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# How Does the Use of External Knowledge Influence Innovative Performance of Service Firm? An Introductory Study of Openness and Service Innovation

**SEONGWUK MOON***
*Sogang University*
*Seoul, Korea*

## Abstract

This study examines how the use of external knowledge influences innovative performance of Korean service firms. Especially, this study underscores whether the relationship between external knowledge and innovation in Korean service industries differs from the relationship in Korean manufacturing industries found by Moon (2011). Using 2006 Korean Innovation Survey in service sector, this study tests whether the use of external knowledge improves innovative performance and how absorptive capacity, new startup and appropriation methods moderate the effect of the use of external knowledge on Korean service firms' innovation. The relationship between openness and innovative performance in service is different from that in manufacturing in Korea: First, openness in service is more effective for radical innovation than for incremental innovation; in contrast, openness in manufacturing was more effective for incremental innovation than for radical innovation. Second, there is no complementarity between openness and R&D intensity in the service sector; in contrast, there existed the complementarity for incremental innovation in the manufacturing sector. Third, when a firm uses too many appropriation methods, openness of service firms is not effective. Lastly, the quality of human capital is important for service innovation while it was not for manufacturing innovation in Korea.

Keywords: Openness to External Knowledge, Types of Innovation, Innovation Performance, and Korean Service Firms

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* Associate professor; The Graduate School of Management of Technology, Sogang University, 35 Baekbeom-ro, Mapo-gu, Seoul, Korea, 121-742; seongwuk@gmail.com

## 1. INTRODUCTION

This study examines the relationship between openness to external knowledge and innovation performance of service firms in Korea. The recent development in the organization of innovation process – so called 'open innovation' – highlights that strategic use of external knowledge contributes to innovation more than 'closed' use of internal knowledge does (Chesbrough 2003). Although the notion of open innovation gets growing attention very rapidly, the evidence based on a large-scale data of how opening up firms' innovation process impacts innovation performance is not sufficient (Laursen and Salter 2006).

Recently researchers have examined the role of openness to external knowledge in manufacturing industries and obtained some patterns in the relationship between openness to external knowledge and manufacturing innovation. In their influential paper, Laursen and Salter (2006) show that the openness to external knowledge significantly increases the innovative performance of UK manufacturing firms. Especially, the authors report that the openness to external knowledge and innovative performance has a curvilinear relationship. Laursen and Salter (2006) also report that the effect of openness to external knowledge sources varies depending on the types of innovation. Openness seems to be more effective when a firm generates incremental innovation rather than radical innovation. Their findings have been confirmed in manufacturing industries of other countries as well. For instance, Vega-Jurado, Gutiérrez-Gracia, and Fernández-de-Lucio (2009) show that the "external knowledge sourcing strategies" influence the types of innovation of Spanish manufacturing firms; Moon (2011) confirms that the use of external knowledge is more important for incremental innovation than for radical innovation in Korean manufacturing industries.

However, will openness to external knowledge influence innovation of service firms similarly? The role of external knowledge in service innovation may be different from that in manufacturing innovation because service activities are highly dependent on the external source of knowledge and technology, non-technological innovation is more important in service innovation, and human capital has more important role in service innovation (Kim and Youn 2010;

OECD 2005; Pavitt1984). It is also reported that the type of external specialists contacted by service firms differs from that contacted by manufacturing firms (Tether and Tajar 2008).

This study examines how the openness to external knowledge affects innovative performance of Korean service firms, and whether the relationship between openness and service innovation differ from the relationship between openness and manufacturing innovation. This study will adopt the same analytical framework that was used to examine innovation of Korean manufacturing firms (Moon 2011) in order to compare results in service industries with those in manufacturing industries. In other words, this study examines the effect on service innovation of external knowledge use and other strategic variables such as absorptive capacity, new startup and use of appropriation methods. Because Korean Innovation Surveys (KIS) on service industries and on manufacturing industries were conducted differently, the implicit comparison adopted by this study is believed to be an insufficient but worthwhile introduction to examine the difference between service and manufacturing innovation.

This study confirms that the effect of external knowledge use on innovation performance is different depending on whether firms are operating in service industries or in manufacturing industries.[1)] First, openness in service sector is more effective for radical innovation than for incremental innovation while openness in manufacturing sector was more effective for incremental innovation than for radical innovation (Moon 2011). Second, there is no complementarity between openness and R&D intensity in service sector; in contrast, there was the complementarity for incremental innovation in manufacturing sector (Moon 2011). Third, the intense use of appropriation method influences the relationship between openness and radical innovation negatively in service sector; it did not in manufacturing sector (Moon 2011). Fourth, being a startup is associated with service innovation positively regardless of types of innovation. However, being a startup was complicatedly associated with manufacturing innovation: being a startup was positively

1) Some similarities between service innovation and manufacturing innovation are also found: The broad use of external knowledge sources is effective for innovative performance both in Korean service industries and in Korean manufacturing industries while the intensive use of each external source is not. In this paper, however, the difference is highlighted.

associated with radical manufacturing innovation while negatively associated with incremental manufacturing innovation (Moon 2011). Fifth, the quality of human capital is much more important for service innovation than for manufacturing innovation.

This paper is organized as follows: Section 2 develops hypotheses to be tested. Section 3 explains data and measures used in this study. Section 4 presents empirical results. Section 5 is a conclusion.

