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The Determinants of Industry-University/GRI Linkages and Their Impacts on Firm Performance: The Case of Korea

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I. Introduction

1. Background and Research Framework

In the knowledge-based economy, knowledge is essential; thus the role of university as a source of new knowledge has even become more important than in the past (Etzkowitz et al., 2000). Fast-paced global competition, following shifts in technological regime, e.g. shorter product life-cycle, adds significance to the firm's links to university from recovery to commercialization of knowledge (Bettis & Hitt, 1995; Etzkowitz & Leydesdorff, 1997; Hwang et al., 2003). In particular, the role of university in a national economy is discussed as a key issue in technological innovation, which is centered on the Triple-Helix thesis: this thesis emphasizes the shift of university' role from being an "academic community" to an "entrepreneurial academy" (Etzkowitz & Leydesdorff, 2000)

Knowledge commercialization in advanced countries has evolved since the 1980s, benefited from the early formed industry-university linkages of the 19th century (Branscomb et al., 1999). The U.S. and UK have established university-centered systems, for example, the *Route 128* or *Silicon Valley* and the *Cambridge Science Park* or *University of Manchester Institute of Science Park*. Germany has developed the GRI (government research institute)-centered system like the *Max-Planck Gesellscharft.*

However, the situation is different for developing countries. In Korea, as a catch-up country, technological innovation has been led mainly by *chaebols* since the early stage of industrialization. It resulted in the national innovation system (NIS) of Korea as being characterized by "strong large firms and weak small firms" (Lim, 2006). As of 2005, 39.7%

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of researchers and 52.2% of Ph.D. researchers belong to the top 20 firms (MOST, 2007). This imbalance eventually made SMEs face trouble in developing or acquiring new technology that is essential for innovation. This *chaebol*-led innovation also has left university lagged behind in terms of growth opportunities in research.[3] As of 2005, 69.9% of Ph.D. researchers and over 10% of national R&D expenditures belong to university, but its role is weak in knowledge commercialization.

In the NIS, it is essential knowledge to be created, shared, and utilized in a balanced manner, benefiting all but not just a few institutional actors. In Korea, where R&D resources are concentrated on large-scale firms, it is particularly necessary to make the most use of public knowledge assets that belong to university or GRI. Namely, it is crucial to establish the NIS where industry-university linkages are firmly established to work as a channel to knowledge transfer, particularly for SMEs or venture firms, eventually contributing to the enhancement of a nation's competitiveness.

In this context, this paper aims to examine the current situation of industry-university or GRI linkages in Korea. Considered the important role of GRI in national R&D,[4] it also includes this into analysis. As a governance form for empirical analysis, this chooses the 'technological cooperation' between industry and university or GRI (IUG cooperation): joint or contract R&D is currently the most prevalent form in Korea (KRF, 2007), although it is now moving towards diverse forms of knowledge commercialization. This paper seeks to answer two main questions: (1) why a firm cooperates with university or GRI and (2) whether IUG cooperation contributes to the innovation probability of firms and to what type of performance, it has a contribution.

This paper tests the following four hypotheses. First, IUG cooperation in Korea may be determined by firm characteristics, sector characteristics, and government's support measures for R&D. The internal resource of a firm or its substitutability to external resource and the effective legal regime for IPR protection matters to the firm's decision in IUG cooperation. Due to the government-led NIS of Korea, the government's policy for R&D is also deterministic to this cooperation. Second, IUG cooperation may not directly increases the innovation probability of Korean firms. Unlike the technology from a private firm that is tangible with the precise impact of its use, a large part of the knowledge from university is intangible with its imprecise impact. Due to these characteristics, IUG cooperation is not deterministic to the firms' success in technological innovation. Third, for Korean innovative firms, the impact of IUG cooperation may be revealed in patent rather than other types of performance. University's research and development is characterized as being new or creative, but knowledge commercialization system has not well developed in Korea, unlike advanced countries. This makes it difficult the knowledge from this cooperation to be shifted commercially, eventually revealing the impact only in patent, the

[3] Kim (1993) argues that the lack of interaction between university and industry due to teaching-oriented university is one of the greatest weaknesses of Korea's national system.

[4] According to the OECD's study (2002), Korea is the only country that GRI, rather than university, had a relatively greater role in national R&D.

prior stage of knowledge commercialization. Fourth, IUG cooperation may contribute to product rather than process innovation. It results from the innate characteristics of university research that is basic or long-term based, not just practical or short-term based. Korean university or GRI has focused on reverse engineering or problem-solving, but their research capacity has been improved to be useful or appropriate for product innovation.

The empirical analysis is based on the *2002 Korean Innovation Survey* (*KIS*) that has been conducted by Science and Technology Policy Institute (STEPI). The *KIS* comprises of firm-level data on technological innovation in the manufacturing sector. In order to allow for data credibility, the *Survey* data is merged with the financial statements of the *KIS VALUE database* compiled by a credit rating agency. This paper, initially, estimates the determinants of IUG cooperation using the Probit model. Then, it estimates the impact of this cooperation on firm performance. First, this analyzes its impact on the innovation probability of firms using the Probit model, where a possible endogeneity of IUG cooperation measure is controlled. Second, for innovative firms, this analyzes its impact by the type of performance (patent vs. sale) and by the type of innovation (product vs. process innovation). Here, a sample selection bias is controlled using Heckman's 2SLS.

This paper is structured as follows. In the next section, a brief overview is presented on the data. Section II reviews the literature on the NIS and examines the evolution of the NIS and IUG linkages in Korea. Section III reviews the existing literature on the determinants of IUG cooperation and on its impacts on firm performance, extracting four hypotheses. Section IV explains the methodology to be used for empirical analysis. Section V reports to discuss the empirical results, and Section VI provides the conclusions.

2. Data

The 2002 *KIS* is the third survey in Korea. The *KIS*, following the definitions in the *Oslo Manual*[5] from the OECD, covers the innovation activities of firms for 2000-2001. Out of the 6,233 surveyed firms, 60.6% or 3,776 responded. After matching with the *KIS VALUE*, a total of 538 firms are used for analysis.

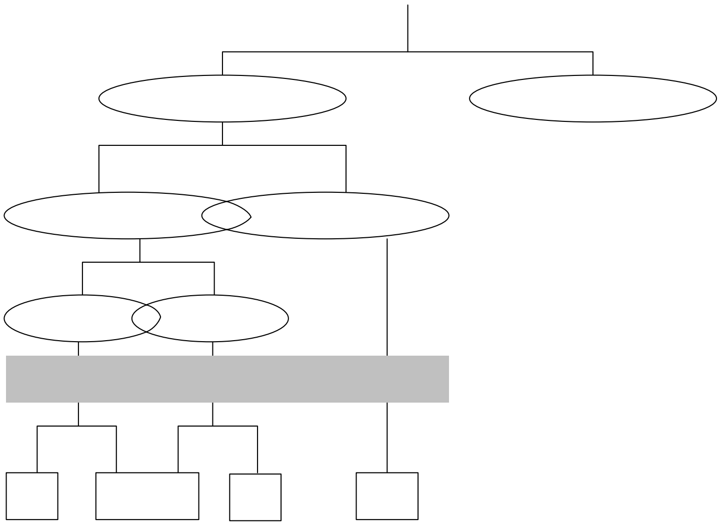
Technological innovation here includes three types – product innovation (new product innovation and product-improving innovation) and process innovation. Only innovative firms are asked how many patents they file from each type of innovation, and what percentage in the sales of innovation outcomes they make from new product innovation and product-improving innovation. The 'innovative firms' are defined as those firms that conduct innovation during 2000-2001 and produce at least one innovative outcome, patent or sale, in 2001.

The structure of firms in this survey is as follows (<Figure 1-1>). Out of the total 538

[5] This is a standardized manual that provides the criteria on innovation surveys. The Manual was firstly published by OECD countries in 1992, based on which several Community Innovation Survey (CIS) projects were conducted. In Korea, three Surveys have been done for last 10 years.

firms, 388 (72.1%) are innovative firms, while 150 (27.9%) are non-innovative firms. The innovative firms are divided into two, namely, 366 (68.0%) firms that do product innovation (269 new product innovators and 324 product-improving innovators) and 250 (46.5%) firms that do process innovation.

<Figure 1-1> The structure of firms in the KIS



The KIS asks firms the question, “Does your firm cooperate with partners for technological innovation? If yes, how important is the cooperation (with each partner) for your innovation (on a five-point scale)?” Out of the total 538 firms, 40.1% or 216 firms had a positive answer regarding cooperation with at least one partner. According to the type of partner, universities and GRIs rank fourth (139, 25.8%) and fifth (129, 24.0%), respectively, in terms of number and percentage, and they rank third (3.32 point) in terms of the degree of importance (<Table 1-1>). These figures are a bit lower than those of clients and suppliers.

<Table 1-1> Technological cooperation according to partner (n=538)

Partners	No. of firms(%)	Degree of importance*(point)
Affiliated firms	113 (21.0)	3.42
Clients	161 (29.9)	3.66
Suppliers (raw materials)	161 (29.9)	3.32
Suppliers (components/SW)	142 (26.4)	3.03
Competitors	122 (22.7)	2.88
Joint venture	94 (17.5)	2.84
Business service firms	101 (18.8)	2.74
Universities	139 (25.8)	3.32
Public research institutes	129 (24.0)	3.32
Public research laboratories	116 (21.6)	3.06
Research associations	99 (18.4)	2.45
Research cooperatives	92 (17.1)	1.00
Private research institutes	95 (17.7)	2.53

Note: * The average value of the firms that cooperate with corresponding partners.

