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The Role of Firm Size and IT Capabilities in Open and Closed Innovation

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ABSTRACT

Open innovation has attracted significant attention from both academics and practitioners. However, theoretical and empirical researchers disagree on how open innovation improves firm performance. The inconsistent results reported in the literature may be attributed to the fact that they failed to provide an integrative view of how to make use of internal and external knowledge to enhance innovation performance. Furthermore, although the adoption value of innovation approaches varies depending on firm size and IT capabilities, their impacts have not been adequately taken into consideration. Drawing on complementarity theory, this study revisits the research problem and develops eight hypotheses. Surveys collected from 339 Korean firms were analyzed to test the hypotheses using the supermodularity functions. The results indicated that an internal knowledge-oriented innovation approach has a positive impact on innovation performance regardless of firm size. However, an external knowledge-oriented innovation approach has a positive effect on innovation performance in large firms while having no significant effect on innovation performance of SMEs. Results also confirmed a complementary relationship between internal and external knowledge-oriented innovation approaches in large firms, whereas substitutable relationships were confirmed in SMEs. This study sheds new light on open innovation by identifying the role of different types of innovation approaches, firm size, and IT capabilities.

Keywords: Open Innovation, Complementarity Theory, Firm Size, IT Capabilities, Innovation Performance

Ⅰ. Introduction

Since the publication of Chesbrough's 2003 book, open innovation has attracted significant attention from both academics and practitioners. A search result of open innovation in Google Scholar returns over 2 million hits in 2010 and over 4 million hits in 2018. In addition, Chesbrough's 2003 book cited more than 1,800 papers and books in 2010 (Huizingh, 2011) and, surprisingly, more than 15,000 in 2018. Open innovation can be defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation, respectively" (Chesbrough

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et al., 2006). Many studies have emphasized that open innovation improves firm performance by enabling a firm to develop and retain a more diverse set of knowledge on critical business issues (Ham et al., 2015). For example, Leiponen and Helfat (2010) asserted that access and utilization of broad knowledge, including external knowledge, can lead to eye-opening innovation and, ultimately, improve firm performance.

However, the decision as to whether a firm should adopt open innovation is more difficult than it might appear. There is no clear evidence that open innovation shows better performance for a firm than closed innovation. Although some studies insisted that open innovation can enhance firm performance by broadening their knowledge base (Pateli and Lioukas, 2019), others argued that open innovation may hinder firm performance due to the increase in adjustment cost between internal and external knowledge (Greenstein, 1996). To solve these inconsistent results, many studies have been conducted to find the specific conditions under which certain innovation approaches are applicable (Van de Vrande et al., 2009).

It is true that previous studies on open innovation have enhanced the understanding of the phenomenon and processes of open innovation to a certain amount. Nevertheless, these studies failed to provide an integrative view of how to make use of internal and external knowledge in order to enhance innovation performance. In addition, previous studies often struggle to identify the impact of firm size on the relationship between innovation approaches and innovation performance. Furthermore, research on the impact of information technology (IT) capabilities on open innovation is very limited even though IT capabilities are very important to acquire, develop, and use internal and external knowledge.

To overcome the limitations of existing studies[1], this paper first investigates the relationship between innovation approaches[2] and innovation performance on the basis of knowledge based theory (KBT) and complementarity theory from the economics literature (Milgrom and Roberts, 1995). KBT helps us understand why different firms' innovation performance can be different. Complementary theory provides a theoretically rigorous and methodologically relevant basis for understanding the synergistic effect of internal and external knowledge on innovation performance. This paper also examines the differential impact of innovation approaches on firm performance in firms of different size. There is limited research on how firm size affects the adoption of innovation approaches even though many studies have clearly emphasized major differences among small, medium, and large organizations, and the need to adopt different approaches for different firm sizes (e.g., Gopalakrishnan and Bierly, 2006). This will help managers specify the size conditions under which innovation approaches can be expected to increase innovation performance. Lastly, the role of IT capabilities[3] in open innovation will be investigated. More specifically, we focus on how internal and external activities support IT capabilities affect firm's engagement in open innovation with internal and external sources of knowledge. This will enable managers to have a better understanding of

1) A summary of existing literature on different innovation approaches from a knowledge sourcing perspective is presented in <Appendix A.>

2) This study categorizes innovation approaches into the internal knowledge-oriented approach, the external knowledge-oriented approach, and the open innovation approach (i.e., combining internal and external knowledge-oriented approaches) based on the study of Ham et al. (2017).

3) "IT capabilities" is divided into two categories according to Sabherwal and Chan (2001): internal activities support IT capabilities and external activities support IT capabilities.

how to use IT capabilities by considering the scope of knowledge sources utilized by a firm.

In sum, this paper is motivated by the following questions: (1) How does innovation performance differ depending on the innovation approach? (2) How does firm size affect the adoption of an innovation approach? (3) What is the role of IT capabilities in open innovation of a firm? This study attempts to answer these questions by empirically analyzing data collected from 339 Korean firms regarding the impact of innovation approaches on innovation performance. The roles of firm size and IT capabilities in open innovation are also examined.

Ⅱ. Theoretical Background

2.1. Knowledge Based Theory (KBT)

KBT was proposed by expanding and developing resource based theory (RBT). The key point of RBT is that firms can achieve a sustained competitive advantage over their competitors through having valuable, rare, imitable, non-substitutable resources or capabilities (Barney, 1991). RBT has been widely accepted and used to define firm behavior. However, the theory has been criticized for treating knowledge as the same as other generic resources (Grant, 1996). KBT was proposed to provide an answer to this criticism.

KBT considers knowledge to be the only and most important strategic resource that enables firms to have a sustainable competitive advantage (Grant, 1996). The theory assumes that i) the principal function of a firm is to create, integrate, and utilize knowledge, and ii) sustainable competitive advantage and firm performance depend on whether they have unique knowledge resources. From an innovation perspective, this implies that the core function of a firm is to develop, acquire, and utilize knowledge in order to improve innovation performance and create value. Unlike RBT, the theory helps managers to understand where and how organizational resources are created to improve performance such as innovation performance by recognizing knowledge as the most important resource guiding managerial decision-making (Bogner and Bansal, 2007).

One of the main contributions of KBT is the recognition of two different knowledge sources for innovation: internal and external (Bierly and Chakrabarti, 1996). KBT played a critical in examining the impact of different knowledge sourcing approaches for innovation on firm performance. The theory, unlike the perspective of transaction cost economics[4], considers closed innovation (i.e., internal knowledge-oriented), external knowledge-oriented innovation, and open innovation (i.e., using internal and external knowledge-oriented innovation simultaneously) as a distinct choice. KBT enables mangers to beyond the discrete internal knowledge-oriented and external knowledge-oriented distinction. Therefore, the choice among closed innovation, external knowledge-oriented, and open innovation approach is the firm's primary consideration (Parmigiani and Mitchell, 2009).

