기술혁신학회지 제14권 3호
2011년 9월 pp.405~430

한국 제조 기업들의 외부지식 활용 결정요인 연구

What Determines the Openness of Korean Manufacturing Firms to External Knowledge?

문성욱(Seongwuk Moon)*

목 차

국 문 요 약

본 연구는 한국 제조기업들이 외부지식을 적극적으로 활용하게 하는 요인들을 고찰한다. 관련문헌들에 의하면 기업의 혁신성과 보호전략 (appropriability strategy), 흡수능력 (absorptive capacity), 기술분야 창업기업여부 (technology entrepreneurship), 기업규모 그리고 산업별 기술발전기회 등이 외부지식 활용을 결정하는 요인들이라고 주장되고 있다. 본 연구는 이러한 요인들 중에서 한국 제조기업들의 외부지식활용도에 실제로 영향을 미치는 것들은 무엇인지를 한국 제조업 분야 혁신활동조사 자료 (Korean Manufacturing Innovation Survey)를 활용하여 분석한다. 그 결과들은 다음과 같다. 첫째, 기업들이 혁신성과 보호 메커니즘을 적극적으로 활용할수록 외부지식 활용도가 높다. 둘째, 고등교육을 받은 종업원들의 비중이 높은 기업일수록 외부지식을 더 많이 활용한다. 셋째, 기술분야 창업기업일수록 외부지식 활용도가 높다. 넷째, 규모가 큰 기업일수록 외부지식을 더 많이 활용한다. 다섯째, 기술발전기회가 더 많은 산업에 종사하는 기업일수록 외부지식 활용도가 높다. 특히 한국 제조기업들의 경우 고등교육을 받은 종업원들의 비중과 기술분야 창업기업여부가 다른 요인들보다 외부지식활용에 더 영향을 미치고 있다고 분석되었다.

핵심어 : 오픈 이노베이션, 외부지식활용 결정요인, 기술분야 창업기업, 흡수능력, 한국 제조기업

※ 논문접수일: 2011.1.20, 1차수정일: 2011.3.14, 게재확정일: 2011.3.28
* KDI 국제정책대학원, 조교수, seongwuk@gmail.com, 02-3299-1042

ABSTRACT

I examine what factors influence a firm's openness to external sources of knowledge in the Korean manufacturing sector. Related literature suggests a firm's appropriability strategy, absorptive capacity, technology entrepreneurship, firm size and industry-level technological opportunities as possible determinants. Using Korean Manufacturing Innovation Survey, I test how these factors influence the degree of openness of Korean manufacturing firms. I find the followings: First, when the appropriability strategy becomes tighter, a firm becomes more open to external sources. Second, when the share of highly educated employees increases, a firm becomes more open. Third, when a firm is a technology entrepreneur, the openness increases. Fourth, a large firm is likely to be more open. Lastly, ample technological opportunities increase the openness. In Korean manufacturing industries, the highly educated employees and technology entrepreneurship are more influential factors for a firm's openness.

Key Words : Open Innovation, Determinants of Openness, Technology Entrepreneurship, Absorptive Capacity, Korean Manufacturing Sector

I. Introduction

Industrial R&D is often considered to be the engine for innovation and growth in an economy. To improve R&D efficiency and their performance, firms recently have been reorganizing their research activities by "opening up" their innovation process (Chesbrough, 2006). Specifically, they try to strengthen collaboration with universities and research-oriented firms and exchange ideas with customer, suppliers and competitors. Although the practice of vertically disintegrating research activities to commercialize external knowledge has become popular, it has been also observed that incorporating external knowledge into innovation can be risky or costly (Chesbrough, 2006; Keupp and Gassman, 2009). In addition, firms also express their concerns over open innovation (Enkel et al., 2009). For example, European firms are worried about the loss of knowledge or control over innovation and internal resistance to external knowledge (Enkel et. al., 2009). Thus, whether to open up a firm's innovation process seems to be an empirical question. If so, what will influence a firm's intensity to use external institutions for knowledge acquisition?

As Chesbrough (2006) points out, there are many factors that influence firms to adopt the open innovation approach. Following Chesbrough's insight, Laursen and Salter (2005b) empirically show that firms open up their innovation process to a varying degree. By examining the degree of openness in 2,304 UK manufacturing firms, the authors find that a firm's intensity to use the external source of knowledge varies across industries. The authors further investigate the sources of variation in openness and suggest the appropriation mechanism, absorptive capacity, start-ups, and technological opportunities as the source of variation.

Korean intellectual communities have also examined implications of open innovation framework for innovative activities in Korean industries. For instance, Hong and Kim (2009) investigate the relationship between types of industry and the sources of innovative idea. Kwon (2010) shows that open innovation increases innovative performances of Korean small-and-medium-sized enterprises. Although these studies provide evidence that Korean industries are also going through the paradigm shift toward open innovation, they seem to pay attention mainly to the effect of openness

on innovative performance. The quantitative analysis of what may determine the openness of Korean manufacturing firms seems to remain relatively neglected.

The purpose of this study is to fill this gap: I will examine the determinants of openness of Korean manufacturing firms. Especially, I will focus on whether factors suggested as drivers of openness in developed countries may also influence the openness of Korean manufacturing firms. If we can understand what makes manufacturing firms more open, we may facilitate diffusion of the open innovation approach in our industries through business strategy and public policy.

Applying the framework of Laursen and Salter (2005b) to 2008 Korean Innovation Survey (KIS) data on manufacturing industries, I examine what factors influence the openness decision of Korean manufacturing firms. Specifically, I investigate whether the appropriability strategy, absorptive capacity, technological entrepreneurship and technological opportunities influence a firm's decision on using external knowledge sources for its innovation as these factors do in the UK manufacturing industries. I will also examine which factors will have more influence on the decision regarding the use external sources for knowledge acquisition.