In comparison with the 2005 *KIS* (2002-2004), university (18%) is the most important partner, out of 10, for technological innovation. They are followed by client (15%), supplier (14%), competitor (11%), and GRI (11%). Even in terms of degree of importance, university receives the highest score. This result partly reflects a change in the status of university as compared to that of the 2002 *KIS* (2000-2001) in the above.[6]

II. NIS and IUG Linkages in Korea

1. IUG Linkages in the NIS

(1) National Innovation System (NIS)

The concept of the national innovation system (NIS) was proposed by Freeman (1987) and Lundvall (1992) in the 1980s. Freeman defines the NIS as a "network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and

[6] The rise in the status of university is also seen from another survey that has been conducted by the Federation of Korean Industries (FKI, 2006). The survey reports that 51.7% of firms cooperated with university in the last three years, a 1.5-fold increase from 33% in 2005, and that 55% of them highly evaluated the research results. Among various forms of cooperative activities, spot-education took the largest share at 21.7%, followed by joint research at 20.7%. However, only 7% of firms acquired technology from university, revealing the weakness of knowledge commercialization in Korea.

diffuse new technologies." Lundvall defines it as the "elements and relationships which interact in the production, diffusion, and use of new, and economically useful, knowledge… and are either located within or rooted inside the borders of a nation state." He broadens the concept of Freeman to include economic structure and institutional set-up that affect searching, learning, and adapting into the definition of the NIS. Meanwhile, Nelson (1993) defines the NIS as a "set of institutions whose interactions determine the innovative performance… of national firms." In a comparison to the NIS of 15 countries, he argues that the differences among these countries reflect different institutional arrangements.

The NIS deals with the issue of how a nation can establish an efficient system for learning and innovation: how efficient can firm, university, and GRI be in creating new or acquiring external knowledge, and how efficient is this knowledge being diffused and utilized by other institutional actors? The definitions of the NIS are somewhat varied, but have common characteristics. First, the NIS is composed of various patterns of innovation by institutional actors, and its specific contents are different according to country. The difference affects the direction or speed of a nation's innovation. Second, the NIS emphasizes on 'learning' and 'learning by doing.' National competitiveness is enhanced when new knowledge is diffused to be shared both by the individual and the nation as a whole. Third, the NIS describes the role of university or research institute as channeling its knowledge to firm. It emphasizes the labor mobility as the most efficient mechanism in the creation, diffusion and utilization of knowledge. Here, university functions as a knowledge diffuser, by producing quality students or by interacting with firm or research institute through cooperative research programs.

The diffusion and utilization as well as the creation of knowledge itself become more diverse and complicated. This means that the economic or social role of university or its link to institutional actors becomes more important than in the past. In this context, the next extends the theoretical framework of the NIS to emphasize the role of university in the knowledge-based economy.

(2) The Triple-Helix Thesis vs. the New Economics of Science

Regarding the role of university in a national economy, there exists a contrasting argument between two streams, the Triple Helix Thesis and the New Economics of Science (Eun et al., 2006).[7] They narrow down the perspectives of the NIS to focus on the role of university in a nation.

Etzkowitz and Leydesdorff (1997) introduce a triple-helix model of industry-university-government relations with an emphasis on both social and economic roles of university.

[7] Criticizing the inappropriateness of the two theories in applications to developing countries, they suggest a "contingent or context-specific" perspective on the industry-university relationships. They try to explain in what conditions university keeps a distance from industry or it becomes entrepreneurial and suggest three major determinants of the relationships—the internal resource of the university, the absorptive capacity of firm, and the existence of intermediary institution.

Here, the interactions among three are keys to facilitating conditions for innovation. The institutional actors exist both independently and partly overlapped in terms of their functions, and simultaneously each takes the roles of the other, thus hybrid organizations emerging at interfaces. This thesis suggests four processes regarding the changes in technological innovation: (1) the internal transformation in each of the helices, (2) the influence of one institutional sphere on another in bringing about transformation, (3) the creation of a new overlay of trilateral linkages, networks, and organizations among the three helices, and (4) the recursive effect of these inter-institutional networks (Etzkowitz & Leydesdorff, 2000).

The Triple-Helix thesis argues that university needs to be directly linked to industry in order to maximize the commercialization of knowledge. This emphasizes on the "third mission" of the university to economic development, as well as teaching and research (Etzkowitz & Leydesdorff, 2000). In a comparative study on Europe, Latin America, and Asia, Etzkowitz et al. (2000) conclude that the "entrepreneurial university" is a global phenomenon. On the other hand, the New Economics of Science (Dasgupta & David, 1994) worries about the relationships between university and industry becoming too close. This argues that they may be detrimental to the scientific potentials of a nation, suggesting the indirect links between the two, such as education. Referring to the different functions of university and industry in a society, this underlines the proper division of labor between these institutional actors.

As pointed out above, each country has its own NIS, so it is natural that the industry-university linkages of each country take various forms, assuming different functions in a nation. In this respect, the IUG linkages in Korea should be understood in the Korean context, specifically, the Korean innovation system.

2. The Evolution of the NIS and IUG Linkages

The NIS of Korea is characterized as being government-led, so its industry-university or GRI linkages have evolved with the influences of science and technology (S&T) policy (MOST, 2007). In the 1960s, after the Japanese colonization for 36 years and the Korean War of 1950~1953, Korea was left with no industrial infrastructure, and its government initiated economic development through the *Five-Year Economic Plan.* In this period, the government set up legal and organizational frameworks for S&T: the Korea Institute of Science and Technology (KIST) and the Ministry of Science and Technology (MOST) were established in 1966 and 1967, respectively; the *Science and Technology Promotion Law* was enacted in 1967. Mechanical and skilled labor education was given importance.

In the 1970s, Korea was in transition from light to heavy and chemical industries, and the government's export-oriented policy stimulated the production of labor-intensive industries, e.g. footwear or textile. Due to the weak R&D capacity of both industry and university, the Korean government tried to promote national R&D capacity by establishing GRIs: a number of GRIs were established, based on the *Special Research Institute*

Promotion Law of 1973, in the fields of machinery, shipbuilding, chemical engineering, marine science, and electronics. Noticeably, *chaebol* firms started to grow rapidly on the basis of heavy and chemical industries from the mid-1970s. For this, the government selected to provide a few *chaebol* firms with exclusive advantages. Engineering and scientist education was given importance, as well.

In the 1980s, faced regulations on technology transfers by advanced countries, the Korean government placed a priority on the building of national R&D capacity (Kim, 1993). It started the National R&D programs in 1982 with an emphasis on large-scale national projects, in which GRI played a role as major institutes: several ministries (including relevant organizations) were involved in the programs with a large amount of R&D budget and investment.[8] It is since then that the industry-university or GRI cooperation in Korea has being proceeding through specific programs.[9] An example is the DRAM semiconductor, co-developed by private firms and the *Electronics and Telecommunications Research Institute* (*ETRI*) to catch up with advanced countries (Lee & Lim, 2001). From the mid-1980s, the R&D capacity of university and, particularly, industry grew up: big firms, *chaebols*, started in-house R&D by hiring quality scientists and engineers from abroad or by acquiring technology in collaboration with foreign partners; university shifted towards being research based, conducting joint R&D with firms. As a result, the role of GRI subsequently became smaller than it used to be.

Korea, as a catch-up country, emphasized the imitation rather than creation of technology, and *chaebol* firms led technological innovations benefited from the large-scale investment in R&D and the government's selective support (Lim, 2006). Kim (1997) states that the dynamic growth in the Korean economy was possible during this period, through the aggressive creation and accumulation of technological capabilities by *chaebol* firms. On the other hand, this *chaebols*-led innovation dichotomized firms into two-strong large firms and weak small firms, which became a chronic problem for the economy (Lim, 2006; Choi et al., 2007). Actually, in 1996, the top 30 largest *chaebols* accounted for 40% of Korea's total outputs, and business groups, such as Samsung, Hyundai, LG, and Daewoo had 80 affiliates under their roofs (Ungson et al, 1997).

In the 1990s, the R&D capacity of university as well as industry grew remarkably. Since the 1990s, the ranking of Korea has been rising in terms of the number of SCI papers to which university has contributed significantly: Korea ranked 19th in 1996 with university accounting for 83.0% of the contributions (Lee, 1998). However, GRI could not catch up with the level or speed of development in university in the late 1990s, in contrast to its great

[8] The first survey on the Programs was conducted in 1999, from which relevant and consistent statistics are available. During the period of 1999~2005, the Programs trended to grow steadily, with a yearly growth rate of 19.3% in R&D investment and 13.4% in the number of projects (NSTC, 2006). In 2005, the former recorded 7,791 trillion won and the latter recorded 30,425. By the type of participants, GRI ranked first with 43.7%, followed by university with 23.5%, and SME with 10.6%.

[9] For example, in the case of the Specific R&D project (1982) and the Industrial Technology Development Project (1987), over 60% have been conducted though IUG cooperation.

role in the 1970s~1980s (Song, 2004).[10] In this period, infrastructures for the regional innovation system (RIS) have been established, with various forms of industry-university linkages, such as SRC/ERC and Techno-parks.

3. Knowledge Commercialization

(1) Legal and Institutional Development in the 2000s

Since the enactment of the *Technology transfer Promotion Law* of 2001, Korean university has had interests in knowledge commercialization (KRF, 2007). This *Law* prescribes that public university should establish units or institutions that are in charge of technology transfer to support for the training of specialists. Based on this, university began to set up industry-university cooperation foundations within themselves.

However, it is after 2003, with the enactment of the *Laws on Industrial Education and Industry-University Cooperation,* that these foundations were built to function actively,[11] thus visualizing the performance of technology transfer or commercialization. Most of all, on the basis of the *Laws*, the intellectual property rights on university research got to belong to universities. Since then, several programs have been created in support of knowledge commercialization.

(2) Technology Transfer

According to a survey by the Ministry of Commerce, Industry, and Energy (MOCIE) in 2006,[12] 60% or 153 out of 256 public research organizations surveyed possess technology. As of 2005, they retain a total of 42,213 technologies, and only in 2005 did they create 7,774 new ones. The number of new technologies created by university in 2005 alone exceeded that by GRI, although the accumulated number by the former was smaller than that by the latter. This implies that university is currently more active in developing new technology than in the past.

As of 2005, 20.7% or 8,754 out of the total 42,213 technologies of public organizations are transferred to firms, recording an increase of 2.2% as compared to that of the previous year. The rate of technology transfer by university, 9.3%, is much lower than that by GRI, 30.0%, but its rate trend increases from 8.2 of 2004.

[10] Song (2004) evaluates that GRI has produced significant research outcomes, such as CDMA and home satellites, during that period, but doubts if it would continue to perform well in response to the demands of the government and industry in the 21st century.

[11] Technology Licensing Offices (TLOs) have a short history, which initiated in 1999 under the support of the Small and Medium Business Administration (SMBA). However, it was only in 2004 that they really began and grew within the industry-university cooperation foundation. The number of TLOs increased from 32 in 2003 to 80 in 2006 (KRF, 2007).