Apart from innovation approaches, IT is recognized as a major factor for open innovation on the basis of KBT because it facilitates knowledge flow within and/or across organizational boundaries to

4) Transaction cost economics views simultaneous sourcing as a linear combination of internal- and external-oriented sourcing along with a make (internal-oriented)/buy (external-oriented) continuum. However, KBT regards simultaneous sourcing as a distinct choice (Parmigiani and Mitchell, 2009). Thus, forces that motivate a firm toward internal-oriented knowledge sourcing may be different from those motivating it away from external-oriented knowledge sourcing.

respond to environmental change, leading to improved innovation performance (Cui et al., 2015). IT can enhance the performance of open innovation by effectively exploring external knowledge and absorbing it into the firm to expand the firm's knowledge base through integration with existing internal knowledge (Hrastinski et al., 2010). For example, IT helps collaborations and interactions among organizational members as well as search for potential external knowledge (Huang et al., 2014; Kmieciak et al., 2012).

Many researchers have paid their attention to the relationship among resources, capabilities, and organizational performance and suggested a hierarchical view of the relationships among them (Grant, 1996). According to KBT, a firm's resources and capabilities determine its performance (Grant, 1996). For example, Ravichandran and Lertwongsatien (2005) insisted that a firm's ability to create superior outcome is a function of capability, which is influenced by resources. In the similar vein, innovation outcome can be considered as a function of capabilities and resources including innovation approaches and IT capabilities.

2.2. Complementarity and Substitutability

Complementarity, developed and enhanced by Milgrom and Roberts (1995), refers to the condition in which an increase in the level of one activity leads to higher marginal or incremental return from an increase in the level of the other activities (Choi and Lee, 2010). By the same token, increasing the level of any one activity can decrease the marginal or incremental return to other activities, which is the case of substitutability (Milgrom and Roberts, 1995). The theory of complementarity places emphasis on a more holistic and aggregated view of how organizational variables interrelate (Whittington et al., 1999).

The mathematical definition of complementarity is given when a real-valued function f on a lattice X is supermodular and its arguments complement, if and only if $f(x)-f(x\wedge y)\leq f(x\vee y)-f(y)$ for any x and y in X (Milgrom and Roberts, 1995). In the case where the variables take continuous values[5], variables i and j are complements if an increase in the amount of one variable increases the marginal return of the other variables. Mathematically, the concept may be represented as

$$f: R_n \rightarrow R \ \partial^2 f / \partial x_i \partial y_j, \text{ for all } x \ \varepsilon \ R^k, i \neq j \quad (1)$$

where f denotes the objective function n variables, $f(x_1,...,x_n)$ and $\partial f() / \partial x_i$ denotes the first partial derivatives.

The concept for substitutability is identical to Equation (1), except that "larger" is replaced by "smaller". The importance of complementary theory does not mean that all factors must be taken into account just to achieve high performance (Whittington et al., 1999). Rather, it stresses that introducing variables or practices that are not mutually complementary can reduce performance. For example, if the internal knowledge-oriented innovation and the external knowledge-oriented innovation are not complementary to each other, then open innovation could damage the innovation outcomes.

Ⅲ. Development of Hypotheses

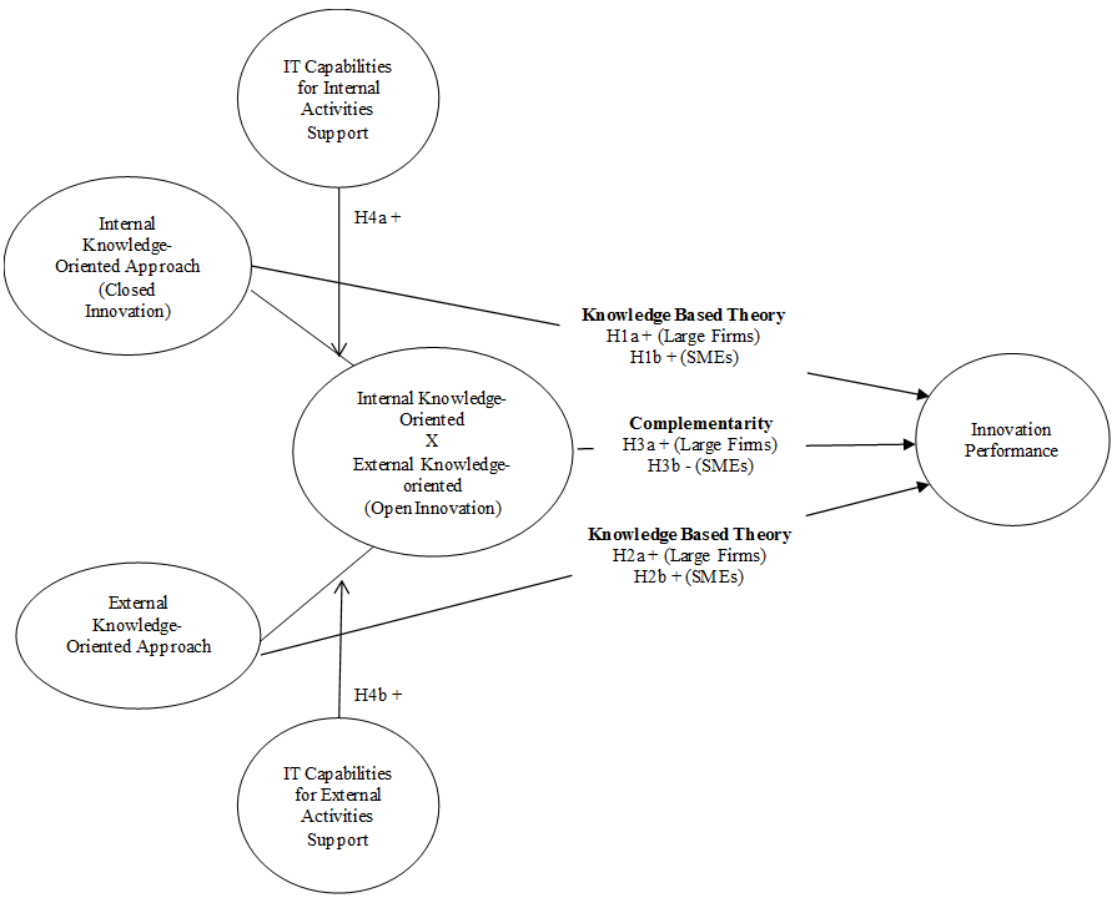
This study attempts to investigate the relationships

5) If discrete variables are used, then complementarities can be defined based on lattice theory and supermodularity (see Milgrom and Roberts (1995) for details).

between the innovation approaches and innovation performance on the basis of KBT and complementarity theory. It will also identify how the effect of innovation approaches on performance changes according to firm size by examining the differences between innovation approaches and performance for large and SMEs. In addition, as part of the internal capabilities of the firm, it includes the effect of IT capabilities on the relationships between internal and external knowledge-oriented approaches and open innovation. <Figure 1> summarizes the hypotheses.