## 2. HYPOTHESES

It has been reported that research on the relationship between openness and types of innovation such as radical and incremental innovations is insufficient (Laursen and Salter 2006). Many radical innovations have significant discontinuity with existing products in the markets. They are frequently associated with scientific knowledge advancing outside a firm or require highly concentrated relationship with universities and public research institutions (Hounshell, Rosenbloom and Spencer 1996; Rosenberg 1990). In contrast, incremental innovation seems to be associated with a broad range of knowledge base. Incremental innovations become more frequent after the dominant design has emerged because diverse external knowledge help generating 'finely-tuning' innovations based on the dominant design (Laursen and Salter 2006; Moon 2011; Utterback 1994). In their study on UK manufacturing firms, Laursen and Salter (2006) show that the "breadth" of openness (i.e., the number of external sources that an innovating firm uses) and the "depth" of openness (i.e., the degree of intense use of external sources by an innovating firm) are distinctly related to incremental innovation and radical innovation. Moon (2011) also finds the effect of openness breadth varies depending on the type of innovations in Korean manufacturing firms. I expect that the openness breadth and openness depth are important for service innovation, and that openness is more important for radical innovation than incremental innovation. This is because new service highly depends on how to reconfigure diverse external knowledge and the recombination of the external knowledge is more likely to generate new-to-the-world service (Kim and Youn 2010; OECD 2005; Pavitt1984) (Hypothesis 1).

> **H1:** The breadth of openness to external knowledge increases innovative performance of service firms, and the openness breadth is more effective when the innovation is radical than when the innovation is incremental. The depth of openness to external knowledge increases innovative performance of service firms, and the openness depth is more effective when the innovation is radical than when the innovation is incremental.

R&D investment has been regarded very important for building up absorptive capacity since the seminal work of Cohen and Levinthal (1989, 1990). Rosenberg (1990) insists that firms invest in basic research with their own money because they want to enhance their ability to assimilate and use external knowledge. Cassiman and Veugelers (2002) show that the internal R&D and external knowledge acquisition are complementary in innovation process. Moon (2011) finds that higher R&D investment is associated with more incremental innovation in Korean manufacturing industries.

However, whether these findings can be extended to service firms is not clear because formal R&D may not be related to better and new service necessarily: the effect of R&D on openness and innovation is an empirical issue. Here, I expect that openness will enhance innovative performance more effectively if a firm invests more in its R&D. Although non-technological innovation is known as important in service innovation, and that the type of external specialists contacted by service industries differs from that contacted by manufacturing industries (Kim and Youn 2010; OECD 2005; Pavitt1984; Tether and Tajar 2008), service activities become more connected to technology. The expanding services offered by the smart phone companies with higher R&D can be an example.[2)] If so, R&D can expand the range of service activities that an owner of the technology can provide (Kim and Youn 2010; OECD 2005; Pavitt1984) (Hypothesis 2).

> **H2:** The effect of openness breadth on innovative performance is stronger when R&D intensity is high: when a firm has a high level of R&D intensity, being open to diverse knowledge source becomes more effective for innovative performance. The effect of

2) I am grateful for reviewer2 who requested me to think the implication of the smart phone industry.

openness depth on innovative performance is stronger when R&D intensity is high: when a firm has a high level of R&D intensity, using external knowledge sources intensively becomes more effective for innovative performance.

Whether being a startup enhances the effect of openness on innovation has yet to be sufficiently examined (Chesbrough, Vanhaverbeke and West 2006). There are two possible explanations on the advantage of being a startup to the effect of openness. First, incumbent firms tend not to implement ideas from external sources because they are highly likely to be hierarchical. The firm is more likely to reject external ideas and subject to higher 'type I error' (i.e., rejecting a good external idea) if a firm's structure is hierarchical than if a firm's structure is flat. This is because multiple decision making nodes along internal hierarchy increase the probability of rejection (Sah and Stiglitz 1986). The negative effect of large organization due to organizational inefficiency is also reported by other scholars (Ahuja, Lampert and Tandon 2008; Cohen 2010). Second, a startup tends to have very narrow knowledge base while an incumbent establishes broad knowledge base. Christensen, Olesen and Kjær (2005) examine different behaviors of small entrepreneurs and large incumbents in the consumer electronic industry, and show that small technology entrepreneurs stay with narrow technology base while the large incumbents incorporate external technologies into their products. Therefore, an additional external knowledge source can have differential effect on innovation performance of a startup and an incumbent: it can increase innovation performance of a startup more than that of a large incumbent. Therefore, I expect that openness is a more effective strategy for innovation to new startups compared to established incumbents. If a startup is an important source of radical innovation rather than incremental innovation as the literature suggests (Cohen 2010), being a startup will strengthen the effect of openness on radical innovation (Hypothesis 3).

**H3:** The effect of openness breadth on innovation performance is stronger when a firm is a new startup. The effect of openness depth on innovation performance is stronger when a firm is a new startup. The effect of being a startup is larger for radical innovation than for incremental innovation.

Innovation through openness and collective effort requires both the acquisition of external knowledge and the protection of intellectual property rights on innovation. Especially, without defining how to appropriate created value and protect individual investments in the value creation, collaboration among different organizations can be very difficult (Chesbrough, Vanhaverbeke and West 2006; O'Mahony 2003; Powell and Giannella 2010). Even the open source software development requires sophisticatedly designed intellectual property rights among participants (Lerner and Tirole 2002). Gans and Stern (2003) suggest that how to use formal appropriation mechanisms such as patent is crucial for types of interaction between innovators and incumbents and innovative performance. For instance, "when the innovator controls formal IPR such as a patent, the potential for expropriation will be reduced, and the innovator is likely to find a cooperation strategy more attractive" (Gans and Stern 2003, p.335).

In contrast, firms and institutions can avoid using the protected external knowledge because the cost of using disjointed intellectual property rights for innovation can be high (Powell and Giannella 2010). In his empirical study on Korean manufacturing firms, Moon (2011) also reports that strong appropriation strategy does not seem to enhance the relationship between openness and innovation performance. Thus, I expect that the openness becomes less effective in generating innovation in service when a firm uses too many appropriation methods to protect its innovation (Hypothesis 4).