I find that the tightness of appropriability is positively related to the openness of a manufacturing firm; the share of employees with high education is positively related to the openness; technology entrepreneurship is positively associated with the openness; a large firm is likely to be more open; and a firm is more open under ample technological opportunities. Among these factors, the share of highly educated employees and technology entrepreneurship seem to be more influential than the other factors in using external sources for knowledge acquisition.

My study may contribute to empirical literature of Korean firms' openness to external knowledge in the following ways. First, I quantitatively examine the determinants of Korean manufacturing firms' openness by using the KIS survey data. The results provide evidence that factors that determine UK manufactures' openness also affect the Korean manufacturing firms' decision to use external knowledge sources. Although my study does not intend to analyze why the determinants of openness are either the same or different between Korea and UK,[1] the results of my

1) Such analysis will require survey of Korean and UK manufacturing industries with the same questionnaire and in-depth studies on related institutions such as intellectual property rights and research universities in

study implies that a common framework of determinants of openness across countries can be developed. Second, I investigate the effect of appropriability strategy - appropriability strategy is broader than patent use - on the openness of Korean manufacturing firms. I also show technology entrepreneurship supported by Korean government increases the openness. To my knowledge, econometric analysis of how appropriability strategy and technology entrepreneurship influence Korean firms' use of external knowledge sources has not been done much.

The paper is organized as follows: Section 2 develops hypotheses to be tested. Section 3 and 4 explain data and variables used in this empirical analysis. Section 5 presents empirical results. Section 6 is conclusion.

II. Hypotheses

1. Tightness of appropriability and openness

According to von Hippel (1988), innovative firms informally exchange ideas with external sources such as customers, suppliers and even competitors. By doing so, the firms can share information and new ideas and prepare for their innovative products and service. Chesbrough (2003, 2006) develops the von Hippel's framework further. He suggests that firms need to open up their innovation process and manage inflow and outflow of ideas because "useful knowledge is...widely distributed and of generally high quality" (Chesbrough, 2006).

However, as Arrow (1962) points out, a firm that opens up the innovation process may risk its profit from innovation and weaken its competitiveness: Sharing the innovative idea may reduce the originality of the idea and make the inventor vulnerable to idea stealing. Gans and Stern (2003) also point out that there are multiple hazards when a firm is open to external firms. The authors insist that a start-up involved in trading their novel ideas faces hazards of being exploited because the incumbents are owners of complementary assets and potential imitators. Thus, "market

both countries.

for idea" based on proper protection mechanisms is required (Gans and Stern, 2003).

Regarding institutional underpinning of well functioning market for idea, Cohen et al. (2000) insist that firms tend to use "a range of mechanisms" to protect their profits from innovations. The "appropriability mechanism" includes the use of patent, secrecy, lead time, lead time advantages and the use of complementary marketing and manufacturing capabilities. After conducting a survey on the protection mechanism of profit in the US manufacturing sector in 1994, the authors insist that the effectiveness of each mechanism differs. For instance, the protection by patent may not be effective in a certain manufacturing sector compared to secrecy and lead time advantage. Thus, firms strategically choose how to formulate their portfolios of appropriation mechanism (Cohen et al., 2000).

Use of appropriability strategy may enhance firms' incentive to exchange ideas with external sources. After examining the successful commercialization by a start-up under the risk of being exploited, Gans and Stern (2003) suggest that commercialization can be facilitated if both parties trading the ideas can use reasonable protection mechanisms.

However, excessive focus on the possible exploitation may reduce the degree of openness of a firm. As Gallini (2002) suggests, when firms need to negotiate licenses separately with owners of potentially blocking patents, the strong appropriability strategy may increase transaction costs of using external knowledge sources. Levinthal and March (1993) also point out that too much focus on the appropriation issue may induce firms to lose the valuable opportunities from the idea exchange.

Thus, the relationship between the openness and tightness of appropriability strategy requires an empirical analysis. But, empirical evidence on how appropriation will influence R&D and innovation is indecisive (Cohen, 2010). From theoretical literature, the effect of appropriation strategy may have both positive and negative effect and the negative effect may eventually prevail when the appropriation strategy is tightly used. Laursen and Salter (2005a) empirically show that the use of patent increases and then decreases innovative performance and that the use of and informal appropriation mechanisms has the same effect. They also examine whether the relationship between openness and appropriability strategy of UK manufacturing firms are curvilinear (Lausen and Salter, 2005b). Thus, I expect that the incentives for

Korean manufacturing firms to use external knowledge will increase and then decrease (i.e., inverted U-shaped) as appropriability strategy becomes tighter.

Conjecture 1. The use of appropriation mechanism is curvilinearly (i.e., inverted U-shaped) related to the degree of openness to external sources of innovation.

2. Absorptive capacity and openness

In their influential paper, Cohen and Levinthal (1990) insist that the "absorptive capacity" is critical to innovative capabilities. They describe the absorptive capacity as "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" and regard the absorptive capacity as a function of the "richness of the preexisting knowledge structure" (Cohen and Levinthal, 1990). The R&D investment has been widely used to measuring a firm's absorptive capacity (Cassiman and Veugelers, 2002).

Recently, the level of skills and human capital inside a firm has been suggested as a measure of absorptive capacity (Zahra and George, 2002; Zahra and Nielsen, 2002). The level of skills and human capital inside a firm can complement the R&D measure because a firm even without a formal R&D department may have strong absorptive capacity (Laursen and Salter, 2005b).

How these measures of absorptive capacity influence the openness decision of Korean firms has yet to be examiened sufficiently. I expect that the relationship between the degree of openness and absorptive capacity measured by R&D intensity and the share of employees with higher education may be positive.

Conjecture 2. The R&D intensity is positively related to the degree of openness to external sources of innovation. The share of employees with higher education is positively related to the degree of openness to external sources of innovation.