3.1. Innovation Approaches, Firm Size, and Innovation Performance

Internal knowledge-oriented innovation emphasizes the importance of managing the flow of knowledge and competencies inside the firm over time in order to improve firm performance (Prabhu et al., 2005). Its practical examples include the extraction of meaningful knowledge from the new product/service introduction processes, the use of existing knowledge in generating proposals, and the fostering of the knowledge of research centers. According to KBT, focusing on internal knowledge enables firms to deep-



<Figure 1> Research Model

ly understand the strengths and weaknesses of their unique knowledge or skills so that they have more opportunities to develop innovative products or services (Bogner and Bansal, 2007; Damanpour et al., 2018). Internal members can effectively pursue the core activities associated with innovation with internal knowledge (Menon and Pfeffer, 2003). Internal knowledge-oriented innovation not only prevents opportunistic behavior of other firms that may arise if firms collaborate with others, but also prevents unintended knowledge outflow (Kessler et al., 2000). Moreover, it is relatively easy to exchange tacit knowledge, which is at the core of radical innovation (Urgal et al., 2013). Internal members can enhance mutual understanding of innovation-related issues based on similar experiences or backgrounds, and have similar perspectives or interpretation framework to facilitate tacit knowledge sharing (Liang et al., 2015). Tacit knowledge is more difficult to copy by competitors than explicit knowledge and is more likely to result in a successful innovation (Ahuja and Katila, 2001). Therefore, firms that create new ideas and chances by using internal knowledge can outperform in innovation those that do not (Damanpour et al., 2018). Therefore, the following hypothesis is proposed:

H1a: Internal knowledge-oriented innovation is positively associated with innovation performance in large firms.

Compared with larger firms, SMEs do not have sufficient internal resources for innovation (Lee et al., 2010). Therefore, they must find available options that can enable them to increase innovation capabilities without critical resource constraint problems by implementing a knowledge management (KM) system for managing internal knowledge. The cost of a comprehensive KM system may not absolutely be justified by an SME. However, SMEs can invest in a simple KM system, such as knowledge repositories or databases, Intranet, and email, which may serve as a cost-effective KM system (Dufour and Son, 2015). These systems have been reported as already being implemented by SMEs to leverage internal capabilities for innovation (Bell and Loane, 2010). In addition, SMEs can effectively source internal knowledge embedded in organizational members without significantly spending because they have a less bureaucratic and more flexible structure than large firms. Owing to their simple, less hierarchical, and less bureaucratic structures, SMEs are believed to be organized to facilitate rapid and effective communication throughout the organization, resulting in a frequency of interaction among members (Gopalakrishnan and Bierly, 2006). Thus, organizational members have opportunities to enhance openness and develop strong intimacy, which helps in the sharing of values, perceptions, and mental models. These factors are considered critical for innovation (Lee et al., 2010; Van de Vrande et al., 2009). Moreover, SMEs can achieve competitive advantage and superior innovation performance by focusing on narrow and smaller market segments that need customized products and services that may be difficult for larger firms to offer (Ebben and Johnson, 2005). It is possible for SMEs to serve such market segments without a significant level of resources. With this premise, we propose the following hypothesis:

H1b: Internal knowledge-oriented innovation is positively associated with innovation performance in SMEs.

External knowledge-oriented innovation stresses the importance of knowledge flow by focusing on accessing and absorbing external knowledge (Fey and Birkinshaw, 2005). According to KBT, it is necessary

for the firm to develop a broader knowledge base and to keep abreast of emerging technologies because new knowledge with the highest degree of impact could come from external knowledge (Bierly and Chakrabarti, 1996). As a result, many firms focus on acquiring and using external knowledge to improve innovation performance. For example, Procter and Gamble's innovation process was organized to achieve 50% of all innovations through external knowledge acquisition and applications (Huston and Sakkab, 2006). Furthermore, firms that employ an external knowledge-oriented innovation approach produce knowledge that is likely to be more dynamic and varied because external sources are not controlled by the firms (Schulz, 2001). This dynamic and heterogeneous knowledge provides fresh thinking to the firms and prevents organizational inertia in exploring new opportunities, leading to improved outcomes (Zhou and Li, 2012). In addition, innovation through the external knowledge reduces unnecessary investments such as "reinventing the wheel" (Lichtenthaler and Ernst, 2006). Therefore, the following hypothesis is proposed:

H2a: External knowledge-oriented innovation is positively associated with innovation performance in large firms.

Innovation through the acquisition and utilization of outside knowledge for SMEs plays a very important role in improving performance. SMEs typically do not have enough financial and human resources for in-house innovation activities (Dufour and Son, 2015). Due to their resource constraints, SMEs cannot cover all the innovation activities required to implement a successful innovation (Brunswicker and Vanhaverbeke, 2015). Therefore, it is essential for SMEs to fill the gap between the knowledge required for innovation and the knowledge they possess by acquiring knowledge or capabilities from external sources (Gopalakrishnan and Bierly, 2006). In particular, the need to acquire diverse knowledge effectively from the outside of a firm to reduce the speed of new product or service development is higher than ever due to the current complex and rapidly changing competitive environment (Van de Vrande et al., 2009). It is also easier for SMEs to improve innovation performance by utilizing external knowledge because SMEs can be relatively free from adopting new knowledge from external sources, whereas large firms may face resistance to external knowledge (Gopalakrishnan and Bierly, 2006). This leads to the following hypothesis:

H2b: External knowledge-oriented innovation is positively associated with innovation performance in SMEs.

Many studies have underlined that internal and external knowledge-oriented approaches for innovation exist separately; however, it has been suggested that it becomes more valuable for firms to combine them (i.e., open innovation) in large firms (Xu et al., 2013). According to KBT, combination of the two approaches for innovation help improve benefits of each approach as well as hedge risk from each approach's weakness (Prabhu et al., 2005). The external knowledge-oriented approach can enhance firm performance by bringing in many new ideas generated by outside firms and enabling firms to have different perspectives for critical issues that may be difficult to address with only internal knowledge-oriented approach due to already implemented organizational routines and procedures (Bierly and Chakrabarti, 1996). The internal knowledge-oriented approach can also substantially improve innovation outcomes by combining an effective external knowl-

edge-oriented approach because how fast a firm can access, absorb, and integrate external knowledge depends on the firm's "absorptive capacity" (Lichtenthaler and Lichtenthaler, 2009); that is, the ability of the firm to value, assimilate, and apply external knowledge internally is largely a function of the level of prior internal knowledge (Lichtenthaler and Ernst, 2006). Consequently, innovation performance depends upon the firm's ability to absorb and utilize external knowledge as well as to integrate it with internal capabilities. Thus, the outcomes of firm innovation stem from the combination of newly acquired external knowledge with existing internal knowledge (Huizingh, 2011; Zhou and Li, 2012). This leads to us to the following hypothesis:

H3a: Open innovation (i.e., pursuing internal and external knowledge-oriented innovation approaches simultan eously) is positively associated with innovation performance in large firms.