> **H4:** Using too many appropriation methods reduces the effect of openness breadth on innovation performance: when a firm uses too many appropriation methods to protect its innovation, being open to diverse external knowledge is less effective for innovative performance. Using too many appropriation methods reduces the effect of openness depth on innovation performance: when a firm uses too many appropriation methods to protect its innovation, using external knowledge intensively is less effective for innovative performance.

## 3. DATA AND MEASURES[3)]

### 3.1. Data

The data I use here is from the Korean Innovation Survey (KIS) on service sector. The survey was conducted in 2006. The method and types of questions of the survey are based on the Oslo Manual (2005) by Organization for Economic Co-operation and Development (OECD) and the methods by Eurostat Community Innovation Survey. The KIS survey is approved by the Korean National Statistics as designated statistics and conducted by the Science and Technology Policy Institute (STEPI), a public research institute sponsored by Korean government. Thus, the reliability, validity and international comparability of this survey are established by previous literature using the similar kind of innovation survey (Cassiman and Veugelers 2002; Laursen and Salter 2005; Mairesse and Mohnen 2002).

The population of the KIS is all enterprises with 10 employees or more in the service industries defined by the Korean Standard Industrial Classification (KSIC). The list of such service enterprises was provided by the Korean National Statistics. The population size was 22,811. The sample was constructed by stratified sampling method. The population was broke down to subgroups by the following stratification criteria: (a) KSIC code and (b) the size of enterprise based on the number of employees. 10 industrial categories and 4 size classes (10-29, 30-49, 50-99, +100) were used to construct the stratifications. Within each stratum the random sampling method was applied. Total 6,545 enterprises were selected as the sample of this KIS survey (Uhm, Choi and Lee 2006).

The survey was mailed by STEPI to the 6,545 service firms in May 2006. It was conducted until September 2006. Before the questionnaires were sent, each firm was contacted to confirm its address, business and size. And in order to encourage firm's

3) The description on "Data and Measures" section in this study has overlap with that in my previous study on manufacturing industries (Moon 2011). The overlap is inevitable because the KIS survey (either on manufacturing or service) is designed based on the same OECD Oslo manual and conducted by the same institution (i.e., STEPI). In order to compare results of service firms with those of manufacturing firms, I also use the variables employed in the study of manufacturing firms (Moon 2011).

participation interviewers visited firms that refused to respond. The response rate was 51.1% (Uhm, Choi and Lee 2006). The current sample has 2,496 enterprises.

### 3.2. Measures

*Dependent variables.* To measure various types of innovative performance, I use the measures for "radical innovation," "intermediate innovation" and "incremental innovation" performances. First, I use the fraction of a firm's sales relating to "products new to the market" for a measure of radical innovation performance. Second, I use the fraction of a firm's sales relating to "products new to the firm, not to the market," for a measure of "intermediate" innovation performance. Third, I use the fraction of a firm's sales relating to "improved products, neither new to the market nor to the firm," as a measure of incremental innovation performance. This categorization of innovation performance is the same categorization that adopted in previous research on innovation of manufacturing firms (Moon 2011). The types of innovation performance in this study has modified the types of innovation performance used by Laursen and Salter (2006). Although the authors use similar types of innovation performance measures, they define radical innovation as new to the world market while I define it as new to the market. The difference comes from the survey questionnaires of KIS and CIS: KSI does not record whether a product new to the market is also new to the world market.

*Independent variables*. First, I use *the degree of openness to external knowledge sources* defined as the number of external knowledge sources related to a firm's innovative activities (Laursen and Salter 2005, 2006). The KIS survey examines 13 external sources and measures the usefulness of each source in firms' innovations on a 0-1-2-3-4-5 scale. First, I construct a binary variable showing whether a firm uses a certain source. Specifically, the variable takes on 1 if the scale is greater than or equal to 1, and 0 otherwise. Second, I add up these binary variables over 13 sources and define the sum as the degree of openness of a firm. Thus, a firm with higher number in the openness measure means that the firm acquires knowledge necessary for its innovations from many external sources. For instance, a firm with 0 openness

measure implies that the firm does not use any external sources for information acquisition while a firm with 13 openness measure implies that the firm uses all the external sources surveyed.

In addition to this openness measure, I also construct the depth of openness measure to reflect the extent to which a firm perceives the external knowledge sources to be important following Laursen and Salter's approach. The depth of openness is defined similar to the openness measure except that the underlying binary variables take on 1 if the usefulness scale is greater than or equal to 4 in the 0-1-2-3-4-5 scale. Thus, 0 in the depth of openness means that a firm does not use any sources intensively (or in a high degree) and 13 means that a firm uses all 13 external sources intensively. As Laursen and Salter (2006) suggest, the openness measure and depth of openness reflect the "exploration" and "exploitation" of knowledge respectively (March 1991).

Second, I use *the R&D intensity* (i.e., the ratio of R&D investments to sales) that reflects the absorptive capacity of a firm. The R&D intensity has been widely used as a measure for a firm's absorptive capacity since seminal works by Cohen and Levinthal (Cohen and Levinthal 1989, 1990). The KIS survey provides the amount of R&D expenditure and sales in 2005, so the R&D intensity used in this study is the 2005 R&D intensity. In addition to the R&D intensity, I use *the share of employees with "high education"* as an additional measure of absorptive capacity of a firm. Recently, the level of skills and human capital inside a firm has been suggested as a possible measure of absorptive capacity (Zahra and George 2002; Zahra and Nielsen 2002; Volberda, Foss, and Lyles 2010). Because the KIS provides information on the share of employees with master's or higher degree, I use the master's or higher degree for the definition of "high education."

