvements in technical specifications, components, and materials; new incorporated software; and user friendliness or other functional characteristics (OECD, 2005).

Reactively, innovation has also been conceptualized as a customer problem-solving process in which solutions are discovered through searching and recombination of local and distant knowledge (Dosi, 1988). Customer demand for problem solving can be referred to as resolutions, answers, and methods for responding to problems, puzzles, questions, doubts, difficulties, etc. (Oxford Dictionary, 2014). Most importantly, solutions are individualized offers for complex customer problems that are interactively designed and whose components combine products and/or services in which the value exceeds the sum of components (Evanschitzky et al., 2011). Companies need to build customer problem-solving capabilities to satisfy customer needs through effective and quick responses (Jayachandran et al., 2004).

Proactively, there is a group of studies on knowledge management for innovation (Sher and Yang, 2005; Elmquist and Le Masson, 2009) that considers innovation capabilities for generating new ideas and knowledge to take advantage of market opportunities and stimulate firm performance (Elmquist and Le Masson, 2009). Through innovative capabilities, enterprises use sourcing, coordination, and reorganization of interorganizational resources to achieve continuous innovation and seize opportunities for businesses growth and expansion into new areas (Tidd et al., 2001).

To sum up, we identify technological and customer knowledge as the key sources of knowledge for business innovation and three quality aspects of knowledge interaction: the scope, depth, and strength of knowledge interaction. Meanwhile, based on customer-encountered situations, we consider business innovation in three areas: product innovation, problem-solving innovation, and innovation capability.

3. Knowledge interaction on business innovation

The research model used in this study is presented in Figure 1, which shows an exploration of the interaction effects of different levels of knowledge scope and depth (on the left of the figure) on the three types of business innovation (the dependent variable on the right of the figure) with the strength of knowledge interaction as a moderator. We compare the effect of knowledge interaction on the three types of business innovation by: (1) higher scope and lower depth of knowledge interaction in Hypothesis 1, (2) lower scope and higher depth of knowledge interaction in Hypothesis 2, (3) higher scope and depth of knowledge interaction in Hypothesis 3, (4) lower scope and depth of knowledge interaction in Hypothesis 4, and (5) the moderating effect of strength in Hypothesis 5.

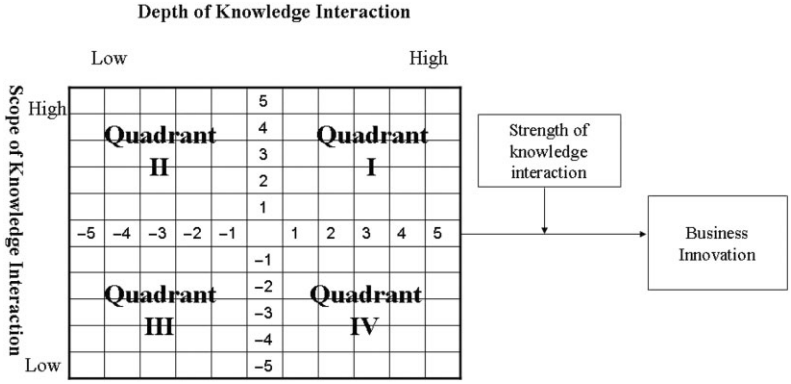

Figure 1. Scope, depth and strength of knowledge interaction for business innovation.