3. Technological entrepreneur and openness

Start-ups with unique technology may not want to exchange their ideas with external institutions if market for idea has yet to be fully developed. Gans and Stern

(2003) point out that the main hazard for a technology entrepreneur collaborating with established firms is the possibility of being exploited by the established firms. Incumbents are owners of complementary assets and possible imitators in the product market. Thus, a technology entrepreneur may be very cautious about exchanging ideas with external sources. A technology start-up may also want to enter a market with a low-key profile because it wants to avoid the product market competition with established incumbents by not attracting their attention (Gans and Stern, 2003). Thus, without well working market for idea, a technology entrepreneur may not want to exchange knowledge with external institutions because the exchange of ideas with external knowledge sources may lead to the idea leakage and put the start-up in the spotlight. Under the assumption that market for idea in Korea has more room to be developed, I expect that a technological start-up in Korea is less likely to open.

Conjecture 3. A technology entrepreneur is less likely to be open to external knowledge sources.

4. Firm size and openness

Firm size influences firms' incentive to use external knowledge. Christensen et al. (2005) examine different behaviors of small and large firms toward managing openness in the consumer electronics industry. The authors insist that "small technology entrepreneurs are bound to attempt to close their technology base," and the large incumbents are willing to incorporate evolving technologies.

The large size may be more advantage for a firm to use external knowledge. Teece (1986, 2006) insists that co-specialized assets are critical for profiting from idea. As Gans and Stern (2003) suggest, large incumbents in product markets are highly likely to be owners of such assets. This implies that large firms may be more willing to assimilate external ideas because they have broader inside knowledge base and the "leverage" for commercializing ideas.

Empirical literature reports the positive relationship between firm size and openness in the German manufacturing industries (Becker and Dietz, 2004), among Spanish firms (Segarra-Blasco and Arauzo-Carod, 2008) and in the UK manufacturing industries

(Tether, 2002; Laursen and Salter, 2005b).[2] Thus, I expect the positive relationship between firm size and openness in the Korean manufacturing industries.

Conjecture 4. A large firm is more likely to be open to external knowledge sources.

5. Technological opportunities and openness

There exists ample empirical evidence showing that technological opportunities influence R&D activities (Cohen 2010). However, the literature seems to focus on the effect of technological opportunities in industries mostly on innovative inputs such as R&D intensity and performance. Recently, Hong and Kim (2009) investigate the relationship between industry type and source of innovative activities (i.e., internal vs. external knowledge) in Korean manufacturing industries. They suggest that firms in the "supply-dominated industry" tend to prefer external knowledge while firms in the "science-based industry" tend to prefer internal knowledge to generate innovation (Hong and Kim, 2009).

Here, I will examine the relationship between technological opportunities and openness using average industrial R&D intensity as a measure of technological opportunity instead of using industry type. This is because I want to quantify which industry provides higher opportunities. As Cohen and Levinthal (1989, 1990) explain, a firm is more willing to absorb external knowledge if the external environment generates ample opportunities. If an industry to which firms belong experiences a rapid technological change, it may be more beneficial for a firm to search for technological opportunities and collaborate with outside partners.

Conjecture 5. The technological opportunities are positively related to the degree of openness to external sources of innovation.

2) However, Lee et al. (2010) insist that open innovation may provide collaboration opportunities to small-and-medium sized enterprises through intermediation.

III. Data

The data I use here is from the Korean Innovation Survey (KIS) on manufacturing industries. The survey was conducted in 2008. 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, 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, 2005b; Mairesse and Mohnen, 2002).

The population of the KIS is all enterprises with 10 employees or more in the manufacturing industries defined by the Korean Standard Industrial Classification (KSIC). The list of such enterprises was provided by the Korean National Statistics. The population size was 47,267. The sample was constructed by stratified sampling method. The population was broke down to subgroups by two stratification criteria: (a) KSIC code and (b) the size of enterprise based on the number of employees. 22 industrial categories and 5 size classes (10-49, 50-99, 100-299, 300-500, +500) were used. Within the first and second categories, the random sampling method was applied. Total 6,341 enterprises were selected as the sample of this KIS survey (STEPI, 2008).

The survey was mailed to the 6,341 manufacturing firms in May 2008. Before the questionnaires were sent, each firm was contacted to confirm its address, business and size. And interviewers visited firms that refused to respond to encourage firms' participation in the survey. The response rate is 67.1%(STEPI, 2008). The current sample has 3,081 enterprises.

IV. Variables

1. Dependent variable

The degree of openness to external knowledge sources is the dependent variable. It is defined as the number of external knowledge sources used by a firm for its innovative activities. The KIS survey examines 10 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 the use of a certain source. Specifically, the variable takes on 1 if the scale is greater than or equal to 3, and 0 otherwise. Second, I add up these "use variables" over 10 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 number of sources that the firm perceives to be important and use increases: A firm with 0 in the openness measure implies that the firm does not use any external sources which it perceives to be important while a firm with 10 in the openness measure implies that the firm uses all external sources which it perceives to be important.