Third, I trace whether a firm is established during the period between 2003 and 2005 to measure *whether a firm is a new startup*. The 2006 KIS in service sector provides information on when a respondent begins its business. Thus, using the year information, I construct a measure of whether an enterprise is a startup in the period between 2003 and 2005.

Fourth, I use *aggressive use of appropriation methods* as an independent variable (Cohen, Nelson and Walsh 2000; Laursen and Salter 2005). The KIS examines firms' appropriation methods and records the importance of each method. Specifically, the

survey lists 5 methods – patent, other intellectual property rights, secrecy, complementary assets, and fast lead-time advantage – and measures the importance of each method on the 0-1-2-3-4-5 scale. After I add up the scores, I define the use of appropriation strategy as being aggressive if the added score is greater or equal to the average number of appropriation methods in the sample. The measure of aggressive use of appropriation measures takes on value 1 if the number of appropriation methods of a firm is greater than the average.

*Control variables*. First, I control for the size effect of a firm by using *the employment size in the logarithms*. Second, I control for *the type of focused market* because the targeted market size influences the innovative activities of firms. The KIS survey gathers information on 6 types of market on which a firm focuses. I regroup 6 types of market into 4 categories: local, regional, national, and international markets, and use these 4 types of markets as categorical variables. Third, I use *industry dummy variables* in order to control for the different technological and market characteristics across industries. Using the Korean Standard Industrial Classification (KSIC) two digit level code, I construct 13 industry dummies. Forth, I use a variable measuring *whether the customers or clients are important sources of knowledge*. According to von Hippel (1988), clients and customers are the most important sources of innovative ideas especially in service innovation. Lastly, I control for *whether a firm is engaged in formal collaboration arrangements when it produces innovation*. This binary variable is complementary to the use of external knowledge sources (Laursen and Salter 2006).

### 3.3. Econometric model

The baseline models are as follows:

$$y_{1i} = \beta_1 X_i + \varepsilon_i$$
$$y_{2i} = \beta_2 X_i + \varepsilon_i$$
$$y_{3i} = \beta_3 X_i + \varepsilon_i$$

where $y_{1i}$ is the fraction of firm i's sales relating to products new to the market (radical innovation), $y_{2i}$ is the fraction of a firm i's sales relating to products new to the firm (intermediate innovation)

and $y_{3i}$ is the fraction of firm i's sales relating to incremental product improvement. The explanatory variable vector $X_i$ includes (1) openness measure(s), (2) whether firm i is a new startup, (3) R&D intensity, (4) aggressive use of appropriation methods, (5) the employee share of master's or higher degree, (6) whether customer and clients are very important, (7) the employment size in the logarithms, (8) market type, and (9) whether firm i participates in a formal collaborative arrangement. It also includes (10) industry dummies variable.

As in the relationship between the openness and innovation in manufacturing firms, the estimation of coefficient $\beta_k$ by the ordinary linear model may not be appropriate (Laursen and Salter 2006; Moon 2011). There are two reasons why the estimation of parameter $\beta_k$ in ordinary linear model may not be appropriate. First, the dependent variables are "corner solution responses" (Wooldridge 2002). It is highly likely that the critical mass of dependent variables may be concentrated at 0 because the variables are the percentage of sales due to innovations. In addition, the upper bound of dependent variables is 100 percent, and it is likely that non negligible number of firms take on the upper bound value. Thus, the Tobit model seems to be more appropriate for this data set instead of ordinary linear model. Second, I need to address the skewedness in the distribution of dependent variables. While the Tobit model assumes normal distribution of a dependent variable, the performance from the new-to-the-market innovation looks highly skewed toward zero. Thus, I transform the dependent variables using logarithms to have a log-transformation of the Tobit Model (Laursen and Salter 2006; Wooldridge 2002). Specifically, 1 use log $(1+y_k)$, k =1, 2, 3 as the dependent variable in the Tobit model. Thus, the Tobit model to be estimated is

$$y^* = \ln (1+y_{ki}) = \beta_k X_i + \varepsilon_i,\ k = 1, 2, 3,$$
$$y = \max (0, y^*) \text{ and } y = \min (y^*, 100).$$

## 4. EMPIRICAL RESULTS

### 4.1. Descriptive results

The KIS survey investigates the knowledge sources for innovation

**Table 1. External knowledge sources for innovation**

| Source | Not-used | Low | Medium | High |
|---|---|---|---|---|
| Other business unit in the same group | 0.86 | 0.02 | 0.03 | 0.09 |
| Competitors | 0.43 | 0.07 | 0.22 | 0.28 |
| Customers | 0.41 | 0.05 | 0.16 | 0.38 |
| Suppliers | 0.53 | 0.09 | 0.19 | 0.19 |
| IT firms | 0.51 | 0.07 | 0.2 | 0.22 |
| Private R&D institutions/ Technology service firms | 0.67 | 0.11 | 0.14 | 0.08 |
| Business service firms | 0.67 | 0.1 | 0.14 | 0.1 |
| University | 0.7 | 0.1 | 0.13 | 0.07 |
| Public/Government R&D institutions | 0.75 | 0.1 | 0.1 | 0.04 |
| Informal meetings, networks | 0.56 | 0.07 | 0.19 | 0.18 |
| Patent | 0.61 | 0.14 | 0.14 | 0.12 |
| Exhibitions & Conferences | 0.5 | 0.15 | 0.16 | 0.18 |
| Newspaper, TV, Internet etc. | 0.4 | 0.1 | 0.23 | 0.27 |
| Average | 0.58 | 0.09 | 0.16 | 0.17 |

in Korean service industries, and provides information on 13 external knowledge sources. Each firm indicates the degree of usefulness of each external knowledge source by using the 0-1-2-3-4-5 scale. Table 1 shows how much important each institution is as the source of knowledge for innovation of Korean service firms.