3.1. Higher scope of knowledge interaction

The scope of knowledge interaction is about the scope and diversity of knowledge exchanged. It implies that there are different knowledge areas within an organization, which can be increased by learning in different areas (Sambamurthy, 2003; Sousa, 2006). A wide scope of knowledge interaction can also stimulate diversified ideas, creativity, and new perspectives as well as increase opportunities for innovation (Sousa, 2006). Knowledge diversity is important for organizational learning – individuals' contacts with different contexts, insights, and information can accelerate new perspectives and raise capabilities for solving problems and developing new products (Quinn et al., 1996; Sousa, 2006). Firms with a wide knowledge base are more likely to achieve innovation (Leiponen and Helfat, 2010; Zhou and Li, 2012). Thus, we propose the following hypotheses about quadrant II in Figure 1:

H1a, 1b, 1c: *Higher scope and lower depth of knowledge interaction is associated with firm performance in (1) product innovation, (2) problem solving, and (3) innovation capability.*

3.2. Higher depth of knowledge interaction

The depth of knowledge interaction is vital for generating new ideas and renewing organizational knowledge in today's rapidly changing environment (Sousa, 2006). Having some extent of knowledge depth is also important for innovation because it increases the degree of sensing new opportunities and turns knowledge into new value for the user (Sousa, 2006). Firms with a deep knowledge base are more capable of developing radical innovation (Zhou and Li, 2012). Therefore, we hypothesize about quadrant IV that higher innovation performance may be achieved with more in-depth knowledge interaction than with less depth-of-knowledge interaction.

H2a, 2b, 2c: *Higher depth and lower scope of knowledge interaction is associated with firm performance in (1) product innovation, (2) problem solving, and (3) innovation capability.*

3.3. Both high scope and depth of knowledge interaction

A high scope and deeply interacted business knowledge can strengthen companies' sensing capabilities by providing managers with superior quality information about the situation of the company, which helps to identify emerging opportunities and threats (Overby et al., 2006). This leads us to infer that both a wider range and deeper complexity of knowledge interaction (quadrant I) can achieve better innovative performance than either high scope or depth of knowledge interaction individually. We propose the following hypotheses:

H3a, 3b, 3c: *Higher scope and depth of knowledge interaction is associated with firm performance in (1) product innovation, (2) problem solving, and (3) innovation capability.*

3.4. Low depth and scope of knowledge interaction

In spite of the above hypotheses about the association between wide scope and in-depth knowledge and various types of business innovation, the innovative effects of knowledge interaction are still to be verified. To further understand the effects of a low level of interaction scope and depth on innovation, we hypothesize about quadrant III that innovation performance may also be achieved with lower scope and depth of knowledge interaction.

H4a, 4b, 4c: *Lower depth and scope of knowledge interaction is associated with firm performance in (1) product innovation, (2) problem solving, and (3) innovation capability.*

3.5. Strength of knowledge interaction for business innovation

The strength of knowledge interaction is the frequency of directly facing or contacting people for personal or business purposes (Lagace et al., 1991). The frequency of interaction is critical to innovation success (Tidd et al., 2001). Frequent communication can promote mutual understanding and harmonious relationships, overcome some technical communication barriers, and improve joint decision making (Van de Ven, 1980; Griffin and Hauser, 1996; Moenaert and Souder, 1996). Also, intensive interaction can help improve the credibility of received information (Gupta et al., 1986). With rapid interaction, people may cooperate to solve problems and perceive mutual benefits (Axelrod and Reisine, 1984). Thus, we propose the following hypothesis:

H5a, 5b, 5c: *The strength of knowledge interaction moderates the relationship between the combination of knowledge interaction and (a) product innovation, (b) problem solving, and (c) innovation capability.*

