The Diversity Effects of Knowledge Sourcing Strategies on Firm Performance: A Complementarity Theory

Completed Research Paper

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Abstract

The complementarity theory suggests that organizations need to adopt synergistically multiple ways of knowledge sourcing in leveraging the strategic value of organizational knowledge. We take a diversity perspective in which firms simultaneously employ multiple knowledge sourcing strategies (KSSs) for competitive advantages. Based on knowledge-based view of the firm, knowledge sourcing scope and type define four individual KSSs: internal knowledge codification, internal knowledge personalization, external knowledge codification, and external knowledge personalization strategies. Then, we classify four distinct knowledge sourcing diversities based on Rumelt's diversity model, and hypothesize their effects on firm performance to identify complementarities and substitutabilities among combined KSSs. Supermodularity tests with 152 firm-level data provide empirical evidence on the complementarities and substitutabilities from a diversity viewpoint. This study might be an initial theoretical attempt to explain joint KSS effects on firm performance with practical implications, thus contributing to a complementarity theory in the strategic knowledge management context.

Keywords: Knowledge sourcing strategy, knowledge sourcing diversity, related knowledge sourcing diversities, unrelated knowledge sourcing diversities, complementarity theory, firm performance
Introduction

Organizational knowledge is widely recognized as an essential strategic resource for firms to create and sustain their competitive advantage in the current knowledge-oriented economy. The growing importance of knowledge as a critical resource encourages organizations not only to pursue knowledge management (KM) initiatives but also to make significant investments. For example, the top consulting firms in the United States spend between 6% and 10% of their revenues in their efforts to manage their knowledge (Dunford 2000). In addition, total spending on knowledge service of the World Bank is approximately $4 billion per year (Denning 2012). According to the Gartner, CFOs believed that KM was the third important business process area that required investment (Van Decker 2013). Knowledge sourcing is considered as the first important step in effective KM (Chen and Lin 2004), thus it makes sense to ask how to manage various knowledge sources effectively to maximize benefits of KM. Diversifying knowledge sources has been investigated to answer this question as safety lies in numbers and in variety of attack (Jewkes et al. 1958; Leiponen and Helfat 2010). In particular, KM literature has devoted substantial attention to the effect of knowledge sourcing diversity (KSD) on firm performance. Knowledge sourcing strategy (KSS) is defined as a logical pattern regarding decisions of firms on knowledge sourcing scope and knowledge sourcing type to gain a sustainable competitive advantage (Choi and Lee 2012), while KSD refers to the degree of variance in KSS that is composed of knowledge sourcing scope and type. Knowledge sourcing scope is decided on whether knowledge originates from within or outside the firm (Menon and Pfeffer 2003; Mitchell 2006), while knowledge sourcing type refers to the degree to which knowledge is accessed through a person or a system (Hansen et al. 1999; Leiponen 2006).

Although substantial theoretical and empirical research has been made, a common understanding of the effect of KSD on firm performance has not been reached yet. Some studies have shown that KSD can be a hindrance for firm performance (De Luca and Atuahene-Gima 2007; Galunic and Rodan 1998) whereas others have suggested that firm performance could be improved by increasing KSD (Katila and Ahuja 2002; Van de Vrande 2013). Studies belongs to the latter can be further classified from the perspective of related and unrelated diversities. Related diversity in knowledge sourcing context refers to diversification of KSSs based on firm’s current main knowledge sources, while unrelated diversity refers to diversification of KSSs by using different knowledge sources from firm’s current ones. Some scholars have argued that related diversity generates greater performance benefits than unrelated diversity (Markides and Williamson 1994; Palich et al. 2000; Rumelt 1982). The other researchers have suggested that diversity based on very high degree of relatedness can lead to lower performance (Gary 2005; Jiang et al. 2010). The conflict might be compromised by empirical evidence identifying what specific patterns for related and unrelated diversities generate firm performance gains or losses.

Even though these studies have expanded our understanding of the relationship between diversity and performance, we could find several gaps to fill in explaining the relationship. First, the prior studies investigate the product- or market-oriented diversity effects, thus missing the underlying knowledge-oriented effects, the roots of sustainable competitive advantage (Lin et al. 2006). Relatedness in product or market domains does not necessarily imply relatedness in underlying knowledge domains (Makri et al. 2010). Second, even though a firm’s KSS and its complementary resource should be considered as an integrated whole, knowledge sourcing scope and type have been considered as a separated dimension (Capron and Mitchell 2009; Cassiman and Veugelers 2006). Since synergy created by the two dimensions of KSS might be a major source of competitive advantage, it is clearly necessary to investigate the synergistic effect of KSSs on firm performance by considering different knowledge sourcing dimensions together. Third, the concept of relatedness, which is important to understand the effect of diversity on performance, has not been clearly defined in prior studies. Although similarity and complementarity are different, relatedness has commonly been defined in broad terms, often using similarity and complementarity interchangeably (Farjoun 1998; Makri et al. 2010). Similarity in the context of KSD is the extent to which a firm has a high degree of overlap in its knowledge source, whereas complementarity in knowledge sources occurs when one knowledge source with another increases the marginal return from that source (Milgrom and Roberts 1995). Finally, methods to measure relatedness of diversity have also been surprisingly imprecise (Gary 2005; Neffke and Henning 2013). The performance effects of related or unrelated diversity remain unclear due to differing diversity measures (Lin et al. 2006).

In order to fill these gaps, this study investigates how KSD affects firm performance measured by Tobin’s
The Diversity Effects of Knowledge Sourcing Strategies

$q$ ratios: a market-based measure oriented towards the future revenue generation potential and associated risks (Bharadwaj et al. 1999). More specifically, we attempt to contribute to knowledge sourcing research by answering the question as what patterns of KSDs enhance firm performance. For this purpose, four individual KSSs are first defined using two knowledge sourcing dimensions, knowledge sourcing scope and type. Then, we theoretically explore the positive or negative synergistic effect of KSD on firm performance based on complementarity theory (Milgrom and Roberts 1995) and Rumelt's diversity\(^1\) categories. The complementarity approach can be conceptualized in terms of the notion of synergy, which holds that the valuation of a combination of agents (or forces) exceeds the sum of valuations for stand-alone agents (or forces) (Barua et al. 1996; Massini and Pettigrew 2003). Thus, the complementarity approach helps properly define and measure relatedness between scope and type aspects of knowledge sourcing. Furthermore, Rumelt's categories have widely used in business diversity strategy to explore the relationship between diversity and performance. By adopting the categories, this study determines to which patterns of KSDs can be considered either related or unrelated.

For empirical analysis, this study analyses 152 cross-industry firms in South Korea, each organization which shows different degrees of KSD. According to a survey by the Korean Chamber of Commerce in 2007, 92.8% of Korean companies consider KM as an indispensable and key ingredient to pursue their success. Moreover, executives of Korean firms emphasized managing knowledge sourcing scope (31.5%) and type (35.1%) as the most critical factor of successful KM. From this statistical evidence, we suppose that most executives of Korean organizations recognize a firm’s success with KM as a core capability for competitive advantages and that South Korea is an appropriate place to gather firm-level data from a cross-industry for an empirical study in KSD. Findings from this study might explain the fit and misfit among knowledge sources with the improvement of firm performance.