The 5 point scale is regrouped in table 1 as follows: 1 and 2 are grouped as “low” use, 3 is grouped as “medium” use, and scale 4 and 5 are grouped as “high” use. Table 1 indicates that the most important knowledge source for Korean companies is customers and clients. 38 percent of respondents indicate that customers and clients are the most important sources for their innovative activities. This result is consistent with von Hippel’s expectation that clients and customers are the most important sources of innovative ideas especially in service innovation (von Hippel 1988). Competitors in the same industry and newspaper, TV and Internet are ranked after the customers and clients: 28 percent and 27 percent of respondents mention them as key sources for information acquisition respectively. Korean service firms seem to regard mass media such

as newspaper, TV and the Internet very important – the third most important knowledge source. The importance of mass media for service innovation implies that the role of external knowledge can differ between service and manufacturing firms. These results are also somewhat different from those of UK manufacturing firms cases reported by Laursen and Salter (2006). They report that suppliers are the second most important source following customers and clients. They also report that technical or health standards are key sources but competitors are not very important (Laursen and Salter 2006). The implications of these differences for industrial policies and firm strategies may need further investigation.

Surprisingly, the share of Korean service firms mentioning that research sectors (i.e., universities, business service firms, public and private research institutions) are important is less than 10 percent, which is low. These results seem to suggest that Korean firms' innovative activities are strongly influenced by vertical relationship and competitors in their industries, and that the influence from research sectors or other business service firms are insignificant.

Table 2 shows the openness, R&D intensity, and radical innovation performance by industry.

On average, Korean service firms use 5 to 6 external sources for their innovative activities. Firms in airline transportation (KSIC 62), telecommunication (KSIC64), finance industry (KSIC 65), finance and insurance related service (KSIC 67), information technology industry (KSIC 72) and R&D business (KSIC 73) are involved in the broad use of external knowledge: the number of external sources that firms in these industries use is higher than the average number of external sources used. In contrast, firms in on-land and pipeline transportation (KSIC 60), maritime transportation (KSIC 61), warehousing service (KSIC 63), insurance and pension (KSIC 66), business service (KSIC 74) and movie and broadcast (KSIC 87) industries do not seem to use many external knowledge sources actively.

Regarding the intensity of using external knowledge sources, Korean service firms intensively access to about 2 external knowledge sources for innovations. Firms in airline transportation (KSIC 62), finance (KSIC 65), finance and insurance related service (KSIC 67), information technology (KSIC 72) and movie and broadcast (KSIC 87) industries have multiple external sources which firms regard as important for their innovations. In contrast,

**Table 2. Openness and innovation by industry**

| Industry | KSIC | No. of firms | Percentage of innovations new to the market | R&D intensity | Openness | Depth of openness |
|---|---|---|---|---|---|---|
| Wholesales | 51 | 336 | 21.83 | 0.01 | 5.13 | 2.07 |
| On-land & pipeline transportation | 60 | 198 | 35 | 0.02 | 2.92 | 1.58 |
| Maritime transportation | 61 | 131 | 25 | 0 | 4.11 | 1 |
| Airline transportation | 62 | 10 | 20 | 0 | 11 | 10 |
| Warehousing service | 63 | 274 | 8 | 0 | 4.52 | 1.55 |
| Telecommunication | 64 | 124 | 16.63 | 0.03 | 5.85 | 2.15 |
| Finance | 65 | 105 | 16.35 | 0.03 | 6.33 | 2.81 |
| Insurance & Pension | 66 | 49 | 38.33 | 0 | 3.88 | 1.38 |
| Finance & Insurance related service | 67 | 122 | 14.17 | 0.01 | 7.24 | 3.18 |
| Information Technology | 72 | 293 | 29.11 | 0.2 | 6.12 | 2.55 |
| R&D business | 73 | 49 | 32.75 | 0.55 | 5.6 | 1.84 |
| Business service | 74 | 674 | 16.12 | 0.03 | 4.82 | 1.91 |
| Movie & broadcast | 87 | 131 | 10.94 | 0.01 | 4.94 | 2.42 |
| Average | | | 22.26 | 0.08 | 5.39 | 2.2 |

Total number of firms: 2,496

firms in on-land and pipeline transportation (KSIC 60), maritime transportation (KSIC 61), warehousing service (KSIC 63), insurance & pension (KSIC 66) have a single external source that they regard as important for their innovative ideas.

The relationship between openness and radical innovative performance – the fraction of a firm's sales relating to products new to the market – at industry level is not clearly shown in table 2. For instance, the degree of openness in finance and insurance related service industry is high (i.e., 7.24), but the innovative performance of the industry does not seem to be impressive: the percentage of innovations new to the market (14.17%) is below the average.

**Table 3. Descriptive statistics**

| Variable | N | Mean | Sd | Min | Max |
|---|---|---|---|---|---|
| Radical Innovation | 340 | 22.3 | 32.12 | 0 | 100 |
| Intermediate Innovation | 341 | 32.03 | 35.16 | 0 | 100 |
| Incremental Innovation | 341 | 50.73 | 38.75 | 0 | 100 |
| Openness (Breadth) | 524 | 5.393 | 4.15 | 0 | 13 |
| Openness (Depth) | 524 | 2.203 | 2.28 | 0 | 13 |
| New Startup | 2492 | 0.13 | 0.33 | 0 | 1 |
| R&D Intensity | 746 | 0.08 | 0.43 | 0 | 8 |
| High Appropriability | 887 | 0.34 | 0.47 | 0 | 1 |
| Share of MA+ | 2469 | 0.07 | 0.14 | 0 | 1 |
| Lead User | 524 | 0.38 | 0.49 | 0 | 1 |
| Log of Employment | 2496 | 3.57 | 1.15 | 2.30 | 9.78 |
| Market Type | 2496 | 2.54 | 0.79 | 1 | 4 |
| Formal Collaboration | 524 | 0.34 | 0.48 | 0 | 1 |

In contrast, the innovative performance in on-land and pipeline transportation industry is the second highest while the degree of openness in the industry is far below average. This implies that the characteristics of industry influence the relationship between the openness and innovation performance.