[12] The MOCIE (2006) surveyed 114 GRIs and 145 universities on the current situation of technology transfer. 98.8%, 256, out of 259 organizations have responded.

In terms of the type of transfer, public research organizations use license the most, followed by sale and technical training/advice. Out of the 1,580 technologies transferred in 2005, licensing account for 89.4% (1,413), sales for 7.4% (116), and technical training/advice for 3.2% (51). Regarding royalties, for a total of 68.7 trillion won, 62.9 trillion won was generated from licensing, 4.0 trillion won from sales, and 1.8 trillion won from technical training/advice. Unlike sale or license, university provides more technical training/advice, 34, than GRI does, 17.

The royalties from technology transfer have accumulated to 564.9 trillion won as of 2005, a 44.3% increase from the 390.6 trillion won accumulated by 2002. In 2005 alone, they recorded 68.7 trillion. GRI accounted for 95.8% of the total amount or 541.5 trillion won, and university, 4.2% or 23.5 trillion won. Although the royalties from university are lower than those from GRI, its rate trend increased from 2.9% in 2002 to 10% in 2005.

In comparison to advanced countries, the knowledge commercialization of public research organizations is not active in Korea (<Table 2-1>). As of 2005, the average number of employees in TLOs is 4.2, about half of that of the U.S. (8.2). The rate of technology transfer measured as a ratio of the number of technologies transferred to that developed is 20.3%, which is smaller than that of the U.S. (28.3%). In the case of R&D productivity measured as a ratio of royalty from technology transfer to R&D expenditure, the ratio is 1.1%, which is also smaller than that of the U.S. (3.5%) and Japan (1.4%). These differences result from the lack of recognition or experience in technology transfers on the part of Korea.

<Table 2-1> Comparisons in the performance of technology transfer (as of 2006)

	Korea			U.S.*			Japan **
	Univ.	GRIs	Total	Univ.	GRIs	Total	
Average no. of employees In TLOs	4.8	3.6	4.2	8.7	6.1	8.2	14.3 ***
Number of technology developments (A)	4,616	3,158	7,774	15,002	1,790	16,792	8,725
Number of technology transfers (B)	629	951	1,580	4,087	671	4,758	1,171
Rate of technology transfer (%) (B/A)	13.6	30.1	20.3	27.2	37.5	28.3	13.4
Royalty from technology transfer ($hundred million) (C)	3.2	53.3	56.5	1,088	346	1,435	n.a.
R&D expenditure ($hundred million) (D)	2,200	2,964	5,164	37,162	4,082	41,244	47,200
R&D productivity (%) (C/D)	0.2	1.8	1.1	2.9	8.5	3.5	n.a.

Note: 1) Base year: Korea (2005); U.S. (2004); Japan (2003)
2) Surveyed organizations: Korea (145 universities, 111 GRIs); U.S. (164 universities, 33 GRIs); Japan (universities and GRIs, 63)
3) * AUTM. *Licensing Survey: FY 2004*
** Japan Patent Office (2003 & 2004)
*** Full-time Non-teaching staff (Technical personnel)/Collage of technology

Source: MOCIE (2006). *A Survey on the Technology Transfers of Public Research Organization*.

III. Theoretical Framework and Hypotheses

1. The Determinants of IUG Linkages: Hypothesis 1

In recognizing intra-firm limitations, extensive literature emphasizes the advantages of external cooperation for advancing new technologies. *The Transaction cost economics* (Pisano, 1990) describes alliances as a "hybrid form of organization between arm's-length transactions in the market and hierarchical transactions within the firm": the former entails high transaction costs, especially when technology is tacit; the latter limits access to specialist know-how while saving the costs. This theory points out that firms face the reciprocity that may minimize opportunism between partners.[13] *The Resource-based theory* states that internal resources play an important role in a firm's decision (Penrose 1959;

[13] According to Gulati (1995), firms tend to select partners where reputation matters or complementarity is maximized or to join a larger network of alliances.

Richardson 1972); the firm tends to engage in cooperation with partners when capital, technology, and human capital are interdependent. Industry-university cooperation has been discussed as one type of R&D cooperation in these contexts. According to Geisler (1995), the more recognized the fact that they are interdependent in terms of resources, the higher the possibility that university and firm establish partnerships. On the other hand, as Santoro (2000) and Freel et al. (2006) argue that, in spite of their importance in research, firm often looks for other partners not university in pursuing technological initiatives, due to the mismatch of research interests between them.

In regard to industry-university cooperation, particular, sector characteristics matter. Pavitt (1984) argues that learning from advancements in technology is crucial for science-based industries, e.g. electronics and chemicals, for which industry-university is particularly significant. Much literature also underlines the importance of this cooperation in these industries, because they rely heavily on basic/core technology for firms' innovation (Meyer-Krahmer & Ulrich Schmoch, 1998; Santoro & Chakrabati, 2002; Schartinger et al., 2002). Besides, the government's policy is emphasized as being crucial for technology transfer. The *Bayh-Dole Act* of 1980, often cited as the legislation for facilitating the growth in university patenting of the U.S., is an example: the *Act* allows the IPR on university results conducted by public funds to belong to university. Since then, OECD countries, such as France, Denmark, Canada and Japan, have emulated it to legislate or adopt similar policies to utilize academic research for commercial advantages (Mowery & Sampat, 2005; OECD, 2003).

Based on the above discussions, our grand hypothesis is that IUG cooperation in Korea is determined by firm characteristics, sector characteristics and government's support measures for R&D.

(1) Firm Characteristics

Firm size: Firm size is an impetus to a firm's decision in R&D cooperation. Large firms can cooperate with partners more effectively than small firms, thereby benefiting from their internal resources (Tether, 2002). On the contrary, there exist a number of studies that argue otherwise: small firms tend to be more eager for external cooperation than large firms as they face lack of internal resources, especially financial, R&D capacity or facility. In empirical analyses, like the theories, the impact of firm size on the firm's decision in cooperation with university or GRI is obscure.

In this study, firm size (*SIZE*) is measured as a log value of the average number of employees during 2000~2001. Unlike previous studies, it uses an average value, not a single one for 2001. In the case of Korea, the mean firm size is larger for firms that cooperate with university and GRI (5.27 and 5.30), respectively, rather than otherwise (5.02 and 5.01). The t-ratio is 2.23 (p=0.03) for university and 2.56 (p=0.01) for GRI, implying the significant difference in firm size between cooperators and non-cooperators (<Table 3-1>).

Therefore, based on the above discussions, we will test if firm size affects the firm's propensity of cooperating with them.

R&D intensity: R&D intensity matters as the absorptive capacity of a firm that maximizes benefits from R&D cooperation (Fontana et al., 2006). Firms, whose R&D capacities are large enough to easily absorb external knowledge, are willing to obtain benefits from it. However, the opposite can occur: these firms may substitute external cooperation by developing technology independently (Love & Roper, 1999). In this case, the smaller the R&D capacity, the more pursuant the firm is to cooperate with partners. Like the empirical analyses for firm size, those for the impact of R&D intensity show obscure results.

In this study, R&D intensity (*RD_INT*) is measured as a ratio of average R&D expenditure during 2000~2001 to sales in 2001. The log mean of R&D intensity is slightly higher for firms in cooperation with university (5.47%) and GRI (5.94%), respectively, than otherwise (2.99% and 2.91%). Accordingly, the difference is not significant as seen from the t-ratios of each (1.12 (p=0.26) and 1.28 (p=0.20)) (<Table 3-1>). Therefore, based on the above discussions, we will test if R&D intensity affects the firm's propensity of cooperating with them.

Cooperation objectives: Cooperation objectives constitute a part of firm capacity. Scientific knowledge tends to entail high costs and uncertainty: developing new knowledge for itself or the market, an innovative firm bears high costs in the initial stage but face uncertainty in demands (Jensen et al., 2003). In the empirical analyses, both Belderbos et al. (2004) and Veugelers et al. (2005) reveal that the cost-sharing objective has a positive impact on the firm's decision in cooperating with university. However, regarding the risk-sharing objective, they obtain a negative result. Some case studies point out that firms tend to cooperate with university for cost-sharing benefits rather than risk-sharing purposes (Park et al., 2000).

The cost-sharing objective (*COST*) and risk-sharing objective (*RISK*) are measured based on the answers to the following question of the KIS: "What is the weight of the following as a barrier to technological innovation (on a five-point scale)?" Among 23 hindrance factors to innovation, the weight of excessive risk or uncertainty is used for the *RISK* variable and that of excessive high cost for innovation or commercialization, for the *COST* variable. The mean score of these two cooperation objectives is much higher for firms that are engaged in this cooperation than otherwise (<Table 3-1>): university (3.14 vs. 2.08) and GRI (3.22 vs. 2.09) for cost-sharing objectives, and university (3.17 vs. 2.20) and GRI (3.26 vs. 2.19) for risk-sharing objectives. The t-ratio is statistically significant for the cost-sharing objective (8.58 (p=0.00) and 9.27 (p=0.00)) and the risk-sharing objective (7.72 (p=0.00) and 8.66 (p=0.00)), implying the existence of differences between cooperators and non-cooperators in terms of their cooperation objectives. Therefore, we hypothesize that the more important the cooperation objective, the higher the firm's probability of cooperating with them.

Affiliation to Business Groups: Affiliated firms are legally independent, but work as "operating divisions" that are controlled by their groups (Chang & Hong, 2000). The authors argue that the superior financial performance of Korean *chaebols* is relevant to group- as well as firm-level resources. *Chaebols* are technologically diversified compared with *non-chaebols* (Choo, 2006), and they can provide a broader technological base for their affiliates. Choo et al. (2006) supports this, saying that business groups can maintain advantages of their capacities when the technology is "lumpy or indivisible." An affiliate can obtain technology from its group, thus feeling no need for cooperating with university or GRI. On the other hand, this may benefit from the brand name, resource, or network of their headquarters, thus making IUG cooperation easier than otherwise (Tether, 2002). Belderbos et al. (2004) empirically prove that firms belonging to a group tend to cooperate with university. On the other hand, Mohnen and Hoareau (2003) reveal the opposite result, that is, the negative impact of this affiliation, interpreting it such that affiliates cooperate with university only through their headquarters while headquarters do directly.