2. Independent variables

First, I use *the overall tightness of appropriability strategy of a firm* (Cohen et al., 2000; Laursen and Salter, 2005b). The KIS examines firms' protection methods and records the importance of each protection method. The survey lists 7 methods: patent, registration of utility model, trademark, registration of design, secrecy, complexity of design and fast lead-time advantage. It also measures the importance of each method on the 0-1-2-3-4-5 scale. To construct the tightness of a firm's appropriability strategy, I add up the scores of protection measures and define the sum as the tightness of appropriability.[3)]

3) The reasons why I construct this tightness in appropriability strategy differently from the openness variable are as follows: First, I intend to have variables as close to Laursen and Salter (2005b) as possible because confirming whether their framework is applicable to Korean manufacturing industries is one of the main

Second, in order to measure the absorptive capacity of a firm, I use *the share of employees with high education, the share of employees with foreign high education, and the share of full-time R&D staff.* These measures are constructed from the KIS survey questionnaire. As a definition of high education, Laursen and Salter (2005b) use undergraduate but I use master's or higher degree. This is because the KIS provides information only on master's or higher degree. I also use *the R&D intensity (i.e., the ratio of R&D investments to sales)* as a measure of a firm's absorptive capacity (Cohen and Levinthal, 1990). The KIS survey does not provide annual R&D expenditure and sales information but those numbers in three years total. Thus, the R&D intensity of a firm used in this paper is three-year-average R&D intensity.

Third, I use *whether a firm is designated as an "Inno-biz" firm* in order to examine the effect of being a technology entrepreneur on the openness to external knowledge sources. The Korean Small and Medium Business Administration (SMBA) has authority of designating a small-and-medium sized firm as an Inno-biz firm after evaluating its eligibility. A small-and-medium sized firm that has been operating more than three years is eligible. If a firm is designated as an Inno-biz firm, it can have financial support, preferential treatment in R&D investments, and other support in management of R&D personnel by government agencies. The KIS survey provides information on whether a firm is a Inno-biz firm or not. Although the Inno-biz firm is not the same as the start-up used in Laursen and Salter (2005b), the use of the Inno-biz firm can reflect the characteristics of a start-up - strong dependency on new ideas but weak control of complementary assets.

Fourth, I use *the number of employees in logarithms* as the firm size measure. The number of employees each year is provided by the KIS survey. And lastly, I use *the average R&D intensity of an industry at the 2 digit SIC level* as a measure of industry-level technological opportunities. As suggested by Laursen and Salter (2005b), the industry-level average R&D intensity may reflect the technological development in the industry. Because the KIS survey does not provide annual but three years R&D

---

purposes of this study. Second, I construct an alternative appropriability variable in the same way as I construct the openness variable: I make binary variables (i.e., 1 if greater than or equal to 3) and then sum the binary variables up. The regression results using this newly constructed appropriability variable do not change much.

expenditure in total, the measure of industry-level technological opportunities is the three-year average of industry-level R&D expenditure. Alternatively, I use 22 industries dummies to control for heterogeneity in technological opportunities across industries.

V. Empirical Results

1. Descriptive Results

The KIS survey investigates the knowledge sources of innovation in Korean manufacturing industries. Among 12 knowledge sources, 10 sources can be identified as external knowledge sources for a firm's innovative activities and 2 sources are as internal sources. A firm expresses the usefulness of each external source for its innovation activities in a 0-1-2-3-4-5 scale.

〈Table 1〉 shows the results of how much important each institution is as a knowledge source for Korean manufacturing firms. The result indicates that the most important knowledge source for Korean companies is internal source of a firm. 91 percent of respondents suggest that the internal source is the most useful in their

〈Table 1〉 Knowledge Sources of Korean Manufacturing Firms

Knowledge Sources	N	Medium or Higher Use
Internal Source	1524	0.91
Other enterprises in your enterprise group	1524	0.22
Suppliers (materials, components and software)	1524	0.47
Clients or customers	1524	0.61
Competitors or other enterprises	1524	0.49
Professional and industry associations	1524	0.34
New employees	1524	0.29
Consultants, private R&D institutes	1524	0.26
Universities	1524	0.26
Government and public research institutes	1524	0.25
Conferences, trade fairs, exhibitions	1524	0.39
Scientific journals and technical publications	1524	0.39

innovations. Clients or customers is suggested as the most important external source for information acquisition: 61 percent of respondents suggest that the source is useful. The next important external sources are competitors or other enterprises: 49 percent and 47 percent of respondents list these sources as important respectively. Surprisingly, the importance of universities and government/public & private research institutions is the lowest at around 26 percent. These results suggest that Korean firms' innovative activities are strongly influenced by vertical relationship and competitors in their industries but not by academic or public research sectors, which seems to be consistent with von Hippel's observation (1988).

〈Table 2〉 shows the key variables by industry. The majority of Korean

〈Table 2〉 Degree of Openness by Industry

KSIC	No. of firms	Small	Venture	Inno-biz	Openness	MA degree /Employees	R&D staff /Employees	Technological Opportunity	Appropriability
Food Product	167	76	8	12	4.03	0.02	0.02	0.07	13.98
Textiles	163	117	1	15	3.87	0.01	0.02	0.02	15.34
Apparel	134	66	7	10	2.58	0.01	0.03	0.02	12.32
Leather Product	108	83	6	11	2.58	0.01	0.02	0.03	12.00
Wood & Wood Product	131	115	9	5	1.88	0.01	0.01	0.02	15.50
Pulp, Paper & Paper Product	132	90	5	5	2.79	0.01	0.01	0.04	11.56
Printing & Recording	151	94	5	8	3.56	0.03	0.02	0.03	9.93
Coke, Coal & Petroleum Product	41	28	8	9	2.77	0.03	0.06	0.02	14.13
Chemicals & Chemical Product	158	58	21	23	5.32	0.05	0.08	0.03	15.59
Rubber & Plastic Product	148	90	17	26	3.36	0.01	0.03	0.03	13.98
Non-metallic Mineral Product	170	110	7	11	2.86	0.02	0.02	0.02	15.45
Basic Metal Product	167	92	15	24	3.67	0.02	0.02	0.01	11.50
Fabricated Metal Product	175	126	22	29	3.58	0.02	0.03	0.04	16.89
Other Machinery & Equipment	205	134	42	48	3.39	0.02	0.06	0.04	15.66
Computer & Industry Equipment	75	48	24	24	3.17	0.05	0.13	0.06	16.91
Other Electronical Equipment	148	96	17	35	3.89	0.03	0.08	0.06	15.85
Elec. Compo. & Comm. Equip.	157	43	30	40	4.35	0.04	0.11	0.04	15.79
Medical & Precision Instruments	126	86	41	34	4.37	0.04	0.11	0.07	15.10
Motor Vehicles	186	58	16	32	4.38	0.02	0.05	0.02	16.47
Other Transport Equipment	92	33	4	9	4.33	0.01	0.03	0.02	15.53
Furniture & Other	151	116	18	21	3.12	0.02	0.03	0.02	15.02
Metal & Non-metal Waste/Scrap	96	89	8	4	2.76	0.01	0.01	0.02	12.33
Total, Average	3,081	1,848	331	435	3.48	0.02	0.04	0.03	14.40