Internal and external knowledge-oriented innovation approaches require different resources, processes, and learning experiences (Damanpour et al., 2018). Thus, adopting both approaches increases organizational complexity and requires additional resources (Xu et al., 2013). Large firms might handle this complexity because they have sufficient resources; however, SMEs lack the resources, capabilities, and experience necessary to successfully integrate the two approaches, failing to realize the benefits of open innovation. In addition, firms adopting internal and external knowledge-oriented approaches face risks such as loss of knowledge, higher coordination costs, and loss of control (Enkel et al., 2009). Large firms can maintain diversified innovation portfolios to spread these risks with their resources and expertise, whereas SMEs cannot spread the risks associated with innovation due to the lack of resources, scant opportunities to recruit talented workers, and smaller innovation portfolios (Van de Vrande et al., 2009). Furthermore, achieving a high level of knowledge sourcing in many areas can be more demanding and complex than most SMEs can handle (Ebben and Johnson, 2005). Therefore, SMEs that attempt to integrate internal with external knowledge-oriented innovation approaches will likely be at a disadvantage, resulting in lower firm performance. We therefore propose:

H3b: Open innovation (i.e., pursuing internal and external knowledge-oriented innovation approaches simultan eously) is negatively associated with innovation performance in SMEs.

3.2. IT Capabilities and Open Innovation

According to KBT, IT capabilities can improve integrating firm's specialized knowledge efficiently and flexibly to sustain its competitive advantage (Teigland and Wasko, 2003). Therefore, many studies have considered IT capabilities as an important enabler for a firm's innovation (Rai and Tang, 2010). For example, IT capabilities improve open innovation not only for storing and analyzing ideas but also for sharing, integrating, and generating new knowledge (Hrastinski et al., 2010).

IT capabilities can be divided into the form of capabilities that support internal activities and capabilities that support external activities (Sabherwal and Chan, 2001). IT capabilities that support internal activities help organizational members collaborate with one another through sharing ideas and knowledge efficiently (Gordon et al., 2008). For example, Dresdner Kleinwort Wasserstein, the European investment bank, facilitates their collaboration and

manages internal knowledge effectively by using three IT technologies (McAfee, 2006). In addition, IT capabilities for internal activities supports enables a firm to collect and search new knowledge effectively through improved search capabilities and data mining techniques (Kleis et al., 2012). For example, the electronic laboratory notebook improves efficiency and reduces transcription errors by capturing and recording experiment data electronically (Elliott, 2006).

The impact of internal knowledge-oriented approach on open innovation may be enhanced when IT capabilities for supporting internal activities is high. Managing knowledge and competencies flow inside the firm is essential for open innovation (Huizingh, 2011). In order to increase knowledge flow within a firm, the firm should provide easy access for firm's internal knowledge and make the knowledge more concrete and transferable. IT capabilities for supporting internal activities can codify and store the firm's internal knowledge for easy access and comprehension, which renders firm's internal knowledge more concrete and transferable and ultimately improving open innovation (Cui et al., 2012). Additionally, the capabilities enable a firm to achieve economics of reuse and decrease search cost by reconfiguring internal knowledge to fit new situations (Liang et al., 2015), which ameliorates the impact of internal knowledge-oriented approach on open innovation. This leads to the following hypothesis:

H4a: IT capabilities to support internal activities have a positive impact on the relationship between the internal knowledge-oriented approach and open innovation.

Firms tend to rely on knowledge from a variety of external sources to provide innovative products and services (Pateli and Lioukas, 2019). IT capabilities that support external activities help firms form innovation networks with their partners, customers, and suppliers (Gordon et al., 2008). These capabilities enable the firm to acquire new and fresh knowledge that they previously lacked (Joshi et al., 2010). For example, Dell, a major personal computer manufacturer, acquires new ideas and knowledge and delivers innovative products and services based on the ideas and knowledge through online communities called "Dell IdeaStorm" (Gangi and Wasko, 2010). In addition, IT capabilities for external activities support render external knowledge more concrete and fluid, thus facilitating knowledge flow across of the firm's boundaries (Cui et al., 2012; Liang et al., 2015). Improved knowledge flow affects the accumulation of new knowledge and expands the firm's knowledge base, and eventually increases open innovation (Wu and Shanley, 2009).

The impact of external knowledge-oriented innovation approach on open innovation will be intensified when IT capabilities for external activities support is high. Assimilation and integration of external knowledge into a firm's existing knowledge are very important for open innovation (Laursen and Salter, 2006) because the potential value of external knowledge is realized only when its functionality is well assimilated and integrated within the innovation processes and activities of the firm (Sher and Lee, 2004). Time and efforts for assimilation and integration of external knowledge with other activities and processes of a firm can be alleviated by codifying and sharing with IT because individuals of the firm can easily integrate their knowledge with new ideas and knowledge accessed through communication with individuals outside their firm using IT (Teigland and Wasko, 2003). IT capabilities that

support external activities decreases adjustment and coordination costs of the knowledge (Greenstein, 1996), which enhances the impact of external knowledge-oriented approach on open innovation. We therefore propose:

H4b: IT capabilities supporting external activities have a positive impact on the relationship between the external knowledge-oriented approach and open innovation.

Ⅳ. Research Methodology

4.1. Development of Measurement

Research constructs were operationalized based on each construct's own definition as well as that of relevant constructs in the literature. We used existing measurement with some modification to suit the context of this study. All measures employed multiple items with a seven-point Likert scale that ranges from "extremely low (1)" to "extremely high (7)." <Table 1> shows the operational definitions of the research constructs and their related literature; the details of all measures used in this study is provided in <Appendix B>.

It is important to control factors that may influence the relationship between innovation approaches and innovation performance. First, firm age, measured by the number of years a firm has existed, was controlled because it is positively associated with firms' ability to implement and capitalize on their innovation (Cui et al., 2015). Second, industry type was also controlled because different industry environments can affect innovation performance (Joshi et al., 2010).

<Table 1> Operational Definitions and Related Literature

Construct	Operational Definition	Key Studies
Internal knowledge-oriented innovation approach	The degree to which a firm depends on its internal knowledge for innovation (e.g., products, services, or processes).	(Bierly and Chakrabarti, 1996; Ham et al., 2017; Teigland and Wasko, 2003)
External knowledge-oriented innovation approach	The degree to which a firm acquires and uses knowledge from outside the firm for innovation (e.g., products, services, or processes).	(Ham et al., 2017; Prabhu et al., 2005; Zahra and Nielsen, 2002)
IT capabilities for internal activities support	The degree to which a firm's internal activities for innovation is supported by the use of IT.	(Choi et al., 2010; Liang et al., 2015; Sabherwal and Chan, 2001)
IT capabilities for external activities support	The degree to which a firm's external activities for innovation is supported by the use of IT.	(Choi et al., 2010; Liang et al., 2015; Rai and Tang, 2010)
Innovation performance	The degree of more flexible product/service provision; having faster, newer, product/service provision; having a higher-quality product/service provision; having a larger market share in comparison with major competitors.	(Urgal et al., 2013; Ham et al., 2017)
Age	The number of years a firm has existed	(Zahra and Nielsen, 2002)
Industry type	0 if the firm belongs to the service industry	(Cassiman and Veugelers, 2006)
	1 if the firm belongs to the manufacturing industry	
	2 if the firm belongs to the finance industry	

<Table 2> Sample Characteristics

(a) Industry

Industry Type	Number of Firms	Percent (%)	Cumulative Percent (%)
Manufacturing	155	45.6	45.6
Finance	49	14.5	60.1
Service	135	39.9	100
Total	339	100	

(b) Size

Firm Size	Frequency	Percent (%)
Less than 100	41	12.1
100 to below 500	170	50.1
500 to below 3000	95	28.0
3000 and above	33	9.8
Total	339	100.00
Median: 321		

(c) Age

Firm Age	Frequency	Percent (%)
Less than 10	47	13.9
10 to below 30	138	40.7
30 to below 50	113	33.3
More than 50	41	12.1
Total	339	100.00
Mepdian: 28		

4.2. Sampling and Data Collection

In this study, 1,000 firms with less than 500[6] employees and 1,000 companies with more than 500 were identified from the Annual Corporation Report in Korea. Survey questionnaires were mailed to executives who are responsible for innovation or to the owners. One week after the initial distribution, a follow-up postcard was mailed. To boost the response rate, the same questionnaires were mailed again 4 and 7 weeks later. A total of 354 companies replied, yielding a response rate of 17.7%. Due to incomplete data, 15 responses were eliminated, leaving 339 responses for the final analysis.