Affiliation to business groups (*GROUP*) is measured in two ways. One is based on the answer to the following question of the KIS: "Your firm is of which type, independent, domestic, or a foreign affiliate?" *GROUP* is measured as a dummy, 1 if it is either a domestic or a foreign affiliate, or 0 otherwise. The mean percentage of firms affiliated to business groups is lower for firms that cooperate with university or GRI (12.03 and 10.66) rather than otherwise (13.79 and 14.18). However, the t-ratio of each is -0.68 (p=0.50) and -1.29 (p=0.20), and the difference is not statistically significant (<Table 3-1>). The other measurement is *chaebol*. *CHAEBOL10* and *CHAEBOL11-30* refer to the top 10 and 11~30 firms as designated by the Fair Trade Commission (FTC). The mean percentage of firms affiliated to business groups is almost similar for firms that cooperate with university or GRI, and the difference between cooperators and non-cooperators is not statistically significant with the t-ratio of 0.52 (p=0.61) and 0.66 (p=0.51), respectively. Therefore, based on the above, I will test if affiliation to group or *chaebol5* decreases the firm's probability of cooperating with university and GRI, respectively.

Firm Location: In spite of developments in communication means, firm location, or geographic proximity to university is still an issue in industry-university cooperation. Those firms in the same region as universities can have easy access to technology or employ quality scientists from the universities. Audretsch and Stephan (1996) emphasize the geographic proximity in terms of specific roles played by scientists, e.g. technology transfers. This is particularly important if knowledge is tacit, in that its transfer can be facilitated by face-to-face communication (Pisano et al., 1988). Jaffe (1986) suggests that the closer the proximity of university research to corporate laboratories, the more probable the potency of spillovers from university. Acs et al. (1994) argue that firms receive R&D

spillovers from the knowledge of university or large counterpart. Mowery and Ziedonis (2001) underline "regional agglomeration effects"–geographical proximity between firms and public research institutes - in the growth of high-technology clusters in the U.S.

Due to data limitation, we use region dummies instead of geographic proximity to reflect firm location. The KIS presents sixteen regions, and this analysis groups them into eight. Firm location is measured as a dummy, 1 if a firm is located in a specific region and 0 otherwise. It is found that 56.5% of all firms are located in the Metropolitan area, followed by Kyungsang-namdo (16.7%), Kyungsang-bukdo (9.5%), Choongchung-namdo (5.8%), Choongchung-bukdo (4.8%), and so on.

(2) Sector Characteristics

Sector characteristics are emphasized in the fields of technological innovation or catch-up. Marlerba (2005) defines the sectoral system of innovation (SSI) as a "set of agents carrying out market and non-market interactions for the creation and sale of sectoral products." He suggests the following four theoretical blocks of the SSI: 1) regimes of knowledge and technology; 2) demand conditions (or marker regimes); 3) actors and networks, and the coordination among them; and 4) surrounding institutions including IPRs, laws, culture, and so on.

Much literature states that the specific patterns of innovation activities are determined by technological regimes. Breschi et al. (2000**)** define a technological regime as the combination of technological opportunities, appropriability of innovations, cumulativeness of technical advancements, and properties of the knowledge base. They empirically prove that Schumpeter Mark I, "creative destruction," is related to the low degree of cumulativeness and appropriability, the high importance of applied sciences, and the increasing role of external sources of knowledge, while Schumpeter Mark II, "creative accumulation," is vise versa. Lee and Lim (2001) study the technological regimes of selected industries in Korea and find that "leapfrogging" was possible for CDMA mobile phone and DRAM, which were benefited from R&D projects combining private and public capacities and entries to new industries in cooperation with foreign firms. Park and Lee (2004) analyze the relationship between technological regime and technological catch-up using U.S. patent data and find that catch-up countries tend to make high growths in the technological sectors with a shorter cycle time, easier access to knowledge, and higher appropriability. Moreover, technological innovation in Korea, as they prove, is characterized by low appropriability and high cumulativeness.

The Industrial organization literature is interested in how the imperfect appropriability of innovation outcomes affects the incentives for a firm's innovation: appropriability increases benefits from R&D cooperation when incoming spillovers are high enough, which is on the contrary when there are inducements for a free-rider. However, due to the generic characteristics of knowledge, industry-university cooperation tends to be less involved in this issue compared to industry-competitor or supplier cooperation (Veugelers &

Cassiman, 2005). Instead, IPR regime matters in this field, reflecting technology or sector characteristics that determine the effectiveness of an industry's legal appropriability regimes. Cassiman and Veugelers (2002) empirically verify that the effective IPR regime facilitates the firm's propensity of cooperating with universities, while its strategic protection, such as secrecy or lead time, does not.

We set up the IPR regime as a sector variable, because it is specific or more related to IUG cooperation rather than others, e.g. industry dummies. The IPR regime (*IN_IPR*) is measured based on the answers to the following question of the KIS: "How important are the following as protection methods for IPR (on a five-point scale)?" Among four methods, patent is used for this variable. *IN_IPR* is measured as the industry average, following the idea of Veugelers and Cassiman (2005). In the case of Korea, the mean score of the IPR regime is higher for firms that cooperate with universities (2.09) than otherwise (1.99), with a t-ratio of 3.01 (p=0.0) (<Table 3-1>). However, the mean score is slightly higher for cooperators with GRIs (2.07) than non-cooperators (2.00), and the difference is not statistically significant as evident in the t-ratio of 2.16 (p=0.03). Therefore, a test whether the IPR regime matters for the firm's probability of cooperating with them will be done.

(3) Government's Policy Measures

Government's support: Government's supports for R&D are helpful for firms that need external partnerships but face financial or networking problems. The government may provide those firms with capitals for acquiring basic or core technology from university or GRI or with opportunities for collaborating on research projects with them (Mohnen & Hoareau, 2003). In the case of national R&D programs in Korea, specific projects require firms to participate with them[14] and to report their research results as the number of patents filed. The measures, as a result, can facilitate the firm's probability of IUG cooperation. Both Mohnen and Hoareau (2003) and Capron and Cinccera (2003) prove that firms, which use the government's support measures, tend to cooperate with these public research organizations.

Government's support (*G_SUP*) is measured based on the answers to the following question of the KIS: "Which government's support measure does your firm use?" Among the nine, whether a firm participates with national R&D projects or not is used for this variable. This variable is 1 if a firm participates with national R&D projects and 0 otherwise. As seen from <Table 3-1>, the mean percentage of firms that use government support is higher among firms that cooperate with universities and GRIs (66.17 and 73.13),

[14] As of 2005, joint research projects, a part of the Programs, conducted through industry-university or GRI cooperation accounted for 61.2% (15,829) of the total projects (25,877) and 58.9% (3,737 trillion won) of the total R&D expenditure (6,339 trillion won). According to the type of cooperation, industry-university-GRI cooperation ranked first, accounting for 16.9% of the projects or 1,069 trillion won of the R&D expenditure. It was followed by industry-university cooperation, 11.8% or 748 trillion won, and industry-GRI cooperation, 7.1% or 452 trillion won (NSTC, 2006).

respectively, rather than otherwise (30.53 and 29.67). The t-ratio of each is 7.95 (p=0.00) and 9.43 (p=0.00), and thus, the difference is statistically significant. Therefore, it is hypothesized that government's supports for R&D facilitate the firm's probability of IUG cooperation.

Table 3-1> Statistics on the possible determinants of IUG cooperation

	Industry-university cooperation			Industry-GRI cooperation		
	Cooperation (*n*=139)	Non-cooperation (*n*=399)	t-test	Cooperation (*n*=129)	Non-cooperation (*n*=409)	t-test
Firm size (log of employees)	5.27	5.02	2.23 (0.03)**	5.3	5.01	2.56 (0.01)**
R&D intensity (%)	5.47	2.99	1.12 (0.26)	5.94	2.91	1.28 (0.20)
% of firms belonging to group	11.51	13.78	-0.68 (0.50)	10.08	14.18	-1.29 (0.20)
% of firms belonging to the top 10 *chaebol* group	4.32	2.06	1.09 (0.28)	3.88	2.44	0.99 (0.45)
% of firms belonging to the top 11-30 *chaebol* group	1.44	3.26	-1.35 (0.18)	1.55	3.18	-1.17 (0.24)
Cost-sharing objective (point)	3.14	2.08	8.58 (0.00)***	3.22	2.09	9.27 (0.00)***
Risk-sharing objective (point)	3.17	2.2	7.72 (0.00)***	3.26	2.19	8.66 (0.00)***
% of firms using National R&D Programs	0.67	0.31	7.95 (0.00)***	0.73	0.3	9.43 (0.00)***
IPR regime (point)	2.09	1.99	3.01 (0.00)***	2.07	2	2.16 (0.03)**

Note: The numbers in parenthesis present *p*-value.
***, **, and * represent 1%, 5%, and 10% levels of significance, respectively.

2. The Impacts of the Linkages on Firm Performance

(1) Innovation Probability: Hypothesis 2

Knowledge is different from technology in terms of "purpose, degree of codification, type of storage and degree of observability" (Landry et al., 2007): the former is tacit stored in people's head, intangible with the imprecise impact of its use, and concretizing theories and principles; the latter is codified in software or blueprint, tangible with the precise impact of its use, and changing technological environments. Namely, technology transfer is considered as the limited activities of knowledge transfer.

Unlike the technology from private firms, a large part of the knowledge from university is transferred to firms informally,[15] although previous studies have focused mainly on citations (Spencer 2001), patents (Hall & Ziedonis), and spin-offs (Link & Scott, 2005). This is particularly the case in Korea, in which education or consulting is more prevalent than others. So, due to their characteristics of knowledge or way of knowledge transfer, industry-university cooperation may not directly influence the firms' success in innovation; rather, it can affect their decision or management of research projects (George et al., 2002; Mowery & Sampat, 2005). Actually, many studies that have tried to conceptualize knowledge transfer from university emphasize on its activities of affecting decision-making processes rather than generating tangible technological products (Knott and Wildasky, 1980; Lester & Wilds, 1990).

The impact of industry-university cooperation, as the intermediate stage of research and commercialization, is empirically obscure. Based on a CIS data of 1,460 French firms, Monjon and Waelbroeck (2003) find that cooperation with university (foreign rather than domestic) increases the probability of radical innovation, while spillover from university does not.[16][17] On the other hand, Sung (2005)'s study in Korea, using a KIS data of 1,120 firms, finds that this cooperation does not affect the innovation probability of Korean firms in general.