manufacturing firms are small business. On average, about 60 percent of firms are small enterprises. The Metal and Non-metal Waste and Scrap industry (KSIC 37) is the highest (92.7 percent) and the Electronics Components and Communication Equipments (KSIC 32) is the lowest (27.4 percent) in terms of the share of small enterprises.

On average 14.1 percent of manufacturing firms are designated as Inno-biz firms. The Computer and Industry Equipment Industry (KSIC 30) has the highest share of Inno-biz firms (32.0 percent) among manufacturing industries; The portion of Inno-biz firms in the Wood related industry (KSIC 20) and Pulp and Paper Industry (KSIC 21) are the lowest (3.8 percent).

The average degree of openness in Korean manufacturing sector is 3.5, which means that a Korean manufacturing firm uses 3 or 4 external sources seriously on average. Firms in the Chemicals and Chemical Products industry (KSIC 24) seem to use 5.3 external knowledge sources on average, which is the highest among manufacturing industries. Firms in the Wood and Wood Products industry (KSIC 20) depend on the external sources the least (1.8 sources). In general, science-based industries such as chemical, electronic components and medical device industries and complex product industries such as automobile and other vehicle manufacturing seem to have high degree of openness. Low technology industries such as wood product and apparel industries seem to have low degree of openness.

The share of employees with master's or higher degree is 2.1 percent on average. The share is the highest in Chemical (KSIC 24) and Computer and Industry Equipment (KSIC 30) industries (5.1 percent). The number is the lowest in Leather, Luggage and footwear industry (0.6 percent). It seems that the share of employees with master's or higher degree tend to be positively associated with the degree of openness by industry.

Technically, the tightness of appropriability strategy can range from 0 to 35: 0 represents that no protection mechanism is perceived effective at all and 35 reflects that all protection mechanisms are extremely effective. The tightness of appropriability strategy ranges from 9.9 (Printing industry) to 16.9 (Computer and Industry Equipment) and the industry average is 14.4. Under the assumption that the importance scale for each protection mechanism is 4, it means that a firm in printing industry uses about

2 protection methods and a firm in Computer and Industry Equipment uses about 4 protection methods.

〈Table 3-1〉 shows the summary statistics for main variables.

〈Table 3-2〉 demonstrates simple correlations among the variables. The degree of openness to external sources seems to have strong positive correlation with appropriability strategy, the share of employees with master's degree, and the firm size. The use of appropriability strategy has a positive relationships with the share of employees with master's or higher degree, and the firm size. There does not seem to be strong correlation among independent variables. The R&D intensity has strong positive relationship with the share of master's or higher degree employees and the share of R&D staff. The average variance inflation factor (VIF) is 1.64[4] and condition

〈Table 3-1〉 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Openness	1524	3.75	3.12	0	10
Appropriability	984	14.94	8.96	0	35
MA degree / Employees	3046	0.02	0.05	0.00	0.72
R&D staff / Employees	3081	0.04	0.09	0.00	0.82
R&D Intensity	1504	0.03	0.15	0.00	4.83
Inno-biz	3081	0.14	0.35	0	1
Technological Opportunity	3081	0.03	0.02	0.01	0.07
Log(employment)	3081	3.91	1.41	2.30	10.93

〈Table 3-2〉 Correllation between Variables

	Open-ness	Appropriability	MA /Employees	R&D Staff /Employees	R&D Intensity	Inno-biz	Technological Opportunity	Log(emp-loyment)
Openness	1.00							
Appropriability	0.40	1.00						
MA/Employees	0.16	0.13	1.00					
R&D Staff/Employees	0.06	0.09	0.36	1.00				
R&D Intensity	-0.01	0.01	0.27	0.37	1.00			
Inno-biz	0.05	0.05	0.08	0.19	0.10	1.00		
Technological Opportunities	0.07	0.03	0.08	0.19	0.13	0.06	1.00	
Log(employment)	0.30	0.29	0.01	-0.19	-0.21	-0.24	-0.09	1.00

4) The minimum is 1.05 and the maximum is 3.44 among the VIFs of independent variables.

number is 3.8. These measures suggest that multicollinearity among independent variables may not be problematic.

2. Econometric Model

The model to be estimated is as follows:

Opennessi
= f(Appropriabilityi, Absorptive-capacityi, Inno-bizi, Sizei, Industry dummies, εi)

To estimate parameters and test hypotheses, I use the negative binomial regression. This is because the dependent variable - the degree of openness to external knowledge sources - is a count variable.[5] Moreover, the brief check of the distribution shows a skewness in the distribution of openness. Thus, I decide to use the negative binomial regression instead of the Poisson regression model. Therefore, the conditional mean to be estimated is as follows:

E(Opennessi | Appropriabilityi, Absorptive-capacityi, Inno-bizi, Sizei, Industrial dummies)
= exp(β0 + β1Appropriabilityi + β2Absorptive-capacityi + β3Inno-bizi + β4Sizei
+ β5Industry dummies + β6 "Interaction_terms")

I test the hypotheses using four different models. The models depend on what measure of absorptive capacity is used. I use three different measures reflecting human capital: (1) the share of employees with master's or higher degree, (2) the share of employees with foreign master's or higher degree, and (3) the share of the R&D staff. The fourth measure of absorptive capacity is (4) the R&D intensity. In

5) Count variable is a type of limited dependent variable because y is a non-negative integer and E(y|x) should be non-negative (Wooldridge, 2002). To address different aspect of limitedness - the upper limit of dependent variable y, I use the Tobit regression with upper and lower limits besides the negative binomial regression. Although I do not report the results of Tobit regression here, they are qualitatively the same as the results of the negative binomial regression.

addition, I include the interaction terms between these absorptive capacity variables and the Inno-biz variable to reflect the possible additional effect of absorptive capacity on technology entrepreneurship.