As shown in <Table 2>, the median organization in the sample has 321 total employees and an age of 28 years. Respondents from a diverse set of industries are represented. Samples are divided into three industry types: manufacturing (45.6%), services (39.9%), and financial (14.5%). In terms of firm size, 211 firms have less than 500 employees (62.2%) and 128 firms have 500 employees or more (37.8%). In terms of firm age, 41 firms (12.1%) have been established for more than 50 years.

4.3. Testing Approach

This study directly estimates the contribution of the combination of two innovation approaches (i.e., internal knowledge- and external knowledge-oriented) to innovation performance by using supermodularity and submodularity based on the productivity approach[7] (Mohnen and Roller, 2005). To formalize the hypotheses, a general production function for the firm is specified: the firm maximizes

6) Many studies have categorized firms with less than 500 employees as SMEs and 500 employees and more as large-sized firms (Bonaccorsi, 1992).

7) Testing for complementarity and substitutability can be achieved by the correlation approach or productivity approach. Unlike the former approach, the latter can give a statistical resolution for complementarity and substitutability and, thus, has been widely used in recent empirical work (Cassiman and Veugelers, 2006; Mohnen and Roller, 2015).

an innovation performance measure $f(x)$ with respect to the vector of two innovation approaches x = (internal knowledge-oriented, external knowledge-oriented).

Because innovation approaches are continuous variables, the interaction terms can be used in the regression framework to test for the sign of the interaction parameters (Mohnen and Roller, 2005). When the practices are measured by continuous values, the following definition of complementarity holds:

$$f(x_1, x_2) = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_{12} x_1 x_2 \quad (2)$$

$f(x)$ is innovation performance for firm i measured as the subjective self-reported items and is a widely used measure of innovation performance (Mohnen and Roller, 2005). Thus, $a_{12} > 0$ (i.e., the coefficient of partial derivatives $\partial^2 f / \partial x_1 x_2$ is positive), implies that complementarity exists for internal knowledge-oriented and external knowledge-oriented innovation approaches, whereas $a_{12} > 0$ means substitutability for the two approaches.

Ⅴ. Analysis and Discussion

5.1. Reliability and Validity

Content validity of the survey instrument was established through the adoption of an instrument that has already been used and validated by other researchers and through a pretest with several professionals in the open innovation area. Cronbach's alpha was used to assess the reliability of the instruments. A higher cutoff value of 0.7 was adopted as it had been adopted previously (Nunnally, 1978). To test convergent validity, items that have item-to-total correlation scores lower than 0.5 were

<Table 3> Reliability and Validity Tests

Measure	Items	Mean	S.D (Standard Deviation)	Reliability (Cronbach's Alpha)	Convergent Validity (Correlation of item with total score-item)	Discriminant Validity (Factor loading on single factors)
Internal knowledge-oriented innovation approach (IKO)	4	3.86	1.25	0.932	0.858, 0.855 0.847, 0.802	0.830, 0.841 0.773, 0.845
External knowledge-oriented innovation approach (EKO)	4	3.58	1.06	0.840	0.681, 0.697 0.608, 0.707	0.923, 0.921 0.916, 0.886
IT capabilities for internal activities support (ITI)	6	4.54	0.93	0.881	0.709, 0.682 0.835, 0.728 0.822, 0.552	0.811, 0.788 0.907, 0.834 0.904, 0.563
IT capabilities for external activities support (ITE)	4	4.12	0.69	0.811	0.583, 0.729 0.624, 0.611	0.761, 0.868 0.795, 0.785
Innovation performance (IP)	4	3.99	0.87	0.880	0.788, 0.752 0.704, 0.721	0.889, 0.868 0.832, 0.844
Age (AGE)	1	29.4	16.62	NA	NA	NA
Industry types (INT)	1	0.74	0.69	NA	NA	NA

<Table 4> Factor Analysis

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
IKO 1	.013	**.815**	.264	.217	.265
IKO 2	.024	**.850**	.237	.205	.162
IKO 3	.049	**.830**	.299	.144	.217
IKO 4	.045	**.787**	.210	.187	.275
EKO 1	.076	.353	.162	.240	**.674**
EKO 2	.084	.280	.215	.178	**.717**
EKO 3	.082	.068	.143	.150	**.801**
EKO 4	.194	.314	.132	.197	**.729**
ITI 1	**.805**	-.010	.001	.065	.078
ITI 2	**.784**	.056	-.076	.070	.043
ITI 3	**.910**	-.022	.013	-.018	.050
ITI 4	**.834**	.067	.013	.009	.040
ITI 5	**.903**	-.017	.066	.021	.056
ITI 6	.544	.058	.080	.123	.102
ITE 1	.081	.065	-.055	**.745**	.182
ITE 2	.058	.173	.035	**.836**	.142
ITE 3	.080	.150	.049	**.782**	.102
ITE 4	.032	.195	.068	**.736**	.156
IP 1	.076	.296	**.830**	.065	.107
IP 2	.002	.237	**.828**	.049	.096
IP 3	.054	.169	**.797**	.030	.168
IP 4	-.035	.136	**.823**	-.040	.180
Variance Explained (%)	32.16	17.33	10.88	5.55	5.26
Cumulative Variance (%)	32.16	49.49	60.37	65.92	71.18

dropped from further analysis. Results of the unidimensional validity and reliability tests confirm that all constructs have satisfactory convergent validity. Factor analysis with varimax was used to check discriminant validity (Kerlinger, 1986). The factors were extracted with the threshold of Eigen value greater than 1. Items with factor loading values lower than 0.5 were deleted. <Table 3> shows the test results of the reliability and validity, and <Table 4> presents the results of factor analysis.

5.2. Results

Multiple hierarchical analysis is used to test hypotheses. In step 1, only control variables (industry and age) were entered into the regression model. Step 2 included both the control variables and internal knowledge- and external knowledge-oriented approaches variables. In step 3, the interaction term was added to the previous model. <Table 5> reports a summary of the analysis results.