4. Methods

4.1. Research setting, participants, and procedure

In order to test the effects of different combinations of knowledge interaction on business innovation, we have completed three stages of data collection for a quantitative study conducted during a 4-month period in 2010 and 2011 in Taiwan. First, we held semistructured interviews with nine industrial experts and professors to validate our scale items. After several minor changes, we provided questionnaires for an extra pilot test to a sample of 100 Executive MBA students who had each worked in the high-tech industry for more than 10 years. The purpose of the pilot test was to examine the reliability and validity of the questionnaire. The hypotheses were then tested through 1,000 random samples of high-tech companies listed as members of industry associations such as the Taiwan Electrical and Electronics Manufacturers' Association, the Taiwan Semiconductor Industry Association, and the Taiwan Medical and Biotech Industry Association. High-tech companies reside in rapidly changing environments and face intense competition, which they try to overcome by engaging in continuous innovation and in mastering technological and customer knowledge. This dataset presents a valuable experience because Taiwan represents an extraordinary story of economic development (Berger and Lester, 2005; Einhorn et al., 2005; Chiang and Hung, 2010). A total of 1,000 online and mail surveys were sent to chief executive officers (CEOs) of high-tech companies. We chose to survey CEOs because they are usually involved in cross-departmental activities between customer contact points and research and development (R&D) and possess the most knowledge about the company's innovation projects. Three weeks after mailing out the questionnaires, we telephoned the companies that had not responded. The questionnaires were mailed along with preaddressed postage-paid envelopes and a cover letter explaining the purpose of the study. In response, we received 178 completed and usable questionnaires. Thus, the response rate was 17.8%. The sample represented different high-tech industries including semiconductor (14.7%), photoelectric (16.4%), communications and network (9.8%), electronics (17.4%), software/hardware (16.4%), mechanical engineering (5.2%), and biotechnology (18.9%). The companies' capital ranged from 1 million to $US 1 billion.

4.2. Measures

4.2.1. Scope of knowledge interaction

We modified measurement of the scope of knowledge interaction by the concept proposed by Gupta et al. (1986) and Song and Dyer (1995). The scale had seven items ($\alpha = 0.906$), including: 'R&D and Sales share knowledge about fundamental product-design concepts and infrastructure', 'R&D and Sales share knowledge about customer new ideas and solutions regarding products/services', and 'R&D and Sales share knowledge about customer demands'. Respondents were asked to assess the degree to which they agreed (1 = 'strongly disagree', to 5 = 'strongly agree') with each statement. We used a dichotomy to distinguish a higher and lower scope (depth) of knowledge interaction. If the scores were equal or greater than 3, we considered it a higher scope (depth) of knowledge interaction, and if the scores were lower than 3, we considered it a lower scope (depth) of knowledge interaction.

4.2.2. Depth of knowledge interaction

To measure the depth of knowledge interaction, we developed seven items based on Gupta et al. (1986) and Song and Dyer (1995). The seven-item measure of the depth of knowledge interaction demonstrated

high reliability ($\alpha = 0.886$). For each statement of the depth of knowledge interaction, we asked respondents to indicate the degree of knowledge sharing between the R&D and Sales departments (1 = 'basic knowledge', 2 = 'factual knowledge', 3 = 'conceptual knowledge', 4 = 'procedural knowledge', 5 = 'causal knowledge').

4.2.3. Strength of knowledge interaction

We measured the strength of knowledge interaction with a five-item scale ($\alpha = 0.662$) adapted from (Moenaert and Souder, 1996). Sample items included: 'The frequency of formal meetings or face-to-face communication between Sales and R&D', 'The frequency of informal chatting between Sales and R&D', and 'The frequency of using Internet platform (e-mails, databases) between Sales and R&D'. Items for the strength of knowledge interaction between Sales and R&D were rated as 1,'never'; 2, 'seldom'; 3, 'sometimes'; 4, 'often'; and 5, 'very often.'

4.2.4. Business innovation

We measured business innovation with a nine-item scale based on Jayachandran et al. (2004), Sher and Yang (2005), and Wang and Ahmed (2004). These nine items ($\alpha = 0.882$) covered three dimensions of business innovation: product innovation, problem solving, and innovation capability. Sample items included: 'Our company has introduced more innovative products and services compared with our major competitors in the last three years', 'Our company can solve customer problems more efficiently and more quickly than our major competitors', and 'Our company has had more intellectual property rights (patent and trade secrets) compared with our major competitors in the last three years'.

4.2.5. Control variables

We incorporated two control variables that are generally considered most relevant to business innovation: firm size and R&D intensity (Damanpour and Aravind, 2006). R&D intensity was measured by firm R&D expenditures divided by firm sales. Because companies may be more able to achieve innovation when they have greater resources (Autio et al., 2000), firm size was measured by the amount of reported capital in the company.