In this study, innovation probability is measured as 1 if a firm does technological innovation and 0 otherwise. In Korea, 26.0% or 139 out of 538 firms have cooperation with university, of which 93.5% or 131 do technological innovation (<Table 3-2>). However, 79.1% or 260 out of 399 firms, which have no cooperation with it, do technological innovation. In the case of GRI, 24.0% or 129 firms of the total have cooperation with it, of which 94.3% or 123 do technological innovation. However, 81.4% or 268 of 409 firms, which have no cooperation with them, do technological innovation.

On the basis of the above discussions, the second hypothesis of this thesis is formulated: IUG cooperation may not directly increase the innovation probability of Korean firms.

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[15] For example, Landry et al. (2007), based on a data of 1,554 researchers, find that Canadian researchers are more actively involved in non-commercial knowledge transfer rather than commercial one, less involved in intellectual property right.

[16] Technological spillovers are often defined as "non-appropriable amounts of knowledge" transmitted voluntarily or involuntarily (Monjon & Waelbroeck, 2003). Regarding industry-university cooperation, the literature refers to indirect or informal interactions between them: Monjon and Waelbroeck (2003) regard0 publications and discussions at conferences as channels of knowledge transmission from universities to industries; Gibbons and Johnston (2000) treat scientific papers and contacts with scientists as the most important sources of academic knowledge.

[17] They measure spillover as the degree of the importance of university as a source of information.

<Table 3-2> IUG cooperation and technological innovation

(unit: no. of firms)

	University		GRI	
	Cooperation (*n*=139)	No cooperation (*n*=399)	Cooperation (*n*=129)	No cooperation (*n*=409)
Innovators	131	260	123	268

(2) Innovation Sale vs. Patent Filed: Hypothesis 3

University's research and development is characterized as being new or creative. Previous literature underlines the fact that industry-university cooperation contributes to radical innovation, which is new not only to the 'firm' but also to the 'market' (Monjon & Waelbroeck, 2003) or to the creation of 'new competencies' (Faems et al., 2005). On the contrary, industry-industry cooperation contributes to incremental innovation, which is new to the 'firm' or to the improvement of 'existing competencies.' This implies that the former has a higher possibility of leading to more patents or generating new products.

This is supported by Belderbos et al.'s study (2004) that is based on the Dutch CIS I and II of 2,056 firms. They empirically prove that both formal cooperation and spillover from university[18] facilitate the growth in innovative sales, concluding that university is important source of knowledge for radical innovation. Using the Belgian CIS II of 221 firms, Faems et al. (2005) examine two types of technological cooperation: the 'explorative' partnerships with university and GRI and the 'exploitative' partnerships with client and supplier. They find that the presence and number of 'explorative' partnerships improve the proportion of turnover generated by product innovation, while that of 'exploitative' partnerships enhance product-improving innovation. George et al.'s study (2002), using a data of 2,457 alliances by 147 U.S. publicly traded biotechnology companies, reveal the significant impact of industry-university cooperation on patents. Considering the quality as well as quantity of university linkages, e.g. the number of Research-I university linkages or total federal R&D funding, they claim that firms with links to university perform better in terms of the number of patents as well as products in the market.

One point should be noticed here. These studies are based on advanced countries where knowledge commercialization systems have been well developed, thus industry-university cooperation being directly linked to innovative sales. However, as seen in Chapter 2, the governance form of commercialization is not diverse in Korea, as a developing country. This implies the possibility that the impact of this cooperation is not fully revealed as sales as much as it is in advanced countries; rather, it could be done as patents which have a merit of being filed only with new idea within a short time or those which are less affected by knowledge commercialization systems.

[18] They measure spillovers as residuals from the auxiliary regression of spillover variables by partner (university, competitor, customer and supplier) in 1994 and 1996.

Unlike on innovative outcomes, most studies report that university-industry cooperation has no significant impact on labor productivity (Belderbos et al., 2004; Monjon & Waelbroeck, 2003). These studies interpret it such that labor productivity is affected directly by other factors, such as capital, rather than IUG cooperation.

As for this subject, this paper considers only innovative firms that retain innovation outcomes, e.g. patents or sales. Firm performance is measured in three ways: the number of patents filed from each type of innovation, percentage in the sales of innovation outcomes produced from product innovation, and labor productivity. The first two as performance variables are based on the KIS, while the last one is based on the KIS VALUE database. In terms of the average number of patents filed from technological innovation, overall, it is higher for cooperators (7.31) than non-cooperators (5.26) with universities, but the difference is not significant (<Table 3-3>). However, in the case of GRI, cooperators have an average number of 10.48 patents, while non-cooperators have 3.88, and the difference is statistically significant with t=1.99 (p=0.05) (<Table 3-4>). Meanwhile, as to the means of percentage in the sales of innovation outcomes and labor productivity, no significant difference can be found between cooperators and non-cooperators.

On the basis of the above discussions, the third hypothesis is formulated: in Korea, the impact of IUG cooperation is revealed in the form of patents rather than the sale of innovation outcomes or labor productivity.

(3) Product innovation vs. Process Innovation: Hypothesis 4

University is the institution that functions higher education with basic or long-term research interests, which is different from firms with practical or short-term market needs (Hoffman et al., 1998). This implies that industry-university cooperation may be helpful for product innovation, while industry-industry cooperation may for process innovation. Rouvinen (2002) supports this through an empirical analysis of CIS data from Finnish manufacturing firms: that is, industry-university or non-profit research organization contributes only to product innovation, while industry-client or supplier contributes to process innovation as well. He explains it such that process innovation benefits from the stocks of capital-embodied technology, while product innovation does from disembodied forms of technology.[19] He also mentions the point that process innovation may constitute a part of product innovation rather than being patented.

On the other hand, there exists the opposite argument: Etzkowitz and Leydesdorff (2000) state that science has been organized in pursuit of practical as well as theoretical interests; Nelson (2000) mentions that university research is keyed into practical technologies and particular industries. Freel and Harrison (2006) empirically prove the positive relationship between product innovation and industry-customer or GRI cooperation, and between process innovation and industry-supplier or university cooperation. They

[19] Evangelista (1999) differentiates disembodied technologies as a stock of knowledge or capabilities and embodied technologies as a stock of productive assets or fixed productive capitals.

argue that, in spite of their influences on product innovation, universities are significant contributors to just the sort of “industry-relevant” research for manufacturing firms at least.

A few papers point out that the IUG cooperation in Korea focuses on process rather than product innovation. For instance, Samsung Economic Research Institute (SERI, 2006) reports that a large number of Korean firms participate in national R&D programs, focusing on problem-solving rather than new product or technology development. In the case studies of the IUG cooperation system of Po-hang Steel, an affiliate of POSCO, Park et al. (2000) find that this system focuses on problem solving, is centered on short-term projects, and mostly contributes to process and product improvement but partly to product innovation. Is this true then? If not, what is the reality?

According to <Figure 1-1>, more Korean firms are engaged in product (342) rather than process innovation (239). Looking at the former in detail, more firms do product improvement (303) rather than new product innovation (251). In terms of firm performance, the average number of patents filed from new product innovation is higher for cooperators than non-cooperators with these public research organizations, with a t-ratio of 1.91 (*p*=0.06) for university (<Figure 3-3>) and 1.92 (*p*=0.06) for GRI (<Figure 3-4>). This means that there exists a difference in the number of patents filed between the two. However, in spite of a large or larger number of firms engaged in process innovation, no significant difference is found in the number of patents filed between the two. On the basis of the above discussions, the fourth hypothesis is formulated: IUG cooperation contributes to product rather than process innovation.

<Table 3-3> Industry-university cooperation and firm performance

	Cooperation				No cooperation			
	All	New Product innovation	Product-improving innovation	Process innovation	All	New Product innovation	Product-improving innovation	Process innovation
	(*n*=130)	(*n*=99)	(*n*=115)	(*n*=91)	(*n*=261)	(*n*=167)	(*n*=207)	(*n*=155)
No. of patent	7.31	5.92 1)	2.4	0.92	5.26	1.98	3.43	2.08
% in sale	49.47				48.8			
Value added per worker (trillion won)	62,103.67				66,544.21			

Note: 1) *t*=2.10 (*p*=0.04)

<Table 3-4> Industry-GRI and firm performance

	Cooperation				No cooperation			
	All	New Product innovation	Product-improving innovation	Process innovation	All	New Product innovation	Product-improving innovation	Process innovation
	(*n*=122)	(*n*=92)	(*n*=108)	(*n*=84)	(*n*=269)	(*n*=174)	(*n*=214)	(*n*=162)
No. of patent	10.48	6.08 1)	4.26	3.04	3.88	2.05	2.46	0.94
% in sale	49.84				48.65			
Value added per worker (trillion won)	56,806.03 2)				68,948.57			

Note: 1) t=1.99 (p=0.05) 2) t=-2.35 (p=0.02)

IV. Methodology

This section sets up empirical models for analysis. First, we analyze what determines a firm's propensity of IUG cooperation, using the Probit model.

$$IUG_i = \alpha_0 + \alpha_1 X_i + u \quad (1)$$

$\boldsymbol{X}$ = {*SIZE, RD_INT, COST, RISK, GROUP* (*CAHEBOL10/CAHEBOL11-30*), regional dummies (*r_*) *IN_IPR, G_SUP*}

IUG indicates whether a firm cooperates with university and GRI, respectively: 1 if the firm cooperates with them and 0 otherwise. The model is specified by firm size (*SIZE*), R&D intensity (*RD_INT*), cooperation objective (*COST* and *RISK*), affiliation to business groups (*GROUP*), firm location (*r_*), IPR regime (*IN_IPR*), and government's support measure (*G_SUP*). It also includes the top 10 *chaebols* (*CHAEBOL10*) and the top 11-30 *chaebols* (*CHAEBOL11-30*) as a variable of affiliation to business groups. Here, marginal effects are estimated at the mean point.[20]

Second, we test whether IUG cooperation affects the innovation probability of firms, using the Probit model.

$$IUG_i = \beta_0 + \beta_1 Z_i + \beta_2 X_i + u_1 \quad (2\text{-}1)$$

$$P\_INNO_i = \gamma_0 + \gamma_1 IUG_i\hat{} + \gamma_2 X_i + u_2 \quad (2\text{-}2)$$

$\boldsymbol{Z}$ = {regional dummies (*r_*)}
$\boldsymbol{X}$ = {*SIZE, RD_INT, COST, RISK, GROUP, G_SUP, Demand-pull, Cost-push, AGE, OPENNESS, FOREIGN,* industry dummies}

[20] Although X_i has a linear effect on unobservable IUG_i^*, it does not have a linear effect on the probability that IUG_i =1. Therefore, the marginal effect varies with each X_i in the Probit model, while this is constant over the sample in the linear model (Baum, 2006).