<Table 5> shows that firm age and industry type

<Table 5> Analysis Results for Innovation Approaches and Innovation Performance

Variable	Large firms			SMEs		
	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
Constant	4.504	4.480	4.549	3.677	2.587	1.744
Step 1						
Age	-0.006	-0.003	-0.003	0.006	0.004	0.003
Industry type	-0.004	-0.060	-0.069	-0.017	0.026	0.030
Step 2						
IKO		0.473**	-0.489		0.271**	0.513**
EKO		0.499**	-0.535		0.039	0.329*
Step 3						
IKO X EKO			0.242*			-0.075*
F - Value	0.970	28.925**	25.057**	1.097	17.201**	15.076**
Adjusted R^2	0.000	0.468	0.486	0.001	0.236	0.251
Change in R^2		0.468	0.018		0.235	0.016
Partial F (Change in R^2)		56.025**	5.424*		32.968**	5.180*

Note: $^{+}p < 0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$

in both large firms and SMEs were not related to innovation performance. The analysis found that the internal knowledge-oriented approach significantly affected firms' innovation performance ($\beta = 0.473$, $p < 0.01$) for large firms. The results thus provide strong support for Hypothesis 1a, which stated that the internal knowledge-oriented innovation approach positively affects the innovation performance of large firms. For SMEs, the internal knowledge-oriented innovation approach was found to have a positive impact on innovation performance ($\beta = 0.271$, $p < 0.01$). This result supports Hypothesis 1b. For large firms, the external knowledge-oriented approach was also positively and significantly related to firms' innovation performance ($\beta = 0.499$, $p < 0.01$), which supports Hypothesis 2a. However, the external knowledge-oriented approach for SMEs did not significantly affect firms' innovation performance ($\beta = 0.039$, $p > 0.1$), thus rejecting Hypothesis 2b.

For large firms, there was complementarity between internal and external knowledge-oriented approaches. Adding the interaction terms significantly improved the results from step 2 ($\beta = 0.242$, $p < 0.01$). Hypothesis 3a posited that open innovation (i.e., pursuing both internal and external knowledge-oriented approaches simultaneously) is positively associated with large firms' innovation performance. <Table 5> strongly supports this prediction. For SMEs, substitutability was found between the internal and external knowledge-oriented approaches. The interaction term between internal and external knowledge-oriented approaches was negative and significant ($\beta = -0.075$, $p < 0.05$), which supports Hypothesis 3b. This finding hints that the open innovation approach might not be profitable for SMEs.

The moderating effects of IT capabilities were analyzed to identify the role of IT capabilities in open innovation and the results are shown in <Table 6>. For this purpose, the direct effects of IT capabilities

<Table 6> Analysis Results for IT Capabilities and Open Innovation

Variables	IT capabilities for internal activity support			Variables	IT capabilities for external activity support		
	Step 1	Step 2	Step 3		Step 1	Step 2	Step 3
Constant	13.459	-9.047	0.934	Constant	13.459	-10.052	-0.626
Step 1				Step 1			
Age	0.039	-0.015	-0.012	Age	0.039	0.008	0.014
Industry	0.044	0.403	0.399	Industry	0.044	-0.264	-0.261
Step 2				Step 2			
IKO		5.265**	2.476**	EKO		5.964**	3.106**
ITI		0.769**	-1.454*	ITE		0.798*	-1.678+
Step 3				Step 3			
IKO X ITI			0.611**	EKO X ITE			0.718**
F - Value	1.288	320.1***	272.7***	F - Value	1.288	289.2**	240.5**
Adjusted R^2	0.002	0.791	0.801	Adjusted R^2	0.002	0.773	0.780
Change in R^2		0.786	0.011	Change in R^2		0.768	0.007
Partial F (Change in R^2)		634.1**	17.94**	Partial F (Change in R^2)		572.7**	11.01**

Note: $^{+}p < 0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$

on open innovation were analyzed first. The analysis found that both IT capabilities for internal activity support ($\beta = 0.769$, $p < 0.01$) and IT capabilities for external activity support ($\beta = 0.798$, $p < 0.05$) have a positive impact on open innovation. Next, the moderating effect of IT capabilities for internal activity support on the relationship between internal knowledge-oriented approach and open innovation was analyzed.

The analysis showed that the effect of internal knowledge-oriented approach on open innovation is significantly higher under higher than lower IT capabilities for internal activity support ($\beta = 0.611$, $p < 0.01$). Therefore, Hypothesis 4a is accepted. In a similar way, the moderating effect of IT capabilities for external activity support on the relationship between the external knowledge-oriented approach and open innovation was analyzed. The results strongly support that the effect of the external knowledge-oriented approach on open innovation is significantly higher under higher than lower IT capabilities for external activity support ($\beta = 0.718$, $p < 0.01$), which supports Hypothesis 4b.

5.3. Discussion

The results support Hypothesis 1a. Some studies suggest that an excessive internal knowledge-oriented approach leads to behavior that is blind to new knowledge or capabilities, exhibiting a dysfunctional downside that inhibits innovative progress (Leonard-Barton, 1992). However, the results of this study indicated that internal knowledge-oriented approach on innovation performance. By focusing on internal knowledge, firms can create their own core competencies that are difficult for competitors to imitate and thereby improve their innovation performance (Menon and Pfeffer, 2003). Therefore, the firms can

improve their products and services systematically using an internal knowledge-oriented approach can outperform firms that do not use this approach. Our results support Hypothesis 1b; that is, adopting an internal knowledge-oriented approach yields higher innovation performance in SMEs. Even though some studies insist that SMEs attempt to adopt an internal knowledge-oriented approach are likely to be at a disadvantage due to lack of resources and capital constraints (Brunswicker and Vanhaverbeke, 2015; Van de Vrande et al., 2009), our results show a positive impact of the internal knowledge-oriented approach on SMEs' innovation performance. Focusing on the internal knowledge-oriented approach enables SMEs to develop core competencies based on an in-depth understanding of their unique knowledge (Ebben and Johnson, 2005). Thus, SMEs rich in internal knowledge can achieve significantly greater innovation (Laursen and Salter, 2006).

Our test results suggest clear evidence of a positive impact of the external knowledge-oriented approach on innovation performance in large firms, which supports Hypothesis 2a. Some studies claim that external knowledge-oriented approach has a negative impact on innovation performance due to difficulties in integration and coordination with existing knowledge (Kessler et al., 2000). However, the analysis shows that the external knowledge-oriented approach has a positive effect on innovation performance. Firms that employ an external knowledge-oriented approach produce dynamic and heterogeneous knowledge that provides fresh ideas and knowledge to the firm, leading to improved outcomes (Schulz, 2001). Contrary to our expectation, Hypothesis 2b is not supported. The results show that the external knowledge-oriented approach for innovation in SMEs does not significantly affect innovation performance. This interesting result could be explained using the concept of the buy-in syndrome (Lichtenthaler and Ernst, 2006) in which external knowledge is overestimated. SMEs use external knowledge to obtain necessary knowledge to achieve the success of innovation. However, relying too much on an external knowledge-oriented approach leads SMEs to a loss of differentiation from their competitors, which could be detrimental for innovation performance (Lichtenthaler and Lichtenthaler, 2009).