Theoretical Background

Two Aspects of Knowledge Sourcing Diversity

Knowledge sourcing scope and type have been considered as two key aspects of firms' strategic effort to manage knowledge sources. This two-dimensional KSS typology is supported by knowledge-based view (KBV) of the firm, which suggests that the strategic ways need to be beneficial in both aspects of how to accumulate organizational knowledge (knowledge flow) and how to regulate the accumulated knowledge (knowledge stock) (DeCarolis and Deeds 1999; Dierickx and Cool 1989). The literature of organizational change also emphasizes simultaneous consideration of two dimensions: the content of the change (what changes) and the process (how these changes occur) (Barnett and Carroll 1995; O'Reilly and Tushman 2008). The KBV has identified two different knowledge sourcing approaches based on the knowledge sourcing scope aspect: internal sourcing and external sourcing (Bierly and Chakrabarti 1996; Menon and Pfeffer 2003). Internal sourcing encourages integrating knowledge within the boundary of the firm, thus providing with firm-specific competences (De Clercq and Dimov 2008; Kessler et al. 2000). On the other hand, external sourcing brings knowledge in from outside sources via either acquisition or imitation, and then to transfer that knowledge across the organization (Bierly and Daly 2007; Prabhu et al. 2005). In addition, the KBV literature has recognized two different knowledge sourcing approaches based on the knowledge sourcing type aspect. Firms can accumulate their knowledge through system-oriented codification or person-oriented personalization (Choi and Lee 2012; Hansen et al. 1999; Santoro and Bierly 2006). Concretely, codified knowledge can be managed by using information technologies, such as KM systems (Kankanhalli et al. 2003), through system-oriented learning (Haas and Hansen 2005), non-relational learning (Rulke et al. 2000), and published sourcing (Gray and Meister 2006) whereas personalized knowledge can be generated through person-oriented learning (Santoro and Bierly 2006), relational learning (Rulke et al. 2000), and dyadic sourcing (Gray and Meister 2006).

We propose a two-by-two framework to define individual KSSs according to both knowledge sourcing scope (internal versus external sourcing) and type (system versus person orientation). Organizations can internally regulate the flow of their knowledge by sharing it within their boundaries (De Clercq and Dimov 2008). Meanwhile, organizational knowledge can be externally circulated and captured beyond their

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\(^1\) Diversification and diversity have used interchangeably in many studies. However, several studies have made a distinction between diversity as a static concept and diversification as a process (Grant et al. 1988; Hall and St. John 1994). Thus, we will use the term diversity instead of diversification throughout the paper because our empirical study is cross-sectional.
boundaries (Grant and Baden-Fuller 2004). With KM systems and information technologies, codifying knowledge enables organizational members to reuse the captured and documented knowledge, thus improving organizational efficiencies (Hansen et al. 1999). According to the personalization approach, socialization of organizational knowledge can be achieved through person-to-person contacts (Haas and Hansen 2005). The two aspects of KSSs mutually interact with each other (Choi and Lee 2012). That is, codifying knowledge which is externally circulated (external person-to-system) requires different strategic activities and generates different advantages from codifying knowledge which is internally regulated (internal person-to-system) and personalizing knowledge which is internally regulated (internal person-to-person) as well as personalizing knowledge which externally circulated (external person-to-person). In this way, this study suggests that the particular characteristics and advantages of each KSS depend on the composition of knowledge sourcing scope and type. This conceptualization leads to a parsimonious typology of four different types of individual KSS, as shown in Figure 1: an internal knowledge codification strategy (IKCS), an internal knowledge personalization strategy (IKPS), an external knowledge codification strategy (EKCS), and an external knowledge personalization strategy (EKPS).

![Figure 1. Typology of Knowledge Sourcing Strategies](image)

**Complementarity Among Knowledge Sourcing Strategies**

The notion of complementarity was first introduced by Edgeworth (1881). It has been developed and enhanced by Milgrom and Roberts (1995) to better explain the revolutionary changes in modern manufacturing which involved changes in technological production and organizational strategy. Complementarities between activities can be defined as existing if and only if increasing the level of any one activity leads to higher marginal return from increasing the level of the other (Milgrom and Roberts 1995). Therefore, a joint implementation of several activities may result in better outcomes. By the same token, increasing the level of any one activity can decrease the marginal or incremental return to other activities. This is the case of substitutability (Carree et al. 2011). Complementarities correspond to positive mixed partial derivatives of some payoff functions, which indicates that marginal returns to one variable are increasing in the level of another variable (Massini and Pettigrew 2003). Complementarities provides a fundamental understanding of notion such as “synergy,” “fit,” “congruency,” “interconnectedness,” and “consistency” (Ennen and Richter 2010; Porter 1996; Whittington et al. 1999). That is, it gives a way to capture the intuitive of synergies and systems effects (Mohnen and Röller 2005). The concept of complementarity offers a useful perspective to study the complex relationships among a set of organizational variables like KSSs as they impact on firm performance. Furthermore, the theory takes a holistic view of organizational variables and proposes that high performance firms are likely to be bundling of organizational variables at the same time. Thus, many knowledge sourcing studies have used the concept of complementarities to study KSS and its diversity to provide insights into how each KSS plays a role in enhancing or hindering firm performance with other strategies.
However, complementarity has not been properly addressed in previous literature on knowledge sourcing. First, few studies have investigated potential complementarities and substitutabilities between knowledge sourcing scope and type (DeCarolis and Deeds 1999; Dierickx and Cool 1989). Previous studies that have dealt with the synergistic impacts of KSSs on firm performance have focused primarily on the complementarities and substitutabilities within either knowledge sourcing scope or type rather than those between them. However, the ability of the firm to achieve superior performance is a function of the flow of selected valuable knowledge across its boundary (Dierickx and Cool 1989). To understand this function, it is imperative to investigate the relationship between knowledge sourcing scope (the flow of knowledge) and type (the selection of appropriated knowledge) aspects. Second, no previous study has assessed complementarity and substitutability with all possible combinations of KSSs from a diversity viewpoint. Some studies, which have considered the four strategies (Kyriakopoulos and de Ruyter 2004; Teigland and Wasko 2003; Zahra and Nielsen 2002), simply estimated pair-wise interaction effects, thus ignoring all the possible interactions among strategies. Although Choi and Lee (2012) examined complementarity between knowledge sourcing type and origin based on product function approach developed by Belderbos et al. (2006), they did not consider the all four KSSs simultaneously from a diversity perspective. Furthermore, they used discrete variable to measure KSSs so that the precision of estimates might be low.

**Diversity and Complementarity**

The concept of synergy is central to the performance of firms with diverse business portfolios (Tanriverdi and Venkatraman 2005) in the management literature. The synergy created by the business portfolios is assumed to be a source of competitive advantage of firms (Lin et al. 2006; Lubatkin and Chatterjee 1994). Prior studies have investigated how diversity efforts firms undertook facilitate synergy between business portfolios, thus leading to better performance (Bettis 1981; Gary 2005; Markides and Williamson 1994). According to resource-based view (RBV) of the firm, organizations diversify their activities to fully utilize their underleveraged resources (Neffke and Henning 2013). Thus, RBV assumes that resource-related diversity generates benefits than unrelated diversity (Lecraw 1984; Varadarajan and Ramanujam 1987).

For example, as the first large-sample study of the relationship between diversity and firm performance, Rumelt (1982) found that related diversity was more profitable than unrelated diversity. He classified diversity into four categories: single business, dominant business, related business, and unrelated business. Related business means any firm deriving less than 70% of its sales from a single business and possessing a high relatedness ratio (Rumelt 1982). Related firms are divided into two sub-classifications: related constrained and related linked. The former indicates any related firm which is diversified by building on a single strength or resource associated with the original business, while the latter means any related firm which is diversified on the basis of one of several strengths or resources. Related constrained firms that are diversified around some single core resource associated with a business are diversified in a highly related and constrained manner (Michel and Hambrick 1992). Related linked firms diversify their business by combining new business to one of several resource associated with a business, which means that every business are not directly related to one other business in the firm. Unrelated business is any firm deriving less than 70% of its sales from a single business and possessing lower relatedness ratios (Rumelt 1982). Unrelated firms can be categorized into two sub-classifications: multi-business and unrelated-portfolio. The former refers to any unrelated firm containing a few large unrelated businesses whereas the latter is any unrelated firm containing multiple unrelated businesses (Grant and Jammime 1988; Rumelt 1974). Diversifying activities of multi-business firms have little direct bearing on each others. Unrelated-portfolio firms diversify business without regard to relationships between current business and new business, leading to their unintended relationships (Michel and Hambrick 1992; Nayyar 1992).