3. Econometric Results

〈Table 4-1〉 demonstrates the estimation results from the negative binomial regression of four models using industry dummies.

All four models seem to support the first hypothesis: the tightness of the overall appropriability strategy is curvilinearly related to the degree of openness to external sources of innovation. Specifically, the hypothesis suggests the inverted U-shaped relation between the appropriability strategy and the openness. First, the coefficients of appropriability strategy variable in four models are positive and significant at a 1 percent level. The amount of estimates are 0.046 to 0.048 across the models. These

〈Table 4-1〉 Negative Binomial Regression with Industry Dummies

Variable	Model 1-1	Model 1-2	Model 1-3	Model 1-4
Appropriability	0.0478***	0.0471***	0.0463***	0.0469***
Approprability^2	-0.0006**	-0.0006**	-0.0005*	-0.0006**
Inno-Biz	0.1449**	0.1689***	0.1107	0.1944***
Share of MA degree	0.8525*			
Inno-Biz*Share of MA degree	0.3502			
Share of Foreign MA degree		1.9033		
Inno-Biz*Share of Foreign MA degree		-0.3904		
Share of R&D staff			0.103	
Inno-Biz*Share of R&D staff			0.4345	
R&D intensity				0.2985
Inno-Biz*R&D intensity				-0.4551
Log(employment)	0.0893***	0.0839***	0.0881***	0.0876***
Constant	0.4944***	0.5209***	0.5066***	0.4896***
	Control Variable: Industry Dummies			
N	957	978	984	975
Pseudo R2	0.05	0.0467	0.0479	0.048

1. ***: p〈0.01; **: p〈0.05, *: p〈0.1

estimates imply that as the appropriability mechanism becomes more important in one additional scale, a firm becomes more open to external knowledge sources by about 4.8 percent. According to Laursen and Salter (2005b), a UK manufacturing firm seems to increase its use of external sources by 6.3 percent as the importance of appropriability strategy increases in one additional scale. It is difficult to directly compare the effect of appropriability strategy in Korean and UK manufacturing industries because the importance scales and the number of methods are different. However, the effect of appropriability seems to be positively significantly in both countries.

Second, the coefficients of squared appropriability strategy variable are negative and significant at least at a 5 percent level. This implies that when a firm is extremely aggressive in using the appropriability strategy, it tends to be less open to the external sources. Such turning point is 39.8 in the degree of appropriability when Model 1-1 is used. This means that the appropriability strategy will have negative effects on the openness of a firm if all 7 appropriability methods are used with the scale either 4 or 5. Noting that the degree of appropriability is measured up to 35, the tightness of appropriability strategy that discourages a firm from using the external sources seems to be out of the range in Korean manufacturing sector. Thus, the appropriability strategy and openness are positively associated within the effective range of appropriability tightness.

The second hypothesis is that absorptive capacity of a firm is positively related to the degree of openness to external sources of innovation. When the share of employees with master's or higher degree is used (Model 1-1), the coefficient (0.85) is positive and significant at 10 percent level. For instance, when the share of employees with master's or higher degree increases by 1 percent, a firm will become more open by 85.3 percent. This is very large amount of responsiveness. One possible source might be that highly educated employees may need to improve their working knowledge through close contact with external knowledge sources. The estimated effect of hiring more undergraduate employees in UK shows increment in openness by 0.3 percent (Laursen and Salter, 2005b). At this stage, it is not clear whether this difference due to the definition of high education or other structural factors. One possible reason might be that the KIS and the UK survey collect information on

employees differently: the KIS provides information on the employees with master's or higher degree while the UK survey provides information on the employees with university degree. Besides the share of employees with high education, other variables for absorptive capacity - the share of employees with foreign master's or higher degree, the share of R&D employees and the R&D intensity - are positive but not significant any more. To examine whether the absorptive capacity in human capital form influences the openness of a Korean manufacturing firm, more detailed data on employees' education seem to be required.

The third hypothesis is that a technology entrepreneur is less open to the external sources of innovation. The results do not support this hypothesis. Rather, when a firm is designated as an Inno-biz firm by the SMBA, it tends to be more open to external sources. The coefficients of all models are positive and significant at least in a 5 percent significance level. Only exception is Model 1-3 that uses the share of R&D staff. When a firm is designated as an Inno-biz firm, the openness tends to increase by 14.5 to 19.4 percent.

This result is different from the observation by Laursen and Salter (2005b): There, the authors insist that a start-up tends to be less open to external sources. Although the coefficients of a start-up in their models are insignificant, the authors show that the interaction terms between the start-up variable and absorptive capacity variables are negative significantly. Thus, Laursen and Salter (2005b) conclude that a technology entrepreneur is less open to external knowledge sources.