The innovation probability of firms is estimated by the eq. 2-2. *P_INNO* is 1 if a firm does technological innovation and 0 otherwise. The model is specified by the estimated *IUG^*, instead of *IUG*, and explanatory variables, *X*.

Previous studies deal with this issue without considering the endogeneity of IUG cooperation measure. In contrast, bearing in mind that certain factors specific to IUG cooperation, e.g. technological capability of firms, indirectly affect firm performance, we try to control this endogeneity. If *IUG* is used instead of *IUG^*, this variable may be correlated with disturbance *u2*, and thus it is endogenous. The zero-covariance condition Cov[*Xi, u2*] = 0 is violated, and thereby, the zero-conditional-mean assumption E[*u2*| *Xi*] = 0 does not hold anymore (Baum, 2006). As a result, OLS estimates become biased and inconsistent. Accordingly, we control the endogeneity by instrumenting for *IUG* that is uncorrelated with *u2* but is highly correlated with *IUG*. We use *regional dummies* (*r_*) as instruments; IUG cooperation is active in the regions that universities and firms cluster, e.g., *Seoul* or *Daejon*, but the firms in there do not always perform better than otherwise.

In the first stage, we regress IUG cooperation (*IUG*) on instrumental variables (*Z*) and exogenous variables (*X*) (eq. 2-1). In the second stage, we then regress the innovation probability of Korean firms (*P_INNO*) on the estimated or endogenous variable (*IUG^*) and exogenous variable (*X*) (eq. 2-2). The explanatory variables in eq. 2-2 include those of eq.1, except for region dummies, and additional variables—innovation objective (*Demand-pull* and *Cost-push*), firm age (*AGE*), openness (*EXPORT*), and foreign capital (*FOREIGN*). In order to control industry effect, industry dummies are used instead of *IN_IPR*, the sector variable in eq. 1. Innovation objective is based on the answers to the following question of the KIS: "What are the objectives of your firm to do technological innovation (on a five-point scale)?" *Demand-Pull* is measured as the average of the degree of importance of product substitutions, market share increases and improvements in quality, and *Cost-Push*, as that of the degree of importance of flexibility increases, material costs, and labor cost reductions.[21] *AGE* is measured as a log value of firm age. The openness of a firm, *OPENNESS*, is measured as a dummy variable, 1 if the firm exports in either 2000 or 2001 and 0 otherwise. Foreign capital, *FOREIGN*, is measured as the average ratio of foreign capitals to total capitals.

Third, we analyze how IUG cooperation affects firm performance, with a sample selection model.

$$P\_INNO_i = \delta_0 + \delta_1 IUG_i + \delta_2 X_i + u_1 \qquad (3\text{-}1)$$

$$INNO_i = \varepsilon_0 + \varepsilon_1 IUG_i + \varepsilon_2 X_i + u_2 \qquad (3\text{-}2)$$

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[21] Both demand pull and cost push are the major determinants of innovation outcomes, which are usually used in the *CDM model* (Crepon et al., 1998).

X = {*SIZE, RD_INT, GROUP, Demand-Pull, Cost-Push, AGE, OPENNESS, FOREIGN,* industry dummies}

Firm performance (*INNO*) is estimated by the eq. 3-2. For *INNO,* three types of variables are used, namely, the number of patents filed from each type of innovation, the percentage in sales of innovative outcomes produced from product innovation and the value added per worker. The model is specified by *IUG* and explanatory variables, *X*. Additionally, another industry dummies are considered here - high, medium-high, medium-low, and low-technology, following the OECD classification (OECD, 2005) based on the levels of R&D intensity.

This analysis deals with only innovative firms. In the KIS, only firms that do technological innovation are asked questions regarding how many patents or sales they make from each type of innovation. This means that performance variables, *INNO*, are censored based on whether they do technological innovation or not. Accordingly, a selection bias based on the unobserved characteristics of firms with the potential of doing technological innovation needs to be checked, and if any, it should be corrected. If OLS is applied without considering this sample selection bias, this selectivity may make the coefficients biased because the sample of firms is not a random one.

In order to deal with this problem, we use *Heckman's 2SLS* (1979), a two-step sample selection procedure. In the first stage, the corrective term, the inverse Miller's ratio (*IMILLS*), is estimated as a prediction of the Probit model (eq. 3-1). Using these estimates, the inverse Miller's ratio is calculated as a function of the standard normal density divided by the cumulative distribution function. The ratio is then used as an additional regressor in the second stage, using the OLS, to correct the sample selection bias, if any (eq 3-2).

V. Results

1. The Determinants of IUG Cooperation

This part analyzes the determinants of IUG cooperation, using the Probit model. The dependent variable measures whether a firm cooperates with university and GRI, respectively, for its innovation: the variable is 1 if it does and 0 otherwise.

<Table 5-1> reveals the results. Among firm characteristics, *COST* and regional dummies are statistically significant: the positive *COST* means that Korean firms tend to cooperate with university for cost- rather than risk-sharing objectives; the coefficient of regional dummies is significantly positive in general, implying the importance of firm location in their decision. On the other hand, neither *SIZE* nor *RD_INT* is statistically significant, which means that none of them is deterministic to this cooperation.[22] In terms

[22] In regard to R&D intensity, Mohnen and Hoareau (2003) and Capron and Cincera (2003) point out that, due to too short period during which study is conducted, firms' investment in R&D may not fully affect

of the affiliation to business group, *GROUP* is negative, but not statistically significant (Model 1). However, when *chaebols* are defined as the top 11~30 firms, the result is noticeable: the coefficient of *CHAEBOL11-30* is significantly negative (Model 3). In comparison, the coefficient of *CHAEBOL10* is positive, but not statistically significant. These imply that middle-leveled *chaebols* tend not to cooperate with university, while top-leveled *chaebols* may do: the top-leveled *chaebols* have richer resources, consequently to cooperate with university in various forms.[23] Namely, group firms normally feel a need for this cooperation less than others as the literature mentions (Mohnen & Hoareau, 2003; Capron & Cincera, 2003), but this is applicable only to middle-leveled *chaebols IN_IPR*, as sector characteristics, is statistically significant as the literature refers to (Veugelers & Cassiman, 2005), which means that the more efficient the IPR regime, the higher the firms' probability of cooperating with university. The coefficient of *G_SUP* is significantly positive, which implies that the government's support measures for R&D, specifically national R&D programs, really encourage firms to cooperate with university. It also confirms that the industry-university cooperation, broadly speaking the NIS of Korea, is characterized as being government-led.

The determinants of industry-GRI cooperation are similar to those of industry-university cooperation, except *RISK*, regional dummies, and *IN_IPR*. The coefficient of *RISK* is significantly positive, implying that Korean firms are likely to cooperate with GRI for risk-sharing. Regional impact is significant too, but relatively weaker than that of industry-university cooperation. Moreover, *IN_IPR* is statistically insignificant, which means that the IPR regime is not deterministic to industry-GRI cooperation.

their propensity for cooperating with universities.

[23] Besides joint or contract research, *chaebols*, such as Samsung, LG or GM Daewoo, offer university students classes or programs in order to be directly linked to internship or business sector, or provide financial and technical supports for research in the fields of basic science. On the other hand, SMEs, which are relatively project-based or lack financial capacity, tend to cooperate with university mainly through joint or contract research.

<Table 5-1> The determinants of industry-university cooperation (Probit model)

	Industry-university cooperation			Industry-GRI cooperation		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
SIZE	0.06 (1.01)	0.03 (0.52)	0.08 (1.21)	0.08 (1.19)	0.05 (0.79)	0.08 (1.27)
RD_INT	0.66 (1.13)	0.68 (1.15)	0.68 (1.17)	0.81 (1.32)	0.84 (1.37)	0.84 (1.37)
GROUP	-0.23 (-1.17)			-0.31 (-1.52)		
CHAEBOL10		0.26 (0.68)			0.08 (0.19)	
CHAEBOL11-30			-0.93 (-2.02)**			-0.84 (-1.79)*
COST	0.11 (1.68)*	0.11 (1.68)*	0.12 (1.71)*	0.10 (1.45)	0.10 (1.46)	0.10 (1.49)
RISK	0.10 (1.46)	0.10 (1.48)	0.10 (1.49)	0.12 (1.83)*	0.12 (1.79)*	0.12 (1.83)*
r_S	0.98 (1.84)*	1.05 (1.95)*	1.02 (1.92)*	1.03 (1.86)*	1.07 (1.93)*	1.07 (1.96)*
r_CB	1.00 (1.65)	1.04 (1.70)*	1.04 (1.72)*	0.75 (1.18)	0.75 (1.17)	0.77 (1.22)
r_CN	1.32 (2.29)**	1.36 (2.33)**	1.31 (2.28)**	1.32 (2.20)**	1.32 (2.20)**	1.30 (2.19)**
r_JB	1.66 (2.53)**	1.72 (2.59)**	1.72 (2.61)**	1.10 (1.55)	1.12 (1.57)	1.13 (1.60)
r_KB	1.07 (1.88)*	1.13 (1.97)*	1.08 (1.92)*	0.92 (1.56)	0.96 (1.62)	0.94 (1.61)
r_KN	1.25 (2.26)**	1.31 (2.35)**	1.28 (2.34)**	1.05 (1.84)*	1.08 (1.89)*	1.09 (1.93)*
G_SUP	0.62 (4.54)***	0.62 (4.57)***	0.62 (4.57)*	0.80 (5.68)***	0.81 (5.76)**	0.81 (5.74)***
IN_IPR	0.33 (1.86)*	0.31 (1.73)*	0.35 (1.93)*	0.16 (0.87)	0.13 (0.73)	0.16 (0.88)
No. of obs	538	538	538	538	538	538
McFadden R^2	0.15	0.15	0.16	0.18	0.18	0.19
Log likelihood	-260.29	-260.77	-258.64	-241.15	-243.32	-240.5
Pro(LR stat)	0.00	0.00	0.00	0.00	0.00	0.00

Note: Numbers in parentheses indicate z-values.