However, the performance effects of diversity remain unclear despite of substantial body of prior empirical studies. Although the logic of the relationship between diversity and performance is attractive, massive prior empirical studies have found no significant relationship between diversity and firm performance (Gary 2005; Grant et al. 1988). This contractive results might be due to industry effects (Bettis 1981; Christensen and Montgomery 1981), prior performance (Hill et al. 1992; Montgomery 1985), and different relatedness measure (Hoskisson et al. 1993; Lubatkin et al. 1993). In particular, defining and measuring relatedness are subject to several theoretical and methodological problems. Theoretically, most previous studies exploring the relatedness focus on product or market domains even though a firm should

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2 Since the main purpose of this study is the synergistic effects of KSSs, we exclude single and dominant categories.
be perceived as a collection of knowledge competences and assets (Lin et al. 2006; Makri et al. 2010). Furthermore, they treat individual dimension of synergies as independent and assess their performance effects separately, leading to inconsistent conclusions on the performance effects of synergies (Tanriverdi and Venkatraman 2005). Methodologically, relatedness measurement has been developed on the basis of resource similarities, which cannot capture the idea that the added value of one resource depends on the use of other resources (Milgrom and Roberts 1995; Stieglitz and Heine 2007).

To fill these existing gaps of prior studies on diversity, this study investigates diversity effects from a knowledge perspective by focusing on diversity of KSSs. In addition, we directly measure relatedness of KSSs to capture their synergistic effects by employing a complementarity testing method developed by Carree et al. (2011). This study helps researchers examine the impact of KSDs on firm performance from a holistic perspective by using continuous measures. Moreover, the study allows managers to achieve a deeper understanding of how to diversify KSSs successfully by considering the complementarities and substitutabilities between knowledge sourcing types and origins.

**Development of Hypotheses**

**Diversity Classification of Knowledge Sourcing Strategies**

The synergy is the central concept of nearly four decades diversity research. The most widely accepted source of synergy in firms is the resource relatedness of business (Tanriverdi and Venkatraman 2005). By the same token, synergy arising from knowledge sourcing relatedness between KSSs is central to the performance of firms. Based on resource relatedness (Davis and Thomas 1993) and knowledge relatedness definitions (Tanriverdi and Venkatraman 2005), this study defines KSS relatedness as the extent to which a firm adopts similar KSSs from the knowledge sourcing scope, knowledge sourcing type, or both aspects. The relatedness among KSSs is a necessary but not a sufficient condition to increase firm performance (Karim and Kaul 2013; Robins and Wiersema 2003; Tanriverdi and Venkatraman 2005). To investigate the synergic effects of KSSs relatedness, this study conceptualizes the patterns of KSDs by adapting Rumelt’s classification with consideration of knowledge sourcing context. Rumelt’s diversity categorization has been played as a fundamental underlying framework for empirical studies of diversity strategies (Grant and Jammie 1988). In addition, the categorization have been validated by many follow-up studies including those that measured diversity using continuous scale such as level or amount of diversity (Montgomery 1982; Palich et al. 2000).

In the context of knowledge sourcing, related KSDs refer to combinations between strategies that have a higher level in a single KSS and a higher level of other KSSs in the same dimension (either sourcing scope or sourcing type). That is, related KSDs have a higher level in a single KSS and where diversity efforts have been made by adopting new KSS in the same dimension. The diversities are divided into two sub-classifications: *related constrained* and *related linked*. Related constrained KSDs refer to any related sourcing patterns which are diversified by combining a new higher level of KSS from the same knowledge sourcing dimensions to the higher level of already implemented single KSS. Since firms diversified their knowledge sourcing activities around single KSS within the same sourcing dimension in related constrained KSDs, KSSs are diversified in a related, highly constrained manner. For example, if a firm that already implemented higher level of IKCS adopts IKPS, this study classifies the combination as a related constrained KSD because both IKCs and IKPS come from internal regulation, one dimension of knowledge sourcing scope. By the same token, simultaneous adoption of higher level of IKCS and EKCS is classified as related constrained as both IKCS and EKCS come from system orientation, one dimension of knowledge sourcing type. In this category, all KSDs are directly related to the base sourcing strategy (an implemented high level KSS).

On the other hand, related linked KSDs refers to any related sourcing patterns which are diversified by combining new higher level of KSSs from the same knowledge sourcing dimensions to the higher level of already implemented several KSSs. Firms that take related linked KSD diversify their KSSs by combing new KSS to one of several core KSSs. For example, if a firm that already implemented higher level of IKCS and IKPS adopts EKCS, this study classifies this combination as a related linked KSD because the KSDs attempt to diversify by adopting EKCS on the basis of several existing well implemented KSSs, such as IKCS and IKPS. The related linked KSDs create related KSDs (e.g., the combination of IKCS and EKCS) as well as unrelated KSDs (e.g., the combination of IKPS and EKCS). Similarly, the combination of IKCS,
IKPS, and EKPS is classified as a related linked KSD. Thus, all KSDs are not directly associated with the base sourcing strategy.

Unrelated KSDs refer to the combinations between strategies that have a higher level in a single KSS and a higher level of other KSSs in different dimensions. That is, unrelated KSDs have a higher level in a single KSS and where diversity efforts have been made by adopting new KSS from different dimensions. The portfolios can be categorized into two sub-classifications: unrelated multiple and unrelated-portfolio. Unrelated multiple refers to any unrelated KSDs containing two unrelated KSDs which come from different dimensions. Thus, KSSs are diversified with little direct bearing on each other. For example, the combination of IKCS and EKPS consists of two unrelated KSDs. The combination of IKPS and EKCS is also made up of strategies coming from two different dimensions. Unrelated-portfolio refers to any unrelated KSDs containing all the four KSSs which come from different dimensions. Firms that take unrelated-portfolio diversify KSSs but in such a way that every KSS has some unintended relationship to one other KSS from different dimensions. For example, the combination of IKCS, IKPS, EKCS, and EKPS includes all the four unrelated strategies, such as IKCS and EKPS, and IKPS and EKCS. All in all, relatedness-based KSD classification is summarized in Table 1.

### Table 1. Relatedness Classification of Knowledge Sourcing Diversities

<table>
<thead>
<tr>
<th>KSS Scope</th>
<th>Internally Regulated</th>
<th>Externally Circulated</th>
<th>Pattern of Knowledge Sourcing Diversities</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>KSS Type</td>
<td>System-Oriented</td>
<td>Person-Oriented</td>
<td>System-Oriented</td>
<td>Person-Oriented</td>
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<tr>
<td></td>
<td>IKCS</td>
<td>IKPS</td>
<td>EKCS</td>
<td>EKPS</td>
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<tr>
<td>Firm-Level KSSs</td>
<td>High</td>
<td>Low</td>
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<td>High</td>
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<td></td>
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<td>High</td>
<td>High</td>
<td>Related Constrained</td>
<td>H1</td>
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<td></td>
<td>Low</td>
<td>Low</td>
<td>Related Multiple</td>
<td>H2</td>
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<td></td>
<td>High</td>
<td>High</td>
<td>Related Linked</td>
<td>H3</td>
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<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Unrelated Portfolio</td>
<td>H4</td>
</tr>
</tbody>
</table>


### Related Constrained Hypothesis

The extant literature has asserted that related diversity positively affected firm performance via economics of scope (Hill et al. 1992; Porter 1987). Furthermore, related constrained diversity was associated with the highest profitability (Bettis 1981; Christensen and Montgomery 1981; Rumelt 1982) owing primarily resource allocations. This relationship between related constrained diversity and performance can be applied to understanding the effect of related constrained KSDs on firm performance.

The efforts of a firm to adopt related constrained KSDs may improve firm performance through economics of scope within the same knowledge sourcing dimension. From the knowledge type perspective, combining system-oriented sourcing strategies with person-oriented sourcing strategies regardless of firm’s boundaries will generate more value than the value generated by using the strategies in isolation. For example, the IKPS can provide new meanings, interpretations, or linkages among existing internal codified knowledge based on the firm-specific skills and experiences of internal personnel (Moorman and Miner 1998). Furthermore, loss of internal personnel knowledge can be protected by capturing, sharing, and applying through information systems within the firm. In addition, the EKPS helps a firm to remain open to multiple viewpoints (Kyriakopoulos and de Ruyter 2004), which enables a firm to interpret, understand, and apply codified external knowledge more diversely, providing a means of overcoming barriers to developing new knowledge and capabilities (Capron and Mitchell 2009).