The reason why being an Inno-biz firm in Korea has the positive effect on its openness in my study may be because of the eligibility of Inno-biz firms and governmental supports to them. To be designated as an Inno-biz by the SMBA, a firm should survive at least three years. Moreover, various government agencies provide financial support, preferential treatment in R&D investments, and other support in management of R&D personnel to newly designated Inno-biz firms. These initiatives may offset the disadvantage of technology entrepreneurs that comes from the lack of complementary assets: The Inno-biz firms' capability signaled by three year survival and governmental supports to them may enable the firms to become more open. Thus, current positive result may confound the effects of being a technology

entrepreneur, being superior to other firms and being supported by the government. To investigate whether newness drives less or more open to external sources, more detailed data on firm formation year should be provided.

The fourth hypothesis - a large firm is likely to be more open to external knowledge sources - is strongly supported. The coefficients for firm size variable (the logarithms of the number of employees) are all positive and significant at the 1 percent significance level. Specifically, 1 percent increase in employment size is associated with the increase in its openness by about 9 percent. An explanation may be that the large firms become more confident about exchanging their ideas with external sources because they have complementary assets to leverage and larger knowledge base. The study of the UK manufacturing firms also shows a similar pattern (Laursen and Salter, 2005b). The authors find significant positive relationships between firm size (the logarithms of the number of employees) and the openness of a firm. The estimated size effect is that 1 percent increase in size is associated with 6 percent

〈Table 4-2〉 Negative Binomial Regression with Technological Opportunities

Variable	Model 2-1	Model 2-2	Model 2-3	Model 2-4
Appropriability	0.0473***	0.0472***	0.0460***	0.0467***
Approprability^2	-0.0007**	-0.0006**	-0.0006**	-0.0006**
Inno-Biz	0.1419**	0.1591***	0.0987	0.1807***
Share of MA degree	1.0646**			
Inno-Biz*Share of MA degree	0.2477			
Share of Foreign MA degree		1.7633		
Inno-Biz*Share of Foreign MA degree		0.4326		
Share of R&D staff				
Inno-Biz*Share of R&D staff			0.4371	
R&D intensity				0.3891
Inno-Biz*R&D intensity				-0.3711
Technological opportunity	3.2792**	3.3900**	3.1579**	3.1884**
Log(employment)	0.1122***	0.1040***	0.1083***	0.1090***
Constant	0.177	0.2337**	0.2224*	0.2081*
N	957	978	984	975
Pseudo R2	0.0425	0.039	0.0402	0.0396

1. ***: p〈0.01; **: p〈0.05, *: p〈0.1

increase in the openness.

Lastly, the fifth hypothesis is that when industry-level technological opportunities are ample firms tend to be more open to external sources. When the three-year-average of industry-level R&D intensity as technological opportunities is used, the result seems to support the fifth hypothesis. All four models in 〈Table 4-2〉 show that the coefficients of technological opportunities measured by the average industry-level R&D intensity are positive and significant at a 5 percent significant level.

VI. Conclusion

Based on the KIS survey, the factors that influence the openness of a Korean manufacturing firm are the tightness of appropriability strategy, the share of employees with high education, technology entrepreneurship, firm size and technological opportunities. Specifically, a Korean manufacturing firm is likely to be more open to external knowledge sources (1) when a firm use the appropriability strategy more tightly, (2) when a firm has employed highly educated workers, (3) when a firm is a technology entrepreneur, (4) when a firm is large and (5) when industries provide ample technology opportunities. Furthermore, the openness of a Korean manufacturing firm seems to respond to the share of highly educated employees and the technology entrepreneurship the most. For instance, 1 percent increase in the share of highly educated employees is associated with increase in openness by about 85 percent. And being a technology entrepreneur (i.e., being designated as an Inno-biz firm) is likely to increase the firm's openness by 14.5 to 19.4 percent.

Results of this study suggest that the determinants of the openness of a UK manufacturing firm suggested by Laursen and Salter (2005b) also influence the openness of a Korean manufacturing firm. This implies that there may exist common determinants of the openness to external knowledge sources regardless of countries. However, I observe some differences of determinants between Korea and UK manufacturing industries. First, the effect of appropriability strategy is curvilinear (i.e., inverted U-shaped) in the UK but effectively linear in Korea. Although the overall

shape of appropriability strategy effect in Korean manufacturing industries also seems to be the inverted U-shaped, the effect is linear within the feasible range of the variable. Second, Laursen and Salter (2005b) do not find the effect of technology entrepreneurship on the openness of the UK manufacturing firms. In contrast, I observe the significant positive effect of technology entrepreneurship on the openness. Third, the employees with higher education seem to be influential in the openness decision more in Korea than in UK. However, this result should be interpreted carefully because the KIS survey records the master's or higher degree but Laursen and Salter (2005b) use undergraduate degree as the definition of high education.

The findings of my study provide implications for open innovation strategy and policy. First, making the balance between appropriability strategy and openness should be considered. Although well functioning appropriation mechanism such as intellectual property rights is suggested as the underpinning of open innovation, the results of my study imply that "too" tight appropriability strategy may eventually restrict the value of open innovation. Thus, firms should design proper level of appropriability strategy to facilitate openness without restricting productive knowledge flow.

Second, my study suggests that government may be capable of encouraging small firms' use of external knowledge for their innovation. In my study small firms are less likely to be open while technology entrepreneurs supported by government (i.e., Inno-biz firms) are more likely to be open to external knowledge. Thus, we can infer that start-ups may become willing to use external knowledge more if our government could provide financial and management supports to them properly.

Although this study may help us identify determinants of firms' use of external knowledge, the following issues need to be examined further. First, the effect of technology entrepreneurship needs to be examine further. The current measure - the eligibility of an Inno-biz firm - may include the effect of technology entrepreneurship and the effect of government support. Also, the eligibility of an Inno-biz firm includes at least three-year operation in the market. These factors may be considered separately. Second, the measures of absorptive capability in terms of human capital and skill should be developed further. In this paper, I use the share of employees

with master's or higher degree, with foreign master's or higher degree in an individual firm. However, more detailed information on employees such as undergraduate degree and major may be useful. To examine these issues further, new set of data is required. Lastly, my study does not intend to analyze why the determinants of openness are either the same or different between Korea and UK although such international comparison of determinants of openness will be very interesting. Further study in this direction may require international survey of manufacturing industries based on the same questionnaire and in-depth studies on related institutions such as intellectual property rights and research universities in those countries.