***, **, and * represent 1%, 5%, and 10% levels of significance, respectively.

Next, we estimate the marginal effects of the determinants at the mean point (<Table 5-2>). The marginal effect of an additional point in the government's support for R&D is to increase the firms' probability of cooperating with university by 19.0% and with GRI by 23.0%, respectively. An additional point in the effectiveness of the IPR regime significantly increases the firms' propensity for cooperation with the former by 10.0%. Moreover, an additional point in the importance of cost-sharing objective increases the firms' likelihood by 3.0%. Regarding cooperation with GRI, an additional point in the importance of risk-sharing objective increases the firms' likelihood by 3.0%.

<Table 5-2> Marginal effects

	Industry-university cooperation	Industry-GRI cooperation
SIZE	0.02(1.01)	0.02(1.19)
RD_INT	0.19(1.13)	0.22(1.32)
GROUP	-0.06(-1.27)	-0.07(-1.49)
COST	0.03(1.68)*	0.03(1.45)
RISK	0.02(1.47)	0.03(1.85)*
r_S	0.27(2.02)**	0.26(2.04)**
R_CB	0.36(1.55)	0.25(1.03)
R_CN	0.48(2.36)**	0.47(2.15)**
R_JB	0.59(3.20)**	0.39(1.43)
R_KB	0.38(1.78)*	0.31(1.39)
R_KN	0.44(2.21)**	0.35(1.67)*
G_SUP	0.19(4.42)***	0.23(5.47)***
IN_IPR	0.10(1.87)*	0.04(0.87)

Note: Numbers in parentheses indicate z-values.
***, ** and * represent 1%, 5% and 10% levels of significance, respectively.

Therefore, based on the above, the first hypothesis of this paper is partly supported: the government's support measures for R&D matter to IUG cooperation, while the IPR regime matters only to industry-university cooperation; neither firm size nor R&D intensity is deterministic to IUG cooperation, while firm location is; firms tend to cooperate with university for the cost-sharing objective and with GRI for the risk-sharing objective; and finally, middle-leveled *chaebols* tend not to be involved in IUG cooperation, while top-leveled *chaebols* may do.

Two points should be noticed, here. One is that IUG cooperation matters for non-*chaebol* firms that cannot but depend on 'firm-level' resources for technological development, facing limits in access to timely and diversified technology. The other is that, unlike the case of advanced countries, firm capacity – firm size or R&D intensity – is not deterministic to IUG cooperation in Korea. Rather, the government's role matters for promoting it, reflecting the government-led NIS of Korea.

2. The Impacts of IUG Cooperation on Firm Performance

(1) Innovation Probability

This part analyzes the impact of IUG cooperation on the innovation probability of firms, using the Probit model. The dependent variable measures whether a firm does technological innovation: the value of this variable is 1 if it does and 0 otherwise. IUG cooperation variable, *IUG*, is measured as 1 if a firm cooperates with university and GRI, respectively, and 0 otherwise. Discriminated from previous studies, this controls the endogeneity using the estimated *IUG*, *IUG^*, to compare both results (<Table 5-3>).

IUG reveals a positive sign (Model 1 and 2), but the result is contradictory when endogeneity is controlled, using *IUG^*: the coefficient of the latter is not statistically significant (Model 3 and 4). Based on the result, we can say that the significance of *IUG* in the first analysis originates from the endogeneity and not from the real impact of this cooperation. This is discriminated from previous studies in advanced countries (Monjon and Waelbroeck, 2003): the latter reports the positive impact of IUG cooperation, without controlling the endogeneity of IUG cooperation measure.

In regard to the other variables, the impact of *RD_INT* investment is obscure: its coefficient is insignificant or significantly negative at the 10% level of significance. This result seems to stem from the possibility that, due to too short period of this research - two years, the impact of firm' investment in R&D may not have been fully revealed. On the contrary, *demand-pull* and *cost-push* are statistically significant, which means the importance of innovation motives for the innovation possibility of firms. *EXPORT* is also statistically positive, implying that open or export-oriented firms tend to do technological innovation.

<Table 5-3> The impact of IUG cooperation on the innovation probability of Korean firms

	Probit model		Probit model (endogeneity controlled)	
	Industry-university cooperation	Industry-GRI cooperation	Industry-university cooperation	Industry-GRI cooperation
	Model 1	Model 2	Model 3	Model 4
SIZE	0.03(0.28)	0.04(0.35)	0.04(0.40)	0.04(0.39)
RD_INT	-1.56(-2.37)**	-1.61(-2.36)**	-1.05(-1.63)	-1.03(-1.76)*
GROUP	0.00(0.02)	0.01 (0.03)	-0.10(-0.36)	-0.15(-0.52)
COST	0.12(1.24)	0.11(1.21)	0.17(1.51)	0.11(1.30)
RISK	0.08(0.83)	0.08(0.82)	0.10(1.20)	0.11(1.37)
G_SUP	0.21(1.05)	0.19(0.95)	0.61(2.19)**	0.62(2.08)**
Demand-Pull	0.42(4.85)***	0.42(4.83)***	0.42(5.02)***	0.42(5.05)***
Cost-Push	0.17(2.11)**	0.17(2.13)**	0.25(2.88)**	0.22(2.65)**
AGE	-0.01(-0.11)	-0.01(-0.17)	0.00(0.01)	0.01(0.05)
EXPORT	0.23(1.18)	0.21(1.07)	0.41(1.87)*	0.43(1.86)*
FOREIGN	0.55(1.10)	0.51(1.03)	0.19(0.46)	0.39(0.97)
Industry dummies	Included	Included	Included	Included
IUG	0.51(2.19)**	0.58(2.24)**		
IUG^			-1.69(-1.65)	-1.40(-1.40)
No. of obs	538	538	538	538
Pseudo R^2	0.56	0.56	0.57	0.57
Log likelihood	-140.63	-140.43	-135.02	-135.33
Pro(LR stat)	0.00	0.00	0.00	0.00

Note: Numbers in parentheses indicate z-values

***, **, and * represent 1%, 5%, and 10% levels of significance, respectively.

Therefore, based on the above, the second hypothesis of this paper is supported: IUG cooperation in Korea does not increase the innovation probability of firms.

Although IUG cooperation does not affect the innovation probability of firms itself, it is possible that innovative firms would cooperate with university or GRI more to generate innovation outcomes. Thus, in the next part, we consider only innovative firms to analyze the impact of this cooperation. Because technologically unprogressive firms are to be dropped, we do not control the endogeneity of IUG cooperation measure any more.

(2) Sale vs. Patent / Product Innovation vs. Process Innovation

This part analyzes the impact of IUG cooperation on firm performance. It deals with only innovative firms, namely, the sub-samples that generate innovation outcomes. Accordingly, this checks the data for sample selection bias, based on whether a firm does technological innovation or not. As seen from the following results, *IMILLS*, the inverse Miller's ratio, is statistically significant in some cases, proving the existence of sample selection bias. The bias is corrected then by this term, *IMILLS*. For dependent variables, three are measured here: the number of patents filed from each type of innovation, the percentage in sales of innovation outcomes from product innovation and labor productivity.

<Table 5-4> and <Table 5-6> present the results for the impact of IUG cooperation according to the type of performance. The coefficient of *IUG* is not statistically significant for patent, sale or labor productivity, which implies that this cooperation has no significant impact on firm performance overall. However, when examined according to the type of innovation (<Table 5-5> and <Table 5-7>), this proves to positively affect the number of patents filed from new product innovation.[24] It means that for innovative firms, IUG cooperation leads to more patents filed from this type of innovation. The result is different from the case of advanced countries where industry-university cooperation contributes to the sales of innovation outcomes as well as the number of patents filed.

To the contrary, *SIZE* is significantly positive for patents, suggesting that larger firms file more patents than smaller ones. *RD_INT* is significant for patents filed from new product and process innovation, although it has no significance in patents overall. This variable is also significant for the sale of innovation outcomes. These facts suggest that for innovative firms, firm size and in-house R&D matter for technological innovation, even to new product innovation, rather than IUG cooperation. Moreover, older firms prove to perform worse than younger ones, in terms of both patents and sales (*AGE*).

Therefore, based on the above, the third and fourth hypotheses of this thesis are partly supported: for Korean innovative firms, the impact of IUG cooperation is revealed as patents rather than sales; moreover, this is significant for new product innovation, as a part of product innovation, rather than process innovation.

[24] In the case of industry-GRI cooperation, this variable is significant only when OECD dummies are controlled, suggesting that this cooperation contribute to the patent-filings but its significance is weak.

<Table 5-4> The impact of industry-university cooperation on firm performance (OLS with sample selection)

	Model 1			Model 2		
	Patent	Sale	Labor productivity	Patent	Sale	Labor productivity
SIZE	0.10(4.88)***	0.01(0.44)	0.00(0.58)	0.11(6.76)***	0.01(0.48)	0.00(0.13)
RD_INT	0.25(0.85)	0.35(1.06)	-0.09(-2.07)**	0.22(1.00)	0.57(2.24)**	-0.09(-2.00)*
GROUP	-0.05(-0.84)	-0.12(-1.75)*	0.03(3.28)***	-0.05(-1.13)	-0.08(-1.51)	0.03(3.13)***
Demand-Pull	0.08(1.50)	0.10(1.50)	0.00(0.08)	0.06(1.55)	0.02(0.84)	-0.00(-0.24)
Cost-Push	0.00(0.18)	0.08(3.39)***	-0.00(-0.49)	-0.00(-0.12)	0.07(3.87)***	-0.00(-0.51)
AGE	-0.06(-2.29)**	-0.06(-2.14)**	0.00(0.83)	-0.06(-2.80)**	-0.04(-1.77)*	0.00(0.29)
OPENNESS	0.05(1.02)	0.03(0.53)	0.00(0.45)	0.04(1.09)	-0.01(-0.23)	0.00(0.67)
FOREIGN	-0.05(-0.43)	-0.08(-0.67)	0.04(2.46)**	-0.04(-0.44)	-0.02(-0.23)	0.03(1.96)*
IUG(UNIV)	0.05(0.90)	0.07(1.10)	-0.00(-0.36)	0.04(0.99)	0.01(0.16)	-0.01(-1.11)
OECD dummies	Included	Included	Included			
Industry dummies				Included	Included	Included
IMILLS	0.40(1.85)*	0.40(1.70)*		0.29(1.99)**		
No. of obs	382	330	310	382	330	310
R^2	0.15	0.12	0.17	0.24	0.17	0.28
Adjusted R^2	0.13	0.09	0.14	0.19	0.12	0.24
Prob(F-stat)	0.00	0.00	0.00	0.00	0.00	0.00

Note: Numbers in parentheses indicate t-values
***, **, and * represent 1%, 5%, and 10% levels of significance, respectively.