Table 3 reports the summary statistics for main variables.

As shown in table 3, given that a firm is innovating, the fraction of the firm's sales related to the new-to-the-market products (i.e, radical innovation) is 22.3 percent in Korean service industries. Given that a firm is innovating, the fractions of a firm's sales relating to the new-to-the-firm products (i.e., intermediate innovation) is 32.1 percent and the fraction of a firm's improved products (i.e., incremental innovation) is 50.8 percent. The average number of external knowledge sources that a firm draws upon for its innovation is about 5, but the number of external knowledge sources that a firm draws upon intensively decrease to about 2. New startups in the period between 2003 and 2005 account for 13 percent of firms in the sample. Although it is not shown in table 3, 59.7 percent of service firms mainly target the national market and only 4.3 percent of service firms target the international market.

Table 4 shows simple correlations between variables.

**Table 4. Correlation between variables**

| | Radical Innov. | Interm. Innov. | Increm. Innov. | Openness | Open Depth | New Startup | R&D Intensity | High Appro-priation | Share of MA+ | Lead User | Log of Employee | Market Type | Formal Collabo-ration |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interm. Innov. | -0.2748* | 1 | | | | | | | | | | | |
| Increm. Innov. | -0.5362* | -0.664* | 1 | | | | | | | | | | |
| Openness | -0.0782 | 0.0318 | -0.014 | 1 | | | | | | | | | |
| Openness Depth | -0.0428 | 0.0117 | -0.0353 | 0.6751* | 1 | | | | | | | | |
| New Startup | 0.2786* | 0.2474* | 0.0597 | -0.0551 | -0.0821 | 1 | | | | | | | |
| R&D Intensity | 0.0534 | 0.0606 | -0.0294 | 0.0275 | -0.0331 | 0.1641* | 1 | | | | | | |
| High Appropriation | 0.0804 | -0.0549 | -0.0301 | 0.2119* | 0.2023* | -0.0254 | 0.0868* | 1 | | | | | |
| Share of MA+ | 0.1149* | 0.1378* | -0.2007* | 0.0714 | 0.0616 | -0.0201 | 0.0885* | 0.1248* | 1 | | | | |
| Lead User | -0.0782 | -0.0032 | 0.0472 | 0.4784* | 0.5985* | -0.067 | -0.0205 | 0.1713* | 0.0115 | 1 | | | |
| Log of Employee | -0.1207* | -0.1174* | 0.1237* | 0.2633* | 0.2521* | -0.1448* | -0.1166* | 0.1037* | -0.0163 | 0.1221* | 1 | | |
| Market Type | 0.0714 | -0.0756 | -0.0292 | 0.1180* | 0.1061* | -0.0609* | 0.0438 | 0.1409* | 0.1184* | 0.0998* | 0.1780* | 1 | |
| Formal Collaboration. | 0.0507 | 0.0352 | -0.1013 | 0.2646* | 0.2632* | -0.0161 | -0.0175 | 0.2410* | 0.1139* | 0.0467 | 0.1406* | 0.0501 | 1 |

1. Legend: * p<.05

### 4.2. Econometric results

Table 5 reports the estimation results from the log-transformed Tobit regressions for three types of innovative performance – radical (i.e, new-to-the-market), intermediate (i.e., new-to-the-firm) and incremental (i.e., improved product) innovations. Industry dummies are used for all three regressions. As shown in table 5, the distribution of innovative performance has the corner solution response property. For instance, 151 firms report that they do not make any revenue from radical innovations and 30 firms report that they make the whole revenue from radical innovations. In the case of incremental innovation, the numbers are 74 and 63 respectively. Thus, there exists critical mass on two end points of dependent variables.

**Table 5. Tobit Regression by innovation type**

| Variable | Radical Innovation | Intermediate Innovation | Incremental Innovation |
|---|---|---|---|
| Openness | 0.1662* | 0.0221 | 0.0607 |
| Openness*New startup | 0.0382 | -0.0539 | -0.1283 |
| Openness*R&D intensity | 0.4274 | 0.2115 | -0.3841* |
| Openness*High appropriability | -0.2793** | 0.0491 | 0.0187 |
| New startup | 4.0283*** | 3.7241*** | 2.1698* |
| R&D intensity | -0.9366 | -0.4818 | 1.3111* |
| Share of MA or higher | 2.9408* | 2.8390** | -1.8831 |
| High appropriability | 1.9725** | -1.0811 | 0.0517 |
| Lead user | -0.4438 | 0.4048 | 0.0674 |
| Log of employment | 0.0607 | -0.0125 | -0.0038 |
| Market type | 0.3002 | -0.0124 | -0.0109 |
| Formal collaboration | 0.6165 | 0.5447 | -0.4863 |
| Industry dummies are used | | | |
| Number | 317 | 317 | 315 |
| Left censored Number | 151 | 111 | 74 |
| Right censored Number | 30 | 41 | 63 |
| Log likelihood | -495.4939 | -552.1919 | -570.3053 |
| chi2 | 54.4279 | 46.1457 | 25.2575 |
| Pseudo R2 | 0.0521 | 0.0401 | 0.0217 |

1. Legend: * p<.1; ** p<.05; *** p<.01
2. Radical innovation: innovation new to the market; Intermediate innovation: innovation new to the firm

The first hypothesis is that openness influences innovative performance, and that it will be more effective when innovation is radical. The coefficients of openness breadth measure supports the first hypothesis partially: openness breadth is positively associated with radical innovation while it is not associated with intermediate (i.e., the new-to-the-firm) and incremental innovation in Korean service industries. The coefficients of openness breadth are positive ranging from 0.17 for radical innovation (i.e., the new-to-the-market) to 0.02 for intermediate innovation (i.e., the new-to-the-firm) to 0.06 for incremental innovation, but only the coefficient (0.17) of the radical innovation regression is significant at the 10 percent level. The magnitude of openness coefficients of intermediate and incremental innovation regressions does not statistically differ from 0. In unreported estimation of average marginal effect of openness the result shows that one additional use of external source will increase radical innovation performance by 4 percent but incremental innovation performance by 2 percent. Thus, the association of openness breadth with radical service innovation is stronger than that with incremental service innovation.