References

권영관 (2010), "학술연구 : 개방형 혁신이 혁신성과에 기여하는가?: 한국 중소기업으로부터의 실증적 증거." 중소기업연구 32, No. 2 : 145-68.

김현호, 조가원, 박동배, 서정화, 이정열 (2008), 「2008년도 한국의 기술혁신조사: 제조업 부문」, 과학기술정책연구원 (STEPI)

윤진효, 권오진, 박진서, 정의섭 (2010), "특허기반 개방형 혁신 분석 모델 개발 및 적용 연구." 기술혁신학회지 13, No. 1 : 99-123.

홍장표, 김은영 (2009), "한국 제조업의 산업별 기술혁신패턴 분석." 기술혁신연구 17, No. 2 : 25-53.

Arrow, K. (1962), "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Research National Bureau of Economic. Princeton: Princeton University Press.

Becker, W., and J. Dietz (2004), "R&D Cooperation and Innovation Activities of Firms-Evidence for the German Manufacturing Industry." *Research Policy* 33, No. 2 : 209-23.

Cassiman, B., and R. Veugelers (2002), "R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium." *American Economic Review* 92, No. 4 : 1169-84.

Chesbrough, Henry, Wim Vanhaverbeke, and Joel West (2006), *Open Innovation: Researching a New Paradigm*. New York, New York: Oxford University Press.

Chesbrough, Henry (2003), *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, Massachusetts: Harvard Business School Press.

Christensen, Jens Fr lev, Michael Holm Olesen, and Jonas Sorth Kj (2005), "The Industrial Dynamics of Open Innovation-Evidence from the Transformation of Consumer Electronics." *Research Policy* 34, No. 10 : 1533-49.

Cohen, W. M. (2010). "Fifty Years of Empirical Studies of Innovative Activity and Performance." In *Handbook of the Economics of Innovation*, edited by B.H.Hall and Nathan Rosenberg: North Holland.

Cohen, Wesley M., and Daniel A. Levinthal (1990), "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35, No. 1, Special Issue: Technology, Organizations, and Innovation: 128-52.

Cohen, Wesley M., and Daniel A. Levinthal (1989), "Innovation and Learning: The Two Faces of R & D." *The Economic Journal* 99, No. 397 : 569-96.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh (2000), "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)." *National Bureau of Economic Research Working Paper*, Series No. 7552.

Enkel, E., O. Gassmann, and H. Chesbrough (2009), "Open R&D and Open Innovation: Exploring the Phenomenon." *R&D Management* 39, No. 4 : 311-16.

Gallini, N. T. (2002), "The Economics of Patents: Lessons from Recent Us Patent Reform." *Journal of Economic Perspectives* 16, No. 2 : 131-54.

Gans, J. S., and S. Stern (2003), "The Product Market and the Market For "Ideas": Commercialization Strategies for Technology Entrepreneurs." *Research Policy* 32, No. 2 : 333-50.

Keupp, Marcus Matthias, and Oliver Gassmann (2009), "Determinants and Archetype Users of Open Innovation." *R&D Management* 39 : 331-41.

Teece, D. J. (1986), "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy." *Research Policy* 15, No. 6 : 285-305.

Teece, D. J. (2006), "Reflections On "Profiting from Innovation"." *Research Policy* 35, No. 8 : 1131-46.

Laursen, Keld, and Ammon Salter (2005a), "My Precious: The Role of Appropriability Strategies in Shaping Innovative Performance." *DRUID Working Paper.*

Laursen, Keld, and Ammon Salter (2005b), "The Paradox of Openness: Appropriability and the Use of External Sources of Knowledge for Innovation." *Working Paper.*

Lee, S., G. Park, B. Yoon, and J. Park (2010), "Open Innovation in Smes-an Intermediated Network Model." *Research Policy* 39, No. 2 : 290-300.

Levinthal, D. A., and J. G. March (1993), "The Myopia of Learning." *Strategic Management Journal* 14 : 95-112.

Mairesse, J., and P. Mohnen (2002), "Accounting for Innovation and Measuring Innovativeness: An Illustrative Framework and an Application." *American Economic Review* 92, No. 2 : 226-30.

Segarra-Blasco, A., and J. M. Arauzo-Carod (2008), "Sources of Innovation and Industry-University Interaction: Evidence from Spanish Firms." *Research Policy* 37, No. 8 : 1283-95.

Tether, B. S. (2002), "Who Co-Operates for Innovation, and Why - an Empirical Analysis." *Research Policy* 31, No. 6 : 947-67.

Von Hippel, E (1988), *The Sources of Innovation.* New York: Oxford University Press.

Zahra, S. A., and G. George (2002), "Absorptive Capacity: A Review, Reconceptualization, and Extension." *Academy of Management Review* 27, No. 2 : 185-203.

Zahra, S. A., and A. P. Nielsen (2002), "Sources of Capabilities, Integration and Technology Commercialization." *Strategic Management Journal* 23, No. 5 : 377-98.

문성욱

노스웨스턴 대학 켈로그 경영대학원에서 경영학 박사학위(Ph.D. in Managerial Economics and Strategy)를 취득하고 현재 KDI 국제정책대학원에서 조교수로 재직 중이다. 유학 전에는 제35회 행정고시(재경직) 합격 후 재무부와 기획예산처에서 근무하였다. 관심분야는 경영전략, 과학기술전략, 인적자본관리, 조직경제학 등이다.