From knowledge sourcing scope perspective, combining internal-oriented sourcing strategies with external-oriented sourcing strategies regardless of firm’s knowledge sourcing type will provide greater performance than the performance generated by adopting the strategies in isolation. For example, IKCS could be enhanced by combining it with EKCS because the speed with which a firm can value, assimilate, and apply externally system-oriented knowledge depends on its internal knowledge level (Cohen and Levinthal 1990). In addition, IKPS can enable a firm to create new and unique knowledge when it is combined with new external personnel knowledge because EKPS helps internal members perceive things differently and add to the breadth of knowledge considered by internal members in their choice sets.
That is, diversities by combining a new higher level of KSS from the same knowledge sourcing dimensions to the higher level of already implemented single KSS will improve firm performance. This leads to the following hypothesis:

**H1:** Related constrained KSDs will have complementary effects on firm performance.

### Unrelated Multiple Hypothesis

Many studies have argued that unrelated diversity was negatively related to firm performance (Christensen and Montgomery 1981; Grant et al. 1988). Particularly, unrelated multiple diversity was reported to show lower performance (Rumelt 1982). The effect of unrelated multiple KSDs on firm performance would be similar with the relationship between unrelated diversity and firm performance. Unrelated multiple KSDs may cause firm performance to deteriorate because these KSDs decreases the possibilities to recombine two different knowledge into new knowledge (Fleming 2001; Van de Vrande 2013). Adopting two KSSs from different knowledge sourcing dimensions hinders economics of scope between knowledge. For example, organizational members depend heavily on decontextualized and encoded knowledge in routines. This leads to the loss of ambiguity (Brown and Duguid 2001), resulting in outgoing knowledge spillovers and the erosion of the performance advantage of a firm (Gopalakrishnan and Bierly 2006). This problem may be exacerbated when a firm uses EKPS together. Knowledge from external personnel (e.g., external experts or consultants) is largely tacit in nature because it is tightly embedded in external individuals (Hoang and Rothaermel 2010; Leiponen 2006). It is generally difficult to understand and interpret knowledge from these sources, causing its frequent misapplications (Bierly and Chakrabarti 1996). This problem is also exacerbated when the firm lacks expertise in that knowledge because it focuses on decontextualized and encoded knowledge (Kessler et al. 2000; Pissarides 1999).

In addition, because external codified knowledge sourced through EKCS is usually not firm specific, internal members are reluctant to consider it as core knowledge base. Although a firm should spend time and effort to source external codified knowledge, it cannot provide a competitive advantage to the firm (Kessler et al. 2000). Therefore, contribution of IKPS to firm performance could be decreased when the firm uses it with EKCS which is not a rich source enough for internet members to truly learn about best practices in the field or to improve their capabilities (Rulke et al. 2000). That is, diversities by combining a new higher level of KSS from the same knowledge sourcing dimensions to the higher level of already implemented single KSS will decrease firm performance. This leads into the following hypothesis:

**H2:** Unrelated multiple KSDs will have substitutable effects on firm performance.

### Related Linked Hypothesis

Firms with related linked KSDs attempt to diversify their knowledge sourcing activities by adopting a new KSS and to combine it with one of KSSs which is a part of existing complementary KSDs. That is, related linked KSDs can be implemented with existing complementary KSDs. Such diversity inevitably entails both complementary and substitutable relationships between existing KSSs and new KSSs. For example, if a firm that is already implemented higher level of IKCS and IKPS adopts EKCS, this combination creates another complementary relationship (IKCS and EKCS) as well as substitutable relationship (IKPS and EKCS). Since a firm adopts new KSSs to improve its performance, they carefully implement new KSSs and try to build complementary relationships with existing KSS within same knowledge sourcing dimension even though substitutable relationship is inevitable. Furthermore, related linked KSDs help a firm save coordination costs by allowing a firm to diversify into a highly related KSS (complementary relationship) but not integrate it with existing KSSs (substitutable relationship). Therefore, the benefits arising due to two complementarities outweigh the cost arising due to substitutability. That is, diversities by combining a new higher level of KSS from the same knowledge sourcing dimensions to the higher level of already implemented several KSSs will improve firm performance. This leads to the following hypothesis:

**H3:** Related linked KSDs will have complementary effects on firm performance.

### Unrelated-Portfolio Hypothesis

As defined, unrelated-portfolio refers to any unrelated KSDs containing all the four KSSs which come from different dimensions. The four KSSs come from different dimensions can hurt firm performance

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because they increase the organizational costs of processing and communicating knowledge. It indicates that using all the four KSSs from different dimensions simultaneously increases the organizational costs of processing and communicating knowledge because coordination and communication efforts to access and acquire knowledge are dispersed on different knowledge sources (Belderbos et al. 2006; Katila and Ahuja 2002). For example, coordination costs are believed to be higher when EKPS is integrated with a firm’s IKCS (Kessler et al. 2000; Pissarides 1999). Furthermore, benefits from a broad set of sources regardless of related or unrelated may be more difficult to realize. Knowledge sourcing from others can entail significant costs as knowledge is a valuable resource (Leiponen and Helfat 2010; Schulz 2001). Once the related and unrelated knowledge sources are in place, managing these simultaneously can be very challenging owing to the natural comparisons, suspicions, and shirking that can occur among these sources (Parmigiani 2007). This is supported by the organizational strategy literature suggesting that implementing multiple strategies simultaneously causes an organization to become “stuck in the middle” or to be mediocre at all the given strategies due to its constrained costs and resources (Porter 1980). Related studies provide empirical evidence that organizations with focused strategies perform better than ones that pursue multiple strategic practices (e.g., Anand and Singh 1997; Ebben and Johnson 2005; Knott and Posen 2005). The KM literature suggests that an organization can be more viable by achieving a balance between exploitation and exploration in which the organization alternates temporal cycles of the two learning approaches rather than simultaneously pursuing both modes (Burgelman 2002). In the same vein, diversities by combining new higher level of all the four KSSs from different knowledge sourcing dimensions to the higher level of already implemented several KSSs will decrease firm performance. This leads to the following hypothesis:

**H4:** Unrelated-portfolio KSDs will have substitutable effects on firm performance.

### Research Methodology

#### Sample Characteristics

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>Number of Employees</th>
<th>Freq.</th>
<th>%</th>
<th>Less than 10</th>
<th>11-20</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>51-100</th>
<th>1001 and above</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 50</td>
<td>19</td>
<td>12.5</td>
<td></td>
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<td></td>
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<td></td>
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<td>12.5</td>
</tr>
<tr>
<td>51-100</td>
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<td>3.3</td>
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<tr>
<td>101-500</td>
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<td>17.1</td>
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<td>17.1</td>
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<td>501-1,000</td>
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<td>10.5</td>
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<td>10.5</td>
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<td>1,001-5,000</td>
<td>52</td>
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<tr>
<td>10,001 and above</td>
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<td>13.8</td>
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<td></td>
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<td></td>
<td></td>
<td>13.8</td>
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<tr>
<td>Total</td>
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<table>
<thead>
<tr>
<th>Firm Age</th>
<th>Number of Years of Existence</th>
<th>Freq.</th>
<th>%</th>
<th>Less than 10</th>
<th>11-20</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>51-100</th>
<th>1001 and above</th>
<th>Total</th>
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<tr>
<td>Less than 10</td>
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<td>11-20</td>
<td>23</td>
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<td>15.1</td>
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<td>21-30</td>
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<td></td>
<td></td>
<td>13.2</td>
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<td>31-40</td>
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<td>18.4</td>
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<tr>
<td>41-50</td>
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<td>17.8</td>
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<td></td>
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<td>17.8</td>
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<tr>
<td>51-100</td>
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<td>16.4</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>100.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industry</th>
<th>Knowledge Intensity</th>
<th>Freq.</th>
<th>%</th>
<th>Low Knowledge Intensive</th>
<th>Manufacturing</th>
<th>Finance/Banking</th>
<th>Service</th>
<th>High Knowledge Intensive</th>
<th>Manufacturing</th>
<th>Finance/Banking</th>
<th>Service</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>152</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100.0</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Measures</th>
<th>Items</th>
<th>Freq.</th>
<th>%</th>
<th>Measures</th>
<th>Items</th>
<th>Freq.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Low: Staff</td>
<td>223</td>
<td>45.5</td>
<td>Industrial Tenure</td>
<td>Less than 5 years</td>
<td>297</td>
<td>46.0</td>
</tr>
<tr>
<td></td>
<td>Middle: Chief and Head</td>
<td>139</td>
<td>27.7</td>
<td></td>
<td>6-10 years</td>
<td>274</td>
<td>26.9</td>
</tr>
<tr>
<td></td>
<td>High: Manager</td>
<td>125</td>
<td>19.3</td>
<td></td>
<td>11-15 years</td>
<td>174</td>
<td>14.9</td>
</tr>
<tr>
<td></td>
<td>Others: Expert and Researcher</td>
<td>46</td>
<td>7.1</td>
<td></td>
<td>16-20 years</td>
<td>96</td>
<td>14.9</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>553</td>
<td>96.0</td>
<td></td>
<td>21 years and above</td>
<td>57</td>
<td>8.8</td>
</tr>
<tr>
<td>Age</td>
<td>Twenties</td>
<td>251</td>
<td>48.9</td>
<td>Organizational Tenure</td>
<td>Less than 5 years</td>
<td>412</td>
<td>63.0</td>
</tr>
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<td>Thirties</td>
<td>303</td>
<td>57.9</td>
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<td>6-10 years</td>
<td>143</td>
<td>22.1</td>
</tr>
<tr>
<td></td>
<td>Forties</td>
<td>82</td>
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<td>11-15 years</td>
<td>44</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>Fifties and above</td>
<td>10</td>
<td>1.9</td>
<td></td>
<td>16-20 years</td>
<td>34</td>
<td>5.3</td>
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<td>Total</td>
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<td>100.0</td>
<td></td>
<td>21 years and above</td>
<td>13</td>
<td>2.0</td>
</tr>
</tbody>
</table>