We used Harmon's one-factor test to examine the common-method variance for all variables in the study (Podsakoff and Organ, 1986). Factor analysis showed that no general factor was found in the unrotated factor structure with the first factor accounting for 31% of the total variance and the independent and dependent variables loading on different factors. Therefore, common-method variance is unlikely to be a serious issue in this study. When we designed the questionnaire, we used some design techniques including counterbalancing question order, improving scale items, protecting respondent anonymity, and reducing evaluation apprehension (Podsakoff et al., 2003).

5. Results

We used a two-way analysis of variance (ANOVA) to test all the hypotheses. The unit of analysis was the employee. The two-way ANOVA procedure was used to examine the joint effects between different combinations of knowledge interaction and the strength of knowledge interaction to affect each of the three aspects of business innovation. Descriptive statistics and correlations of all variables in the analysis are given in Table 1.

The performance of product innovation showed significant differences in different extents of knowledge interaction ($F = 11.008$, $P < 0.001$). The performance of problem solving also showed significant differences in different extents of knowledge interaction ($F = 21.413$, $P < 0.001$). The performance innovation capability showed significant differences in

Table 1. Means, standard deviations, and correlations

Variables	Mean	SD	Correlation coefficients					
			(1)	(2)	(3)	(4)	(5)	(6)
(1) Scope of knowledge interaction	4.0285	0.67702	1.00					
(2) Depth of knowledge interaction	3.3726	0.91570	0.445**	1.00				
(3) Strength of knowledge interaction	3.3768	0.62262	0.301**	0.337**	1.00			
(4) Product innovation	3.4427	0.78741	0.250**	0.302**	0.305**	1.00		
(5) Problem solving	3.8735	0.68822	0.337**	0.352**	0.277**	0.507**	1.00	
(6) Innovation capability	3.5069	0.76811	0.241**	0.339**	0.355**	0.668**	0.564**	1.00

**$P < 0.01$.
SD, standard deviation.

Table 2. Two-way analysis of variance (ANOVA) of the effect of the combination of knowledge interaction and innovation

Source of variation	Sum of Squares (Ss)	degree of freedom (df)	Mean square	*F*	*P*
Product innovation	19.272	3	6.424	11.008	0.000***
	278.9572	478	0.584		
	98.229	481			
Problem solving	26.990	3	8.997	21.413	0.000***
	200.8322	478	0.420		
	27.822	481			
Innovation capability	26.863	3	8.954	16.660	0.000***
	256.9222	478	0.537		
	83.786	481			

***$P < 0.001$.

different extents of knowledge interaction ($F = 16.660$, $P < 0.001$). We also used Scheffe's method to compare different extents of knowledge interaction.

Regression analysis shows a higher scope and lower depth of knowledge interaction positively relate to firm performance in product innovation (higher scope $\beta = 0.053, < 0.05$; lower depth $\beta = 0.143$, $P < 0.05$). Thus, Hypothesis 1a is supported. Hypothesis 1b, which argues a higher scope and lower depth of knowledge interaction, relate to firm performance in problem solving (higher scope $\beta = 0.131$, $P = 0.676$; lower depth $\beta = -0.012$, $P = 0.308$). This result does not support Hypothesis 1b. A higher scope and lower depth of knowledge interaction relate to firm performance in innovation capability (higher scope $\beta = 0.08$, $P < 0.05$; lower depth $\beta = 0.191$, $P < 0.01$). Hypothesis 1c is supported.