This result is significantly different from those of Korean manufacturing firms. In Korean manufacturing industries, the openness is positively associated to incremental improvement while it is not related to radical and intermediate innovation (Moon, 2011).

The second hypothesis is that a firm's R&D intensity is complementary to the relationship between openness and innovation performance: If a firm has a high level of R&D intensity, being open to external knowledge is more effective for innovative performance. Table 5 shows that the complementarity does not exist in service innovation. The R&D intensity does not seem to influence the relationship between openness and innovation when innovation is radical and intermediate because the coefficients of R&D intensity and openness interaction term are statistically insignificant. Even the coefficient in case of incremental innovation is negative (-0.38) and statistically significant at the 10 percent level. Although the R&D intensity does not strengthen the relationship between openness and innovation, it is positively associated with incremental innovation as in Laursen and Salter (2006): the coefficient is 1.3 and significant at the 10 percent level in Korean service firms.

This result also suggests that the role of the R&D intensity for service innovation is very different from that for manufacturing

innovation. Moon (2011) reports that the coefficient of interaction between openness and the R&D intensity in case of incremental innovation is positive (0.28) and significant at the 1 percent level, and that the coefficient of the R&D intensity in case of incremental innovation is negative and significant at the 1 percent level. Rather the R&D intensity in manufacturing is positively associated with intermediate innovation (Moon 2011).

The role of the R&D intensity in service innovation is complicated. In unreported estimation the average marginal effect of openness at different R&D intensity levels shows that the relationship between the openness and R&D intensity varies across the level of R&D intensity and types of innovation. In the radical innovation regression, at the 25 percentile of R&D intensity, using one additional information source will reduce radical innovation performance by 0.1 percent. At the 75 percentile of R&D intensity, however, using one additional information source will increase radical innovation performance by 3 percent. The result of incremental innovation regression shows the opposite. As R&D intensity increases from 25 percentile to 75 percentile, the effect of having one additional external source decreases from 7 percent to 3 percent. This complicated relationship among openness, R&D intensity, and types of innovation will be a very interesting future research topic.

The third hypothesis is that openness will be more effective for innovation if a firm is a startup, and that the complementarity between the startup and openness will be stronger when the innovation is radical. Table 5 suggests two results regarding the role of startups. First, the third hypothesis is not supported: being a startup does not strengthen the effect of openness on radical innovation. The coefficient of openness-startup interaction for radical innovation is positive but insignificant; the coefficients in intermediate and incremental innovations are negative and insignificant (-0.05 and -0.13 respectively). Second, being a startup is important for all types of innovation and its effect is the strongest for radical innovation especially. The main effect of being a startup on innovation is very strong and significant: all coefficients are positive and significant either at the 1 percent level or at the 10 percent level.

In Korean manufacturing industries, the main effect of being a startup varies depending on the types of innovation: being a startup

is positively associated with radical innovation while negatively associated with incremental innovation (Moon 2011). However, as in service industries, being a startup does not strengthen the relationship between openness and innovation regardless of the types of innovations (Moon 2011).

The fourth hypothesis is that aggressive appropriation strategy weakens the effect of openness on innovation. Table 5 shows that the effect of aggressive appropriation strategy varies depending on types of innovation. In case of radical innovation, when a firm uses appropriation methods aggressively, being more open to external sources reduces its performance: The coefficient of the interaction term is -0.28 and significant at the 5 percent level. In case of intermediate and incremental innovation regressions, however, the use of aggressive appropriation methods does not influence the effect of openness on innovation: the coefficients are statistically insignificant. However, the aggressive use of appropriation method itself is effective for radical innovation from Korean service firms: the coefficient is significantly positive (1.97) at the 5 percent level. This implies that although the intellectual property right strategy of Korean service firms is not helpful for acquiring external knowledge the strategy is important for radical innovation.

In Korean manufacturing industries, the aggressive appropriation strategy weakens the openness – innovation relationship in case of incremental innovation (Moon 2011). It is also reported that the aggressive appropriation strategy is important for incremental innovation (Moon 2011). This is an interesting future researcher topic why the effectiveness of strong use of appropriation strategy differs depending on types of innovation and sectors.

In unreported estimation the average marginal effect of openness when a firm uses high and low levels of appropriation methods also shows the negative interaction between openness and aggressive appropriation: using one additional external source will reduce the radical innovation performance by 5 percent when a firm uses appropriation methods in a high degree. In contrast, using one additional external source will increase the radical innovation performance by 19 percent when a firm uses appropriation methods in a low degree. The negative effects of using appropriation methods to a high degree is also detected in intermediate and incremental innovation cases but the magnitude is not as considerable as that in radical innovation case. Thus, data seems to support the

fourth hypothesis: In Korean service sector, the aggressive use of appropriation methods is not compatible with open innovation strategy.

In addition to the openness breadth measure that counts the number of external knowledge sources that a firm uses, Laursen and Salter (2006) use an additional openness measure – the depth of openness. The authors use the depth of openness to reflect the extent to which a firm uses each source to a high degree, and show that the effect of openness breadth and openness depth influence innovating firms distinctively in UK manufacturing industries (Laursen and Salter 2006). So, which measure between openness breadth and openness depth is more important for innovative performance in Korean service industries? Table 6 reports estimation results using the breadth and depth of openness simultaneously.