To enhance the representativeness of our study sample and the generalizability of results, we selected Korean firms, whose industrial composition is proportional to that in South Korea, based on the 9 edition of the Korean Standard Industrial Classification (Statistics Korea, 2008). We could use the final 646 questionnaires from 152 firms for hypothesis testing; we filtered out responses in the firms that included missing values or failed to meet within-agreement criteria including \( r_{wg} \) (James et al. 1993), \( \eta^2 \), intraclass correlation coefficients: i.e., ICC(1) and ICC(2). We calculated all of these indices, because each index has its own strengths and weaknesses and there is no one best measure for within-agreement (Klein and Kozlowski 2000). The availability of descriptive statistics of firm-level data was confirmed as a result of interrater reliability tests with \( r_{wg} \) and ICC(1) and ICC(2). As we found no significant differences in the
ratings of the study variables across respondents’ ranks, age, gender, years in the industry, and organizational tenure, all the final data were pooled for analyses. Table 2 presents the details of the sample firms and the demographic information of their respondents.

**Measurement**

Prior to the main survey administration, a pilot test was conducted to examine the reliability and validity of the measures adapted from previous studies. The 56 participants of the pilot test were graduate students in Master of Business Administration programs at two top-tier universities in South Korea and had worked in business organizations for at least three years. Results of the pilot test supported the measures used for testing the research hypotheses. The four KSS measures were assessed on a seven-point response scale ranging from “strongly disagree” to “strongly agree.” The structure of all survey measures used in this study is shown in Appendix. In addition, we used a set of public fact data from the 152 firms’ 4-year financial statements and records in Korean stock markets to measure their recent 4-year financial performance, Tobin’s q ratios, as well as their organization- and industry-level characteristics. The inter-correlations, means, and standard deviations of all the variables are presented in Table 3.

Single-item measures of the four KSS types were developed by combining a pair of individual approaches towards knowledge sourcing scope and type, as shown in Appendix. To help respondents clearly understand each KSS before rating on the measures, we provided in-depth explanations and examples of how organizational knowledge is internally regulated or externally circulated (knowledge sourcing scope) and is accumulated through system or human network (knowledge sourcing type). This explanation was followed by a Q&A session to further ensure the respondents’ accurate understanding of all the KSSs. Additionally, in the survey questionnaire, we presented the four single-item measures of KSSs in parallel to help respondents more easily differentiate one KSS from the others and compare among them. This presentation of KSS measures in the survey is recommended to assist respondents to determine the relative dominance of certain KSSs to the others in a firm (Jordan and Turner 2008). Using single-item measures of the four KSSs seems acceptable given the procedures and survey design (Sackett and Larson 1990). Table 4 shows that our firm-level measures of the four KSSs were also supported by the acceptable levels of multiple indices for both within-firm agreement and between-firm variance and F-test results.

Table 3. Descriptive Statistics and Inter-Correlations

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FP (4-Year Average Tobin’s q Ratios)</td>
<td>0.478**</td>
<td>0.478**</td>
<td>0.478**</td>
<td>0.478**</td>
<td>0.478**</td>
<td>0.478**</td>
<td>0.478**</td>
<td>0.478**</td>
</tr>
<tr>
<td>2. Firm Size</td>
<td>0.148</td>
<td>0.148</td>
<td>0.148</td>
<td>0.148</td>
<td>0.148</td>
<td>0.148</td>
<td>0.148</td>
<td>0.148</td>
</tr>
<tr>
<td>3. Firm Age</td>
<td>-0.117</td>
<td>-0.257**</td>
<td>-0.257**</td>
<td>-0.257**</td>
<td>-0.257**</td>
<td>-0.257**</td>
<td>-0.257**</td>
<td>-0.257**</td>
</tr>
<tr>
<td>4. Industry (Knowledge Intensity)</td>
<td>-0.209*</td>
<td>0.381**</td>
<td>0.381**</td>
<td>0.381**</td>
<td>0.381**</td>
<td>0.381**</td>
<td>0.381**</td>
<td>0.381**</td>
</tr>
<tr>
<td>5. Internal Knowledge Codification Strategy</td>
<td>0.146</td>
<td>0.146</td>
<td>0.146</td>
<td>0.146</td>
<td>0.146</td>
<td>0.146</td>
<td>0.146</td>
<td>0.146</td>
</tr>
<tr>
<td>6. Internal Knowledge Personalization Strategy</td>
<td>0.101</td>
<td>0.101</td>
<td>0.101</td>
<td>0.101</td>
<td>0.101</td>
<td>0.101</td>
<td>0.101</td>
<td>0.101</td>
</tr>
<tr>
<td>7. External Knowledge Codification Strategy</td>
<td>0.403**</td>
<td>0.403**</td>
<td>0.403**</td>
<td>0.403**</td>
<td>0.403**</td>
<td>0.403**</td>
<td>0.403**</td>
<td>0.403**</td>
</tr>
<tr>
<td>8. External Knowledge Personalization Strategy</td>
<td>0.209*</td>
<td>0.209*</td>
<td>0.209*</td>
<td>0.209*</td>
<td>0.209*</td>
<td>0.209*</td>
<td>0.209*</td>
<td>0.209*</td>
</tr>
</tbody>
</table>

**Note.** N = 152. *p < 0.05, **p < 0.01. FP: Firm Performance.

Table 4. Interrater Reliabilities

<table>
<thead>
<tr>
<th>Criterion</th>
<th>IKCS</th>
<th>IKPS</th>
<th>EKCS</th>
<th>EKPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average r_{xx}</td>
<td>0.836</td>
<td>0.841</td>
<td>0.840</td>
<td>0.836</td>
</tr>
<tr>
<td>r^2</td>
<td>0.617</td>
<td>0.559</td>
<td>0.643</td>
<td>0.616</td>
</tr>
<tr>
<td>ICC(1)</td>
<td>0.458</td>
<td>0.415</td>
<td>0.516</td>
<td>0.486</td>
</tr>
<tr>
<td>ICC(2)</td>
<td>0.800</td>
<td>0.751</td>
<td>0.839</td>
<td>0.801</td>
</tr>
<tr>
<td>F</td>
<td>4.997**</td>
<td>4.007**</td>
<td>5.524**</td>
<td>5.018**</td>
</tr>
<tr>
<td>d.f.</td>
<td>151.468</td>
<td>151.468</td>
<td>151.463</td>
<td>151.473</td>
</tr>
</tbody>
</table>

**Note.** **p < 0.01; N = 152 Firms; n = 646 Respondents; Average Number of Respondents per Firm = 4.25. IKCS: Internal Knowledge Codification Strategy; IKPS: Internal Knowledge Personalization Strategy; EKCS: External Knowledge Codification Strategy; EKPS: External Knowledge Personalization Strategy.