Similarly, a higher depth and lower scope of knowledge interaction is related to firm performance in product innovation (lower scope $\beta = 0.132$, $P < 0.05$; higher depth $\beta = 0.268$, $P < 0.01$). Hypotheses 2a is supported. However, a higher depth and lower scope of knowledge interaction is not related to firm performance in problem solving (lower scope $\beta = -0.107$, $P = 0.285$; higher depth $\beta = 0.245$, $P = 0.179$). Hypothesis 2b is not supported. Hypothesis 2c argues that a higher depth and lower scope of knowledge interaction is related to firm performance in innovation capability (lower scope $\beta = -0.07$, $P = 0.464$; higher depth $\beta = 0.375$, $P = 0.245$). Hypotheses 2c is also not supported.

We found a higher scope and depth of knowledge interaction is associated with firm performance in product innovation (higher scope $\beta = 0.062$, $P < 0.001$; higher depth $\beta = 0.157$, $P < 0.001$). Therefore, Hypothesis 3a is verified. The results also reveal a positive influence of a higher scope and depth of knowledge interaction on firm performance in problem solving (higher scope $\beta = 0.094$, $P < 0.001$; higher depth $\beta = 0.229$, $P < 0.01$). So Hypothesis 3b is verified. A higher scope and depth of knowledge interaction is related to firm performance in innovation capability (higher scope $\beta = 0.052$, $P < 0.001$; higher depth $\beta = 0.113$, $P < 0.01$). Thus, Hypothesis 3c is supported as well.

A lower depth and scope of knowledge interaction is found not related to firm performance in product innovation (lower scope $\beta = 0.126$, $P = 0.595$; lower depth $\beta = 0.238$, $P = 0.213$). Thus, Hypothesis 3a is not supported. Hypothesis 3b argues that a lower depth and scope of knowledge interaction is found not related to firm performance in problem solving (lower scope $\beta = 0.283$, $P = 0.366$; lower depth $\beta = 0.158$, $P = 0.245$). Hypothesis 3b is not supported as well. We found that a lower depth and scope of knowledge interaction is not related to firm performance in innovation capability (lower scope $\beta = 0.115$, $P = 0.151$; lower depth $\beta = 0.225$, $P = 0.838$). Hypothesis 3c is not supported. Table 2 summarized the results.

The results for Hypothesis 5a indicate that the combination of knowledge interaction is significantly related to product innovation ($F = 7.58$, $P < 0.001$). The strength of the knowledge interaction is also significantly related to product innovation ($F = 11.22$, $P < 0.001$). However, the joint effect of the strength of knowledge interaction and the combination of knowledge interaction did not significantly affect product innovation ($F = 1.37$, $P > 0.05$). The relationship between the combination of knowledge interaction and product innovation are not affected by the strength of knowledge interaction (see Table 3).

Table 3. Two-way analysis of variance (ANOVA) of the effect of strength of knowledge interaction* and the combination of knowledge interaction by product innovation

Source of variation	Ss	df	Mean square	*F*	*P*	Post hoc test	Ω2	1-B
Strength of knowledge interaction	6.32	1	6.32	11.22	0.001***			
Combination of knowledge interaction	12.80	3	4.27	7.58	0.000***	III < I III < II III < IV	0.09	0.99
Strength of knowledge Interaction * Combination of knowledge interaction	2.31	3	0.77	1.37	0.252			
Error	266.82	474	0.56					
Total	6010.97	482						

***$P < 0.001$.

Table 4. Two-way analysis of variance (ANOVA) of the effect of strength of knowledge interaction* and the combination of knowledge interaction on problem solving

Source of variation	SS	df	Mean square	*F*	*P*	Post hoc test	ω2	1-β
Strength of knowledge interaction	1.56	1	1.56	3.77	0.05*			
Combination of knowledge interaction	21.26	3	7.09	17.2	0.00***	III < I III < II III < IV	0.13	0.99
Strength of knowledge interaction * Combination of knowledge interaction	1.43	3	0.48	1.15	0.33			
Error	195.51	474	0.41					
Total	7459.85	482						

*$P < 0.05$, ***$P < 0.001$.