The testing results support Hypothesis 3a; that is, a positive impact of using an open innovation approach (i.e., internal and external knowledge-oriented approaches together) on the innovation performance of large firms. The results are in line with prior literature emphasizing a firm's organizational capabilities such as "combinative capabilities" (Van den Bosch et al., 1999) and "architectural competence" (Henderson and Cockburn, 1994), which conceptualize the value of integrating both innovation approaches. Such integration enables firms to have a wider range of knowledge sources and adaptive responses, leading to an ability to exploit their cumulative knowledge and explore a broader set of external knowledge (Parmigiani and Mitchell, 2009). Our results show a negative impact of using an open innovation approach on innovation performance in SMEs as expected. SMEs suffer from a lack of capital, management expertise, and absorptive capacity (Forbes and Milliken, 1999). Although the integration of different knowledge sources is essential for innovation, high levels of knowledge sourcing in many areas are costly and, thus, often unrealistic for SMEs (Lee et al., 2010). Therefore, SMEs that attempt to combine internal with external knowledge-oriented innovation approaches tend to be at a disadvantage, resulting in lower innovation performance.

The analysis supports Hypothesis 4a; in other words, the impact of internal knowledge-oriented

approach on open innovation differs depending on the level of IT capabilities for internal activity support. Some researchers argue that a high level of IT capabilities for supporting internal activities increases the potential for knowledge leaking across porous boundaries (Haas and Hansen, 2005) and preventing a firm from participating in open innovation. However, the analysis results of this study show that IT capabilities for internal activities provides fast and reliable access to organizational knowledge within the firm and expands the firm's knowledge base, thereby enhancing open innovation through efficient reuse of the firm's internal knowledge (Cui et al., 2015). The results support Hypothesis 4b; that is, the positive impact of an external knowledge-oriented approach is intensified with IT capabilities for supporting external activities. Some studies insist that the potential benefits of an external knowledge-oriented approach could be decreased (Haas and Hansen, 2005) because depending too much on IT capabilities for external activities support can exceeds the firm's current absorptive capacity (Wu and Shanley, 2009). However, our results reveal that a high level of IT capabilities that support external activities help a firm identify relevant knowledge even if it is located in distant domains, thus intensifying the positive effect of external knowledge-oriented approach on open innovation (Joshi et al., 2010). This result is consistent with previous studies that suggest IT capabilities, including exploratory learning, transformative learning, exploitative learning, and social integration, play a moderating role in a firm's open innovation (Cui et al., 2012).

5.4. Implications

The results of this study have several implications for researchers. First, this paper contributes to the literature on open innovation by answering the question on the conditions under which internal and external knowledge-oriented approaches work well together; that is, how firm size influences the adoption pattern of innovation approaches through comparing large firms and SMEs. Although earlier studies have shown that firm size is one of the key conditions in an organization's context that impacts innovation, they have mostly focused on the innovation of large firms (Bogner and Bansal, 2007). Because SMEs are already deficient in expertise and resources compared with their large competitors, there are potential differences between the two different groups in the patterns of adopting innovation approaches (Brunswicker and Vanhaverbeke, 2015; Van de Vrande et al., 2009). The findings of this study can serve as a stepping stone for identifying the conditions that affect the adoption pattern of innovation approaches to improve innovation performance.

Second, this study contributes to the existing literature on open innovation by examining the impact of three different approaches on innovation performance. Although the idea that firms can use internal and external knowledge-oriented approaches together to improve the performance of innovation is widely accepted (Huizingh, 2011; Zhou and Li, 2012), little research has demonstrated the impact of adopting the two approaches together (i.e., open innovation) on innovation performance. Most prior studies have tended to examine the independent effects of internal knowledge- and external knowledge-oriented approaches on innovation performance without considering their combined impact. This study analyzes not only the independent effects of these two different approaches but also complementary or substitutable effects of them on innovation performance. In addition, this study uses the productivity approach to analyze the synergistic

effect of innovation approaches. The productivity approach is believed to provide statistical resolution for the complementarity test.

Third, this study extends existing knowledge by investigating the moderating role of IT capabilities in open innovation. Existing research has focused on identifying the direct effects of IT capabilities on open innovation (Cui et al., 2012; Liang et al., 2015). In contrast, this study has contributed to expanding our understanding of the role of IT in open innovation by examining how IT capabilities can influence the relationship between internal and external knowledge-oriented approaches and open innovation. The results imply that firms focusing on internal and external knowledge-oriented approaches obtain benefits significantly in open innovation, especially when IT capabilities for supporting internal and external activities is high. Thus, firms that want to improve innovation performance should enhance their ability to acquire, distribute, and leverage IT resources including software and hardware (Bhatt and Grover, 2005).

This study also bears some implications for practitioners. One implication is the complementarity between internal and external knowledge-oriented innovation approaches for large firms. Such synergistic interactions might prove particularly valuable for improving innovation performance because increasing the level of one approach leads to higher marginal return from increasing the level of the other (Liang et al., 2015; Prabhu et al., 2005). Although firms can improve innovation performance by promoting each approach separately, adopting internal and external knowledge-oriented approaches together yields higher innovation performance (Lichtenthaler and Lichtenthaler, 2009). Therefore, managers of large firms can improve innovation performance by understanding the critical role of combining these two approaches in their innovation processes.

Another implication is for managers in SMEs. Our finding suggests that adopting both internal and external knowledge oriented innovation approaches for SMEs decreases firm performance. This study also finds that they can benefit from an internal knowledge-oriented approach. On the basis of these two results, it is apparent that managers of SMEs should focus on innovation from the internal knowledge-oriented strategic viewpoint. Pursuing a single innovation approach would be more beneficial because they have relatively less financial budget and resources. Moreover, managers of SMEs with a single innovation approach can improve their firms' adeptness in managing knowledge for innovation in a much easier and more cost-efficient manner by continuously working on their specific approach to innovation (Ebben and Johnson, 2005).

The final implication for practitioners is that using appropriate IT capabilities is critical for open innovation. IT capabilities encourage effective collaboration among organizational members by facilitating knowledge flow within a firm and enable a firm to integrate internal knowledge with external knowledge effectively by promoting knowledge exchanges with external partners, resulting in "shaped" open innovation (Kleis et al., 2012). Managers who are eager to achieve higher performance through implementing open innovation have to shape their IT capabilities for both internal and external activities support.

Ⅵ. Conclusion

Understanding how to utilize innovation approaches, i.e., internal knowledge, external knowledge, and open innovation, is important for a firm

to gain competitive advantage. To provide a comprehensive view of the impact of innovation approaches on innovation performance, this study investigated the performance implications of different approaches of innovation drawing on the complementarity theory. The results suggest that successful innovation approaches differ depending on firm size. While a combination of internal and external knowledge-oriented approaches in large firms is complementary, it is substitutional in the case of SMEs, reflecting the importance of firm size in implementing open innovation. This study provides managerially useful results by considering three different innovation approaches and reflecting on the open innovation reality in the business environment.