We measured firm performance with Tobin’s q ratios to test the causal effects of KSDs on a firm’s future performance. The market-based measure is the capital market value of a firm divided by the replacement value of its assets (Chung and Pruitt 1994). Unlike such historical accounting measures as ROA, ROE, ROI, ROS, and so on, Tobin’s q ratios incorporate a market measure of firm value because the q ratio is

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3 Appendix describing the detailed structure of survey questionnaire is available upon request from the authors.

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forward-looking, risk-adjusted, and less susceptible to changes in accounting practices (Montgomery and Wernherfelt 1988). Moreover, it taps into a firm’s long-term performance as well as the value of the intangible assets a firm possesses. Based on such beauties of Tobin’s q ratios for causality tests, this study employs the market value measure as the dependent variable in predicting the KSD effects. The 4-year average Tobin’s q ratios for the 152 firms over time were reliable measures: i.e., Cronbach’s α = 0.930.

The analysis controlled for firm size, firm age, and industry because of their potential impacts on firm performance. In measuring firm size, we used the natural logarithm of the number of employees to correct for its diminishing effect (Blau 1970) due to its wide variation for sample firms (Yeoh and Roth 1999). Firm age measured by the number of years a firm had existed was controlled for (Zahra and Nielsen 2002) because it manifests a firm’s external legitimacy of existence in the relationships with other firms, staying power, and the pervasiveness of internal routines which influence firm performance (Mosakowski 1991). To control for industry, we adopted the OECD industrial classification (2007) and categorized sample firms into either high or low industrial environment in knowledge intensity which reflects a set of industrial sector-level characteristics. The OECD classification (2007) based on R&D expenditure and its output data differentiates knowledge-intensive industries from others by focusing on the distinction between analytic and synthetic knowledge bases (Tödtling and Trippl 2007).

**Supermodularity Tests**

We attempted to test all the possible complementarities and substitutabilities among the four KSSs to fully investigate their multiple interactions in organizations. Due to the absence of robust testing methods available to empirically test for complementarities and substitutabilities with more than two strategies, prior empirical studies limited their analyses to estimation of all pair-wise interaction effects, i.e., two-way interactions (e.g., Caroli and Van Reenen 2001) or of only some pair-wise interactions of interest (e.g., Bresnahan et al. 2002). The adoption approach is potentially problematic because it does not consider the impact of additional cross-terms, such as three- and four-way interactions in case of four strategies. That is, although most prior empirical studies have relied on such approach due to its simplicity (Arora 1996), it examines only a partial expression for the cross derivative, thus exposing to an omitted exogenous variable bias which affects all coefficients (Carree et al. 2011). In this sense, Athey and Stern (1998) emphasized the consideration of complete sets of organizational strategies in testing complementarities and substitutabilities, suggesting the production function approach in which organizational outcome can be explained by combinations of multiple strategies. This approach enables an empirical analysis of all the potential complementarities and substitutabilities among the four combined KSSs.

Organizational practices can be measured by “dichotomously” or “continuously” in testing their complementarities and substitutabilities. To decide the value of organizational practices, we need to understand the nature of organizational decision on certain practices. If the decision on a particular practice can be asked for an answer “yes” or “no”, it is reliable to dichotomously measure the practice (e.g., the organizational decision on whether to introduce a new information system to workplaces). In the case of KSSs, on the other hand, we can assume that a firm depends on all the four strategies, but with different extent. According to the relative importance of each strategy in an organization, the dominant and inferior types of the four KSSs might be different across organizations. That is, the organization-level decision of KSSs results from a consensus shared by collective members in an organization in which a huge amount of knowledge for multiple tasks and different businesses are managed by people in various functions (Davenport 2011). Thus, the KSSs are understood with continuous measurements in this study.

We conducted multiple supermodularity tests on two-, three-, and four-interactions of KSSs. With the controls (firm size, firm age, and industry), the expression of the objective function \( f \), i.e., a firm performance function, for the four strategies is:

\[
 f(x_1, x_2, x_3, x_4) = \text{controls} + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_4 x_4 + \alpha_{12} x_1 x_2 + \alpha_{13} x_1 x_3 + \alpha_{14} x_1 x_4 + \alpha_{23} x_2 x_3 + \alpha_{24} x_2 x_4 + \alpha_{34} x_3 x_4 + \alpha_{123} x_1 x_2 x_3 + \alpha_{124} x_1 x_2 x_4 + \alpha_{134} x_1 x_3 x_4 + \alpha_{234} x_2 x_3 x_4 + \varepsilon
\]

where \( x_1 = \text{IKCS}, x_2 = \text{IKPS}, x_3 = \text{EKCS}, x_4 = \text{EKPS}, \) and \( \text{controls} = \) firm size, firm age, and industry.

Each supermodularity test provided a discriminant with a different set of \( \varepsilon \)-values for certain coefficients of a regression with the firm performance function. For two-way interactions, strategies \( x_i \) and \( x_j \) were considered to be complement with each other in the function \( f \) if and only if \( \partial^2 f / \partial x_i \partial x_j = \alpha_{ij} \) and \( \alpha_{ik} x_k + \alpha_{jk} x_j \geq 0 \) for all values of four KSSs (each \( i, j, k, \) and \( l \) is one of 1, 2, 3, or 4, respectively) with the...
inequality holding strictly for at least one value. In other words, the complementarity between strategies \(x_i\) and \(x_j\) can be supported when at least one of the following four inequalities is satisfied with two \(t\)-distribution critical values:4

\[
(t_1 > t_2) \land (t_2 > -t_d) \land (t_3 > -t_d) \land (t_4 > -t_d) \lor \\
(t_1 > -t_d) \land (t_2 > t_d) \land (t_3 > -t_d) \land (t_4 > -t_d) \lor \\
(t_1 > -t_d) \land (t_2 > -t_d) \land (t_3 < t_d) \land (t_4 > -t_d) \lor \\
(t_1 > -t_d) \land (t_2 > -t_d) \land (t_3 < -t_d) \land (t_4 > t_d)
\]

where \(t_1 = t\)-value of \((x_ix_j + x_ix_kx_l - x_ix_k - x_ix_l)\), \(t_2 = t\)-value of \((x_ix_k - x_ix_kx_l)\), \(t_3 = t\)-value of \((x_ix_l - x_ix_kx_l)\), \(t_4 = t\)-value of \((x_ix_kx_l)\), \(t_d = 2.24\), and \(t_d = 1.65\).

On the other hand, the definition for substitutability (or subadditivity) is identical to the definition of complementarity except that “larger” is replaced with “smaller” (Carree et al. 2011). Strategies \(x_i\) and \(x_j\) are considered to be substitutable to each other in the function \(f\) if and only if \(\partial^2 f/\partial x_i \partial x_j \leq 0\) for all values of four KSSs with the inequality holding strictly for at least one value. The condition for the substitutability between strategies \(x_i\) and \(x_j\) can be represented as follows with at least one of the four inequalities:

\[
(t_1 < t_2) \land (t_2 < -t_d) \land (t_3 < -t_d) \land (t_4 < -t_d) \lor \\
(t_1 < -t_d) \land (t_2 < t_d) \land (t_3 < -t_d) \land (t_4 < -t_d) \lor \\
(t_1 < -t_d) \land (t_2 < -t_d) \land (t_3 < t_d) \land (t_4 < -t_d) \lor \\
(t_1 < -t_d) \land (t_2 < -t_d) \land (t_3 < -t_d) \land (t_4 > t_d)
\]

where \(t_1 = t\)-value of \((x_ix_j + x_ix_kx_l - x_ix_k - x_ix_l)\), \(t_2 = t\)-value of \((x_ix_k - x_ix_kx_l)\), \(t_3 = t\)-value of \((x_ix_l - x_ix_kx_l)\), \(t_4 = t\)-value of \((x_ix_kx_l)\), \(t_d = 2.24\), and \(t_d = 1.65\).

These definitions are demanding in the sense of requiring the cross derivative to be non-negative for all possible or observed values of strategies. Such cross-term specifications of the objective function \(f\) were used to test for two-way complementarities and substitutabilities between the four KSSs.