The results for Hypothesis 5b demonstrate that the combination of knowledge interaction is significantly related to problem solving ($F = 17.18$, $P < 0.001$). The strength of knowledge interaction is also significantly related to problem solving ($F = 3.77$, $P < 0.05$). However, the joint effect of the strength of knowledge interaction and the combination of knowledge interaction did not significantly affect problem solving ($F = 1.15$, $P > 0.05$). The relationship between the combination of knowledge interaction and problem solving are not affected by the strength of knowledge interaction (see Table 4).

The results for Hypothesis 5c state that the combination of knowledge interaction is significantly related to innovation capability ($F = 25.15$, $P < 0.001$). The strength of knowledge interaction is also significantly related to innovation capability ($F = 10.70$, $P < 0.001$). However, the joint effect of the strength of knowledge interaction and the combination of knowledge interaction did not significantly affect innovation capability ($F = 1.68$, $P > 0.05$). The relationship between the combination of knowledge interaction and innovation capability is not affected by the strength of knowledge interaction (Table 5).

6. Discussion

Different knowledge interaction combinations have different influences on business innovation (Figure 2).

For product innovation, with the exception of the lower scope and lower depth of knowledge interaction, other combinations of knowledge interaction (higher scope and higher depth, higher scope and lower depth, and lower scope and higher depth) have positive effects on business innovation (quadrants I, II, IV). Product innovation means transforming ideas into tangible products and requires the exchange of knowledge, resources, information, and money. Managers may consider diversifying and broadening the scope of knowledge interaction with regard to such things as design concepts, customer demands,

Table 5. Two-way analysis of variance (ANOVA) of the effect of strength of knowledge interaction* on the combination of knowledge interaction by innovation capability

Source of variation	SS	df	Mean Square	*F*	*P*	Post hoc test	ω2	1-β
Strength of knowledge interaction	12.74	1	12.74	25.15	0.000***			
Combination of knowledge interaction	16.26	3	5.42	10.70	0.000***	III < I III < II III < IV	0.14	0.99
Strength of knowledge interaction * Combination of knowledge interaction	2.56	3	0.85	1.68	0.17			
Error	240.05	474	0.51					
Total	6211.62	482						

***$P < 0.001$.

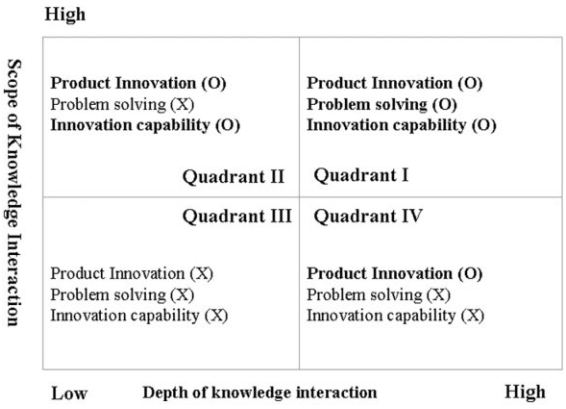

Figure 2. The combination of knowledge interaction and business innovation.Note: 'O' represents the positive effect of the combination of knowledge interaction on business innovation. 'X' represents the negative effect of the combination of knowledge interaction on business innovation.

customer and technological operations, and applications. In the meantime, it is also helpful to increase the degree of the depth of knowledge interaction from basic-level understanding to deep-level discussion about procedural and causal issues.

For problem solving, the results show that only higher scope and higher depth of knowledge interaction can enable efficient problem solving (quadrant II). Customers may have various unexpected problems during the whole product lifecycle. The sales staff need to have enough background understanding of the technological operation and application in order to identify and arrange proper resources for responding to instant requests, while the R&D staff need to have sufficient knowledge and a certain understanding of customer background and operations in order to consolidate knowledge about possible solutions.