Worth noting are the several limitations of this study, some of which propose opportunities for future research. First, this study uses self-reported performance. Because the complementary relationship is very sensitive to the performance measure, different types of performance measures, such as development time and cost, may sharpen the results. Second, this study does not consider the feedback effect between innovation approaches and innovation performance as it uses cross-sectional data. Researchers should use longitudinal data in order to understand fully the impact of innovation approaches on innovation performance. Third, because this study focuses on the effects of innovation approaches and IT capabilities on innovation performance, a comprehensive list of potential factors that may affect innovation performance are not covered. Thus, a study that considers other factors, such as leadership, social capital, and culture, would be of interest. Fourth, the data used in this study including innovation approaches, IT capabilities, and innovation performance, are gathered from a single key informant. A study using multiple respondents would provide more robust results. Finally, the results are restricted to Korean firms. The generalizability to other countries may, therefore, be questionable. Clearly, replication of this study in other countries would be helpful to broaden the generalizability of our findings.

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<Appendix A> Review of Key Extant Studies on Different Innovation Approaches

Innovation Approach	Main Arguments	Selected Studies				
		Researchers	Firm Size	IT Capabilities	Theories	Research Method
Closed innovation (Internal knowledge-oriented)	An internal knowledge-oriented innovation emphasizes the importance of managing knowledge and competencies flow inside the firm over time to increase performance.	Bogner and Bansal (2007)	Large firms	N/A	KBT	Empirical
		Bougrain and Haudeville (2002)	SMEs	N/A	Absorptive capacities (Implicitly)	Case study
		Joshi et al. (2010)	All size	IT-enabled social integration	Absorptive capacity	Empirical
		Kmieciak et al. (2012)	SMEs	IT capability	RBT	Empirical
		Leiponen (2006)	All size	N/A	Theory of knowledge	Empirical
		Zhou and Li (2012)	All size	N/A	KBT	Empirical
External knowledge-oriented innovation	An external knowledge-oriented innovation stresses the importance of knowledge flow by focusing on accessing and absorbing external knowledge, leading to improved outcomes.	Calia et al. (2007)	SMEs	N/A	Network theory	Case study
		Cui et al. (2015)	All size	IT flexibility IT integration	IT alignment	Empirical
		Dittrich and Duysters (2007)	Large firms	N/A	Learning theory	Case study
		Fey and Birkinshaw (2005)	Large firms	N/A	RBT KBT	Empirical
		Kang and Kang (2014)	SMEs	N/A	Knowledge sourcing	Empirical
		Vega-Jurado et al. (2009)	All size	N/A	RBT	Empirical
Open innovation (both internal knowledge- and external knowledge-oriented)	Open innovation enables a firm to substantially improve outcome through combination of newly acquired external knowledge with existing internal knowledge.	Cassiman and Veugelers (2006)	All size	N/A	Complementarity	Empirical
		Chen et al. (2016)	All size	N/A	Knowledge sourcing	Empirical
		Dodgson et al. (2006)	Large firms	IvT (innovation technology)	Theory of innovation	Case study
		Dufour and Son (2015)	SMEs	Knowledge management systems	Organizational change	Case study
		Ham et al. (2017)	SMEs	N/A	KBT	Empirical
		Hoang and Rothaermel (2010)	Large firms	N/A	Dynamic capabilities	Empirical

Based on knowledge sourcing origin, past research on innovation can be classified into three categories (see <Appendix A>). The first category primarily focus on internal knowledge for a firm's innovation. The internal knowledge-oriented innovation (i.e., closed innovation) emphasizes the importance of managing knowledge and competencies flow inside the firm over time to increase performance (Bogner and Bansal, 2007). For example, Bougrain and Haudeville (2002) found that internal knowledge enhanced the firm's ability to co-operate and led to successful innovation.

In contrast to the first category of studies, the second category studies consider external knowledge as a crucial driver for a firm's innovation performance (Kang and Kang, 2014). The external knowledge-oriented innovation stresses the importance of knowledge flow by focusing on accessing and absorbing external knowledge, leading to improved outcomes. For example, Fey and Birkinshaw (2005) insisted that external knowledge increased the likelihood of superior innovation performance. The studies under the third category concentrate on both internal and external knowledge to increase a firms' innovation performance. Open innovation (i.e., both internal knowledge- and external knowledge-oriented) enables a firm to substantially improve outcome through combination of newly acquired external knowledge with existing internal knowledge (Cassiman and Veugelers, 2006). For example, Hoang and Rothaermel (2010) observed that a firm's internal knowledge had positive effects on innovation performance when coupled with external knowledge.

The synthesis of prior studies reveals some observations. First, although many studies have put their emphasis on the effective use of internal and external knowledge, integrated discussion on how closed innovation, external knowledge-oriented innovation, and open innovation affect innovation performance is very rare. Second, many studies have focused on the phenomenon of open innovation in large firms (Bogner and Bansal, 2007). Recently, some studies have begun to focus on the phenomenon of open innovation in small and medium enterprises (SMEs) (Ham et al., 2017) by arguing that SMEs' open innovation approaches are not scaled-down versions of larger firms' approaches (Kmieciak et al., 2012). However, questions of the firm size conditions under which innovation approaches show superior innovation performance are not well addressed. Third, the roles of IT capabilities in open innovation have received relatively little attention. Although recent studies are determining the direct impact of IT capabilities on open innovation (Cui et al., 2015; Liang et al., 2015), these studies fail to show how the effects of the development, acquisition, and utilization of internal and external knowledge on open innovation change depending on the IT capabilities.

<Appendix B> Questionnaire Items

Variables	Items
Internal knowledge-oriented innovation approach	To create and develop new knowledge for new innovations, my company frequently uses knowledge from… 1. … colleagues. 2. … internal documents. 3. … existing products/service. 4. … internal forums/(electronic) communities.
External knowledge-oriented innovation approach	A large portion of new knowledge for innovation in my company comes… 1. … from customers. 2. … from suppliers. 3. … from collaboration and alliance with external institutions or organizations. 4. … from external consultants.
IT capabilities for internal activities support	Generally speaking, IT capabilities of my company… 1. … improve the efficiency of our day-to-day business operation. 2. … support effective coordination across functions. 3. … provide us with the facts and figures we need to support our day-to-day decision making. 4. … enable us to develop detailed analyses of our present business situation. 5. … provide sufficiently detailed information to support prudent decision making. 6. … support detailed analyses of major business decisions.
IT capabilities for external activities support	Generally speaking, IT capabilities of my company… 1. … provide seamless connection with external business partners (e.g., suppliers, customers, or experts). 2. … enable us to exchange real-time information with external business partners (e.g., suppliers, customers, or experts). 3. … easily aggregates relevant information from external business partners (e.g., suppliers, customers, or experts). 4. … enable us to search and access necessary information from external business partners (e.g., suppliers, customers, or experts).
Innovation performance	Compared with key competitors, my company 1. … provides a wider range of products/services. 2. … provides a new product/service more quickly. 3. … provides a higher quality of product/service. 4. … has a greater market share.
Age	The number of years a firm has existed.
Industry type	0 if the firm belongs to the service industry 1 if the firm belongs to the manufacturing industry 2 if the firm belongs to the finance industry

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