In the same way, three-way interactions of certain KSSs were considered to be complementary relationships in the function \(f\) if and only if \(\partial^3 f/\partial x_i \partial x_j \partial x_k = \alpha_{ijk} + \alpha_{ijk} \geq 0\) or substitutable relationships if and only if \(\partial^3 f/\partial x_i \partial x_j \partial x_k \leq 0\) with the inequality holding strictly for at least one value. The complementarity among strategies \(x_i, x_j,\) and \(x_k\) can be satisfied with at least one of the two inequalities:

\[
(t_1 > t_2) \land (t_2 > -t_d) \lor \\
(t_1 > -t_d) \land (t_2 > t_d)
\]

where \(t_1 = t\)-value of \((x_ix_jx_k - x_ix_jx_k)\), \(t_2 = t\)-value of \((x_ix_jx_k)\), \(t_d = 2.24\), and \(t_d = 1.65\).

Finally, the four-way interaction among all four KSSs can be considered to be complementarity in the function \(f\) if and only if \(\partial^4 f/\partial x_i \partial x_j \partial x_k \partial x_l = \alpha_{ijkl} \geq 0\) or substitutability if and only if \(\partial^4 f/\partial x_i \partial x_j \partial x_k \partial x_l \leq 0\) with the inequality holding strictly for at least one value. That is, the substitutability among all KSSs can be satisfied with the inequality:

\[
t_1 < t_d
\]

where \(t_1 = t\)-value of \((x_ix_jx_kx_l)\), \(t_d = 2.24\).

### Analysis and Results

Using the objective function \(f\), we tested our hypotheses via a set of supermodularity tests by showing all complementarities and substitutabilities among the four KSSs, as summarized in Table 5. Regarding the effects of control variables on firm performance measured by the 4-year average Tobin’s \(q\) ratios, a noticeable result was that while firm age and industry were not significant, only firm size was consistently significant (its \(t\)-value = 2.317, \(p < 0.05\)) across the multiple regressions for supermodularity tests for two-, three-, and four-way KSS interactions. This result might be explained by that larger organizations with a number of their employees are more likely to access diverse knowledge sources and achieve high

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4 To reduce the overall probability of a type I error in the supermodularity tests, we took the original Bonferroni procedure in which \(t_d = 2.24\) is a \(t\)-distribution critical value at 2.5% two-sided significance level (\(A/2^{\alpha} = 10\%, n = 4\), i.e., the number of strategies) and \(t_d = 1.65\) is \(t\)-distribution critical value at 10% two-sided significance level (Olejnik et al. 1997).
A set of four supermodularity tests for two-way interactions of four pairs of strategies supported H1, suggesting the complementarities between each pair of KSSs in the related constrained KSDs with firm performance measured by 4-year average Tobin’s q ratios: i.e., the complementarities between IKCS (x1) and IKPS (x1) (t1 = 4.081, t2 = 4.308, t3 = 1.315, t4 = 2.430; ∂f/∂x1∂x2 ≥ 0 3), between IKCS (x1) and EKCS (x2) (t1 = 7.354, t2 = 6.626, t3 = 5.706, t4 = 5.663; ∂f/∂x1∂x3 ≥ 0 2), between IKCS (x2) and EKPS (x3) (t1 = 3.946, t2 = 1.275, t3 = 3.279, t4 = 0.756; ∂f/∂x2∂x4 ≥ 0 4), and between EKCS (x4) and EKPS (x4) (t1 = 4.709, t2 = 3.795, t3 = 3.024, t4 = 2.490; ∂f/∂x3∂x4 ≥ 0 3). In addition, H2 was supported by the two supermodularity tests for two-way interactions of KSSs with 4-year average Tobin’s q ratios, indicating the substitutabilities between KSSs in the unrelated multiple KSDs, i.e., the substitutabilities between IKCS (x1) and EKPS (x4) (t1 = -5.139, t2 = -4.974, t3 = -3.308, t4 = -4.811; ∂f/∂x1∂x4 ≤ 0 4) and between IKPS (x2) and EKCS (x3) (t1 = 4.107, t2 = -1.653, t3 = -3.328, t4 = -1.485; ∂f/∂x2∂x3 ≤ 0 5).

Only the complementarity among IKCS (x1), IKPS (x2), and EKCS (x3) was supported by one of four supermodularity tests for three-way interactions of KSSs in the related linked KSDs with firm performance measured by Tobin’s q ratios (t1 = 2.886, t2 = 1.565; i.e., ∂f/∂x1∂x2∂x3 ≥ 0 2). The other three supermodularity tests did not support the complementarities among IKCS (x1), IKPS (x2), and EKPS (x3) (t1 = -2.490, t2 = -2.478; ∂f/∂x1∂x2∂x3 ≤ 0 2), IKCS (x1), EKCS (x2), and EKPS (x3) (t1 = 1.483, t2 = 0.548; not ∂f/∂x1∂x2∂x3 ≥ 0), and IKPS (x2), EKCS (x2), and EKPS (x3) (t1 = -0.169, t2 = -0.624; not ∂f/∂x1∂x2∂x3 ≤ 0).

H3 was partially supported by the supermodularity tests, indicating that only one KSS of the related KSDs, i.e., IKCS, IKPS, and EKPS, complement each other in improving firm performance. Finally, the supermodularity test for four-way interactions of all the four KSSs supported H4. It indicates that the effects of the unrelated-portfolio KSDs on firm performance, measured by Tobin’s q ratios, are substitutable for each other (t1 = -0.811; ∂f/∂x1∂x2∂x3∂x4 ≤ 0 3).

\[ \begin{align*}
\text{Table 5. Summary of Supermodularity Tests with Firm Performance} \\
\text{Diversity} & | \text{KSSs} & t_1 & t_2 & t_3 & t_4 & \text{Test Result} & \text{Hypothesis Test} \\
\hline
\text{Related Constrained} & \text{IKCS (x1) × IKPS (x2)} & 4.081 & 4.308 & 1.315 & 2.430 & \text{Complementarity} & \text{Support H1} \\
& \text{IKCS (x1) × EKPS (x3)} & 4.709 & 3.795 & 3.024 & 2.490 & \text{Complementarity} & \text{Support H1} \\
& \text{IKCS (x2) × EKCS (x3)} & 7.354 & 6.626 & 5.706 & 5.663 & \text{Complementarity} & \text{Support H1} \\
& \text{IKPS (x2) × EKPS (x3)} & 3.949 & 1.275 & 3.279 & 0.756 & \text{Complementarity} & \text{Support H1} \\
\hline
\text{Unrelated Multiple} & \text{IKCS (x1) × EKPS (x3)} & -5.139 & -4.974 & -3.308 & -4.811 & \text{Substitutability} & \text{Support H2} \\
& \text{IKPS (x2) × EKCS (x3)} & -4.107 & -1.653 & -3.328 & -1.485 & \text{Substitutability} & \text{Support H2} \\
\hline
\text{Related Linked} & \text{IKCS (x1) × IKPS (x2) × EKCS (x3)} & 2.886 & 1.565 & & & \text{Substitutability} & \text{Support H3} \\
& \text{IKCS (x1) × IKPS (x2) × EKPS (x3)} & -2.490 & -2.478 & & & \text{Substitutability} & \text{Not Support H3} \\
& \text{IKCS (x1) × EKCS (x3) × EKPS (x3)} & 1.483 & 0.548 & & & \text{Not Support H3} & ns \\
& \text{IKPS (x2) × EKCS (x3) × EKPS (x3)} & -0.169 & -0.624 & & & \text{Not Support H3} & ns \\
\hline
\text{Unrelated Portfolio} & \text{IKCS (x1) × IKPS (x2) × EKCS (x3) × EKPS (x3)} & -0.811 & & & & \text{Substitutability} & \text{Support H4} \\
\hline
\text{Note.} & \text{KSS: Knowledge Sourcing Strategy; IKCS (x1): Internal Knowledge Classification Strategy; IKPS (x2): Internal Knowledge Personality Strategy; EKCS (x3): External Knowledge Codification Strategy; EKPS (x4): External Knowledge Personalization Strategy.} \\
\end{align*} \]
Discussion and Implications