Finally, for accumulating innovation capabilities, organizations may require a higher scope and higher depth or higher scope and lower depth of knowledge interaction (quadrant I). Innovation capability means the skills and knowledge needed to effectively absorb, master, and improve existing technologies, and to create new ones (Lall, 1992). Therefore, innovation capabilities need to accumulate knowledge from a wide range of interactions. Meanwhile, a higher scope and depth of knowledge interaction may accelerate innovation capabilities.

Moreover, the strength of knowledge interaction may not affect the influence of the combination of knowledge interaction on business innovation except for the relationship between a lower scope of knowledge interaction and innovation capability. This may indicate that with a lower scope of knowledge interaction, frequent interaction may stimulate innovation capability.

6.1. Contributions

With dynamic analysis of the empirical data, this research captures the subtle interplay between content of knowledge interaction and different types of innovations. Findings on the associations among various patterns of knowledge interaction and different kinds of business innovation add to the knowledge-based view theories (Grant, 1996) that make use of the heterogeneous knowledge for innovation. In particular, with regard to theories of boundary spanning and innovation processes (Marrone et al., 2007), our study stresses that the activities of knowledge combination and creation would need to address the content level and that the management of cross-boundary activities in an innovation system may establish knowledge bases for inspiring ideas for various innovation processes.

Additional findings on the strength of knowledge interaction provides a different view in regard to the general understanding that frequent communication

can lead to high innovation capabilities. It is important to note that the strength of knowledge interaction between customer and technological knowledge does not seem to affect all types of business innovation except for the situation of a lower scope of knowledge interaction. This may provide a situational explanation for the conflicting findings about the frequency of communication directed toward business innovation.

In practice, this finding helps decision makers in allocating resources for developing innovative capabilities for serving customers effectively. The design and management of knowledge interaction between marketing and research groups would require careful control in stimulating innovative results. The functional indicators of scope and levels of customer- and technological-knowledge interaction should be of special interest to managers as an essential reference in planning direct and indirect contacts, guiding cross-departmental interactions, organizing communication events, and planning training and educational programs to satisfy customers in different business situations. The building of a solid and useful interorganizational knowledge base will involve verifying the scope and depth of all forms of knowledge interaction, including forums, meetings, conferences, chat rooms, knowledge tanks, or any event of direct and indirect contact across the two major groups of an organization – sales and R&D. Business managers may consider leveraging all communication opportunities and carefully planning the interaction content between these two departments to increase the effectiveness of knowledge interaction for various kinds of innovative activities.

6.2. Limitations and future research

Although our research has reached its aims, we are aware of its limitations in research design and data collection. First, we used survey data collected from CEOs of high-tech companies whom we felt had good knowledge of the R&D and sales departments, as well as their firms' innovation situations. However, they may not have had a complete view of the details of knowledge interaction. Future researchers might apply temporal or methodological separation of the measurement (Podsakoff et al., 2003) of knowledge quality to collect data from the heads of the R&D and sales departments, respectively, so as to build a complete view of the scope and depth of the knowledge interaction.

The next limitation of our study is generalizability, which is limited by our focus on high-tech companies. It would be worthwhile to focus on different industries that may have diverse industrial characteristics, customer demands, and technological trends. The effects of scope and depth of knowledge interaction on innovation may result in different patterns.

7. Conclusion

What are the effects of intraorganizational knowledge interaction on various kinds of business innovation? Our answer is that different forms knowledge interaction between major knowledge carriers can affect innovative results in different customer situations. Product innovation requires both wide-ranging and deep interaction between customers and technological knowledge and problem-solving innovation requires either wide-ranging or deeper interaction between customers and technological knowledge, whereas wide-ranging knowledge interaction is the most important driver for building general innovation capability. The findings reveal a thorough interpretation of the rather obscure changes among different innovative contexts. This study helps to address the practical matter of knowledge management and business innovation within an organizational setting. Research on knowledge management for business innovation should shift focus from a general level of communication to a detailed level of interacted content knowledge and classify the innovative results based on the contextual status of customer encounters.

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