Lastly, it is confirmed that human capital is more important for service innovation than for manufacturing innovation. Table 5 shows that the share of employees with high education is positively associated with radical and intermediate innovation in service industries. The coefficients are 2.94 for radical service innovation and 2.84 for intermediate innovation, and both are statistically significant at the 10 percent level and at the 5 percent level. However, the share of highly educated employees is not important for incremental service innovation.

For manufacturing innovation the share of highly educated employees is not associated with neither types of innovation performance (Moon 2011). Although the share of highly educated employees is not the only measure for quality of human capital and thus results might change if different human capital measures are used, why the quality of human capital influences innovation performance differently in service and manufacturing will be very interesting.

Results from table 6 show that openness breadth influences innovation performance while openness depth does not. The openness breadth related coefficients in table 6 are similar to those in table 5 in terms of their sign, magnitude, and significance. In contrast, the openness depth does not influence the performance significantly for all three types of innovation. The ineffectiveness of openness depth on innovation performance is also reported by the study of Korean manufacturing firms (Moon 2011). However, the result that openness depth does not influence the innovation

**Table 6. Tobit regression model with openness depth**

| Variable | Radical Innovation | Intermediate Innovation | Incremental Innovation |
|---|---|---|---|
| Openness | 0.2052* | -0.014 | 0.0733 |
| Openness*New startup | 0.2643 | 0.1634 | -0.1304 |
| Openness*R&D intensity | 0.3873 | 0.1315 | -0.3897 |
| Openness*High appropriability | -0.3428** | 0.1249 | 0.0316 |
| Openness depth | -0.1247 | 0.1075 | -0.0582 |
| Openness depth*New startup | -0.4601 | -0.599 | -0.0152 |
| Openness depth*R&D intensity | 0.1394 | 0.2939 | -0.0028 |
| Openness depth*High appropriability | 0.1685 | -0.2179 | -0.0336 |
| New startup | 3.9496*** | 3.8734*** | 2.2112* |
| R&D intensity | -1.063 | -0.7458 | 1.3159 |
| Share of MA+ | 2.8655* | 3.0356** | -1.7598 |
| High appropriability | 1.9728** | -1.0171 | 0.0609 |
| Lead user | -0.3804 | 0.4005 | 0.2134 |
| Log of employment | 0.0781 | -0.0091 | 0.0085 |
| Market type | 0.285 | -0.0538 | -0.0062 |
| Formal collaboration | 0.6561 | 0.5306 | -0.4447 |
| Industry dummies are used | | | |
| Number | 317 | 317 | 315 |
| Left censored Number | 151 | 111 | 74 |
| Right censored Number | 30 | 41 | 63 |
| Log likelihood | -495.0539 | -550.9889 | -570.0045 |
| chi2 | 55.3079 | 48.5517 | 25.859 |
| Pseudo R2 | 0.0529 | 0.0422 | 0.0222 |

1. Legend: * p<.1; ** p<.05; *** p<.01
2. Radical innovation: innovation new to the market; Intermediate innovation: innovation new to the firm

performance of Korean service firms is very different from the result of UK manufacturing firms reported by Laursen and Salter (2006). According to the authors, both search breadth and depth are important for innovative performance of UK manufacturing firms and the depth of openness is more important for radical innovation, which I do not observe both in Korean service firms and in Korean manufacturing firms. The reasons why the openness depth does not matter for innovation of Korean firms is an interesting topic for future research.

## 5. CONCLUSION

The external source of knowledge is important for Korean service firms: a firm can increase its innovative performance by drawing on the broader base of external knowledge. However, the effect of openness varies depending on the types of innovation that a firm introduces. For instance, expanding external knowledge base is positively associated with radical innovation while it is not associated with intermediate or incremental innovation. When a firm pursuing radical innovation has one additional external source, the ratio of radical innovation to sales will increase by 4 percent in Korean service industries. This result is very different from the effect of expanding external knowledge base of manufacturing firms: the additional external knowledge improves not the radical innovation but the incremental innovation of Korean manufacturing firms

The complementarity between openness and absorptive capacity (R&D intensity) also depends on the type of innovation. Using one more external source does not influence the relationship between openness and radical innovation. However, in case of incremental innovation the increase in R&D intensity is associated with the decreasing effect of openness on innovative performance. Regarding the effect of the appropriation methods, expanding knowledge source becomes effective for radical innovation if a firm employs appropriation method less aggressively.

For Korean service firms, drawing upon a larger number of external sources seems to be more important than deepening the relationship within each external source for innovation performance. This result is also reported from a study of Korean Manufacturing firms (Moon 2011). Interestingly, the openness depth is reported to increase innovation performance significantly in the study of UK manufacturing industries by Laursen and Salter (2006). The authors report that both breadth and depth of external search are important to UK manufacturing firms, especially radical innovation is related to the depth of openness. For Korean service firms, however, forming deep relationships with external sources is not effective for innovative performance. Why deep relationships with external sources are not effective in Korea is currently a puzzle. One possible conjecture is that non-corporate institutions may not be competent enough for firms to want to develop deep collaborative

relationships. Other possibility is that regulations and policies may hinder the formation of stable and deep relationships between firms and external knowledge sources. These seem to be an interesting topic for future research.

Lastly, whether the way of using external knowledge in service sector may change after mobile technology has been diffused among firms is an interesting future research topic. The mobile technology reduces the costs of accessing distinct knowledge sources differently and expands the range of service activities that a firm can provide, the relative position of a firm in such technology is likely to moderate the relationship between openness and service innovation.[4)]

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