Our results support complementarities between each pair of KSSs in the related constrained KSDs (H1 is supported), thus suggesting that adopting KSDs within the same knowledge sourcing dimension improves firm performance. Using KSSs in the related constrained KSDs, firms can increase operational efficiency by codifying their knowledge and acquiring external knowledge, and increase effectiveness by expanding their knowledge based with externally generated new idea (Kyriakopoulos and de Ruyter 2004) and creating unique new knowledge. Firms can also reduce risk of knowledge loss from knowledge holder’s turnover or retire. In contrary to our expectation, the results do not show clear evidence of complementarities of KSSs in the related linked KSDs (H3 is partially supported). Although IKCS, IKPS, and EKCS show the complementarity, IKCS, IKPS, and EKPS show the substitutability and the other two related linked KSDs show neither complementarity nor substitutability. This may be explained in part by the unclear relative effects of related constrained KSDs and unrelated multiple KSDs on firm performance. This study anticipated that the related linked KSDs would show complementary relationships because they consist of two complementary relationships (related constrained KSDs) and one substitutable relationship (unrelated multiple KSDs). However, it is not clear whether the effect of two complementary relationships overwhelm that of one substitutable relationship because coordination and communication costs increase more than linearly with the number of KSSs (Zhou 2011). Furthermore, interactions between complementary sourcing activities behave quite differently from interactions between substitutable sourcing activities (Siggelkow 2002). The strength of complementary interactions should be differently interpreted from the strength of substitutable interactions. Therefore, it might be unclear whether the benefits arising due to two complementarities outweigh the cost from one substitutability.

On the other hand, our results suggest substitutabilities among KSSs of the unrelated multiple KSDs, as predicted in H2. Adopting two distinct KSSs from different knowledge sourcing dimensions shows negative impact on firm performance. Benefits of a KSS are diminished by adopting another KSS from a different dimension. For example, IKPS that focuses on creating firm specific knowledge could lose its strength by combining decontextualized external knowledge from EKCS (Choi and Lee 2012; Leiponen 2006). Furthermore, problems of a KSS are exacerbated when a firm uses another KSS from a different dimension. Misapplication problems of external personnel knowledge can be intensified when it is used with decontextualized and encoded internal knowledge (Kessler et al. 2000; Pissarides 1999). The results also support substitutabilities among KSSs in the unrelated-portfolio KSDs, uploading H4. Using all the four KSSs simultaneously increases coordination and communication cost of processing diversified knowledge because coordination and communication efforts to access and acquire knowledge dispersed on multiple knowledge sources are sophisticated and complex (Belderbos et al. 2006; Katila and Ahuja 2002). In addition, benefits from complementarity within the unrelated-portfolio KSDs may be difficult to realize. Once the four knowledge sources are in place, managing them simultaneously can be challenging owing to the natural comparisons, suspicions, and shirking among these sources (Parmigiani 2007).

Implications and Limitations

Our complementarity theory generates several theoretical contributions. First, this study contributes to the literature on diversity by explaining the impact of KSD on firm performance. Diversity effects have been investigated from a product or market perspective even though knowledge is the roots of sustainable competitive advantage (Lin et al. 2006; Makri et al. 2010). Investigating diversity effects from knowledge perspective, this study shed new light on how a firm manages its knowledge sources effectively to increase firm performance. Second, this study extends the extant knowledge by examining knowledge sourcing scope and type simultaneously. Previous studies have tended to investigate their effects separately in spite of the fact that major source of competitive advantage come from synergy created by the knowledge sourcing scope and type. Third, Choi and Lee (2012) recently considered both knowledge sourcing scope and type together. However, they did not fully investigate all the possible combinations; they omitted interactions among four forms of KSSs. Likewise, the KSS literature has ignored the interactions among the strategies even though it have contributed to the understanding of whether each single strategy improves firm performance (an universalistic view) with organizational or environmental factors (a contingency view). Our complementarity view explains the interactions among combined strategies and identifies their complementarities which might be underleveraged by firms. Fourth, we investigated complementarities and substitutabilities among four continuous variables with the complementarity
testing method developed by Carree et al. (2011), which enables us to directly measure KSSs relatedness for capturing their synergies. Prior research has measured complementarities among KSSs by adding interaction terms because they only considered effects of pair-wise KSSs on firm performance. However, firms can consider three or four KSSs simultaneously in reality. Beyond considering two KSSs, this study reflects the reality of KSSs adoption and examines their impacts on performance precisely.

Our results also provides valuable practical implications by identifying what specific combinations of certain KSSs form complementarities improving firm performance and what other combinations cause substitutabilities lowering firm performance. First, KSSs in the related constrained KSDs are complementary. Synergistic interactions between IKCS and IKPS, between EKCS and EKPS, between IKCS and EKCS, and between IKPS and EKPS might prove particularly valuable for improving firm performance because increasing the level of one strategy leads to higher marginal return from increasing the level of the other strategy (Kyriakopoulos and de Ruyter 2004; Prabhu et al. 2005; Zack 1999). Managers who intend to achieve higher performance by implementing effective and efficient KSSs must adopt their KSSs within the same knowledge sourcing dimensions. Second, KSSs in the related linked KSDs show various relationships. One KSS combination in the related linked KSDs is complementary, another is substitutable, and the others are neither complementary nor substitutable. Pursuing KSSs in the related linked KSDs could lead to improved results, the same results as would be seen if no sourcing diversities were pursued, or even worse results. The results of related linked KSDs are unpredictable, implying that diversifying knowledge sourcing activities too much is not helpful for firms to improve firm performance. Thus, managers should carefully evaluate the results of related linked KSDs before they diversify KSSs. Third, unrelated KSDs including unrelated multiple and unrelated-portfolio hurt firm performance. That is, increasing the level of a KSS results in lower marginal returns from other KSSs in different dimensions. Some studies suggested that unrelated KSDs enable managers to source unique knowledge beyond industry boundary, resulting in reduction of industry specific risk (Montgomery 1982; Palich et al. 2000). However, our findings show that unrelated KSDs have negative impacts on firm performance. To increase firm performance, managers should combine KSSs within the same knowledge sourcing dimension. Via related KSDs, they quickly acquire new knowledge and assimilate it with their processes (Cohen and Levinthal 1990). This study provides deeper insight for managers to gain efficiencies from existing KSSs and maximize firm performance in further KSS diversifications.

Our study has several limitations, some of which offer possibilities for further research. First, this study has taken only Tobin’s $q$ ratios as a performance outcome. However, the measure does not fully capture the benefits from KSDs. A study to investigate the different firm performance of KSDs, such as innovation (Cassiman and Veugelers 2006) and learning outcomes (Gray and Meister 2004), would provide further robust results. Second, this study has categorized KSSs relatedness based on Rumelt’s categorization. Although the categorization has been widely accepted in the previous research, it has been also criticized for several reasons such as overrepresentation in the related constrained category (Ramanujam and Varadarajan 1989). Third, we used cross-sectional data. Researchers should employ longitudinal data that have long time periods in order to understand the impact of KSDs on corporate performance elaborately. Another avenue to expand this study is to develop and test similar models with longitudinal data and attempt to understand how KSDs that affect corporate performance evolve over time even though the strategies are known to be relatively stable (Bierly and Chakrabarti 1996). Finally, the results of the study are limited to Korean firms. The generalizability from a South Korean setting to other countries may be questionable. Clearly, future research testing our hypotheses in other countries setting would be worthwhile to increase the generalizability of our findings.

Conclusion

The concepts of KSS and KSD are important to fully understand a firm’s competitive advantage in the knowledge economy. For a holistic view towards the effects of KSDs on firm performance, we investigated the performance implications of four KSDs based on complementarity theory and Rumelt’s diversity categories. Specifically, successful KSDs require a judicious combination of IKCS, IKPS, EKCS, and EKPS within the same knowledge sourcing dimension. Our results present substitutable relationships of the unrelated KSDs including the unrelated multiple diversity and the unrelated-portfolio. The production function approach to test complementarities among KSSs renders this research more robust, thus providing managerially valuable results by classifying eleven KSS combinations into four KSDs.
References


The Diversity Effects of Knowledge Sourcing Strategies