<Table 5-5> The impact of industry-university cooperation on the number of patents filed

	Model 1			Model 2		
	New product innovation	Product improvement	Process innovation	New product innovation	Product improvement	Process innovation
SIZE	0.05(6.06)***	0.06(7.15)***	0.02(2.50)**	0.05(5.76)***	0.07(7.27)***	0.02(2.51)**
RD_INT	0.28(1.83)*	0.15(1.09)	0.38(2.39)**	0.31(1.91)*	0.12(0.90)	0.36(2.23)**
GROUP	-0.04(-1.78)*	-0.04(-1.56)	-0.00(-0.00)	-0.04(-1.59)	-0.04(-1.69)*	0.00(0.04)
Demand-Pull	0.01(0.53)	-0.01(-0.49)	-0.01(-0.86)	0.01(0.76)	-0.01(-0.62)	-0.01(-0.86)
Cost-Push	-0.00(-0.28)	-0.01(-0.62)	-0.02(-2.25)**	-0.00(-0.27)	-0.01(-0.58)	-0.02(-2.28)**
AGE	-0.02(-1.79)*	-0.05(-4.11)***	-0.00(-0.14)	-0.02(-1.85)*	-0.05(-4.10)***	-0.00(-0.03)
OPENNESS	-0.00(-0.23)	0.02(0.82)	0.02(0.67)	-0.00(-0.18)	0.01(0.59)	0.01(0.56)
FOREIGN	-0.00(-0.12)	-0.05(-1.03)	-0.04(-1.12)	-0.01(-0.17)	-0.05(-0.99)	-0.04(-1.05)
IUG(UNIV)	0.03(2.03)**	-0.02(-1.06)	-0.02(-0.93)	0.03(1.91)*	-0.02(-1.13)	-0.01(-0.87)
OECD dummies	Included	Included	Included			
Industry dummies				Included	Included	Included
No. of obs	266	322	246	266	322	246

R^2	0.17	0.17	0.09	0.17	0.17	0.09
Adjusted R^2	0.13	0.13	0.04	0.11	0.12	0.02
Prob(F-stat)	0.00	0.00	0.04	0.00	0.00	0.23

Note: Numbers in parentheses indicate t-values
***, **, and * represent 1%, 5%, and 10% levels of significance, respectively.

<Table 5-6> The impact of industry-GRI cooperation on firm performance (OLS with sample selection)

	Model 1			Model 2		
	Patent	Sale	Labor productivity	Patent	Sale	Labor productivity
SIZE	0.10(7.44)***	0.01(0.46)	0.00(0.67)	0.11(7.48)***	0.01(0.47)	0.00(0.18)
RD_INT	0.40(1.92)*	0.40(1.42)	-0.08(-1.90)*	0.36(1.72)*	0.56(2.18)**	-0.07(-1.76)*
GROUP	-0.05(-1.36)	-0.11(-1.93)*	0.03(3.22)***	-0.05(-1.35)	-0.08(-1.49)	0.03(3.05)***
Demand-Pull	0.00(0.04)	0.08(1.54)	0.00(0.08)	-0.00(-0.01)	0.02(0.84)	-0.00(-0.21)
Cost-Push	-0.02(-1.39)	0.08(3.91)***	-0.00(-0.39)	-0.02(-1.32)	0.07(3.86)***	-0.00(-0.38)
AGE	-0.06(-3.27)**	-0.06(-2.45)**	0.00(0.84)	-0.06(-3.13)***	-0.04(-1.78)*	0.00(0.31)
OPENNESS	0.02(0.49)	0.02(0.48)	0.00(0.64)	0.01(0.34)	-0.01(-0.26)	0.01(0.95)
FOREIGN	-0.07(-1.01)	-0.08(-0.82)	0.04(2.46)**	-0.07(-0.95)	-0.02(-0.24)	0.03(1.98)*
IUG(GRI)	0.04(1.34)	0.07(1.15)	-0.01(-1.50)	0.04(1.52)	0.01(0.37)	-0.02(-2.50)**
OECD dummies	Included	Included	Included			
Industry dummies				Included	Included	Included
IMILLS		0.33(1.72)*				
No. of obs	382	330	310	382	330	310
R^2	0.16	0.12	0.18	0.16	0.17	0.25
Adjusted R^2	0.13	0.09	0.15	0.12	0.12	0.2
Prob(F-stat)	0.00	0.00	0.00	0.00	0.00	0.00

Note: Numbers in parentheses indicate t-values
***, **, and * represent 1%, 5%, and 10% levels of significance, respectively.

<Table 5-7> The impact of industry-GRI cooperation on the number of patents filed

	Model 1			Model 2		
	New product innovation	Product improvement	Process innovation	New product innovation	Product improvement	Process innovation
SIZE	0.05(5.98)***	0.06(7.07)***	0.02(2.42)**	0.05(5.71)***	0.06(7.19)***	0.02(2.49)**
RD_INT	0.28(1.76)*	0.13(0.96)	0.34(2.13)**	0.30(1.85)*	0.10(0.73)	0.31(1.89)*
GROUP	-0.04(-1.73)*	-0.04(-1.54)	0.00(0.09)	-0.04(-1.58)	-0.04(-1.65)	0.00(0.13)
Demand-Pull	0.00(0.42)	-0.01(-0.41)	-0.01(-0.87)	0.01(0.64)	-0.01(-0.52)	-0.01(-0.89)
Cost-Push	-0.00(-0.15)	-0.01(-0.74)	-0.02(-2.38)**	-0.00(-0.13)	-0.01(-0.72)	-0.02(-2.37)**
AGE	-0.02(-1.77)*	-0.05(-4.13)***	-0.00(-0.20)	-0.02(-1.85)*	-0.05(-4.10)***	-0.00(-0.05)
OPENNESS	-0.01(-0.26)	0.01(0.68)	0.01(0.52)	-0.00(-0.18)	0.01(0.40)	0.01(0.33)
FOREIGN	-0.01(-0.27)	-0.04(-0.93)	-0.04(-1.04)	-0.01(-0.30)	-0.04(-0.86)	-0.04(-0.92)
IUG(GRI)	0.02(1.68)*	0.00(0.27)	0.01(0.85)	0.02(1.45)	0.01(0.45)	0.02(1.11)
OECD	Included	Included	Included			

dummies						
Industry dummies				Included	Included	Included
No. of obs	266	322	246	266	322	246
R^2	0.16	0.16	0.09	0.17	0.17	0.1
Adjusted R^2	0.12	0.13	0.04	0.1	0.1	0.02
Prob(F-stat)	0.00	0.00	0.04	0.00	0.00	0.21

Note: Numbers in parentheses indicate t-values
***, **, and * represent 1%, 5%, and 10% levels of significance, respectively.

From the above results, two things should be noticed. One is that the impact of IUG cooperation is revealed as patents rather than as sales, which can be explained in terms of the level of development in knowledge commercialization system. The logic is this!: it takes a relatively shorter time the knowledge from IUG cooperation to be filed as patents rather than to be sold, because the former is possible only with new ideas or through simple processes; the latter, however, heavily depends on the level of development in knowledge commercialization systems of a nation. In other word, unlike the case of advanced countries, the governance form of knowledge commercialization in Korea is still limited to education and joint or contract research, thereby making it difficult this knowledge to be quickly commercialized to sales. That is why, in Korea, the result of IUG cooperation is revealed as patent, the prior stage of knowledge commercialization. However, a limitation should be taken into account here: patents in this period can probably facilitate the increase of sale or productivity in the next period, but this paper could not capture this time-lag effect due to data limitation, that is, cross-sectional data.

The other is that IUG cooperation is directly linked to the performance of new product rather than product-improving or process innovation. This can be interpreted such that the knowledge from this cooperation in Korea is not just technical or short-term based as the literature mentions (SERI, 2006; Park et al., 2000). University and GRI may have contributed to process innovation in the past, because their research focused on reverse engineering or problem-solving. However, their research capacity has been improved at present, which is useful or appropriate for new product innovation. However, it also should be considered as a limitation that the impact of IUG cooperation may not be fully revealed as patents filed from process innovation. Process innovation tends to be less readily protected via patents or trademarks; rather, it is exploited internally (Rouvinen, 2002). Moreover, process innovation can constitute a part of product innovation simultaneously.

VI. Conclusions

The NIS of Korea is government-led, which has allowed *chaebol* firms to lead technological innovation since the 1970s. This *chaebol*-led innovation resulted in the "dual system" comprised of strong large and weak small firms and the weak status of university in national R&D. These unique characteristics of the Korea NIS have left its IUG linkages knowledge commercialization systems discriminated from those of advanced countries. Unlike the said countries, it is only recently that Korea has been realized the significance of knowledge commercialization to set up institutions for it.

In this situation, this paper empirically analyzed 538 firms, in terms of the determinants of industry-university or GRI cooperation and its impact on firm performance. Regarding the latter, it focused on innovation probability and on sale vs. patent (by the type of performance) and product innovation vs. process innovation (by the type of innovation). The empirical results of this paper reflect these phenomena well.

First, IUG cooperation in Korea is determined by firm characteristics, sector characteristics, and government's support measures for R&D. The National R&D Programs are deterministic to the firm's decision in IUG cooperation while firm size or R&D intensity is not, which reflects the characteristics of IUG linkage, broadly speaking the NIS of Korea as being government-led. Also, this cooperation is important for non-*chaebol* firms, specifically, those below the top-30. The IPR regime finds to matter only to industry-university cooperation.

Second, IUG cooperation has no significant impact on the innovation probability of firms. A large part of the knowledge from university is intangible with its imprecise impact, thus not directly affecting the firms' success in technological innovation; rather, it may have an influence on the selection or direction of firms' research projects. This analysis is discriminated from that of previous ones that have been undertaken without controlling the endogeneity of cooperation measure.

Third, for Korean innovative firms, the impact of IUG cooperation is revealed in patent rather than other types of performance. The result is different from the case of advanced countries in which knowledge commercialization has been well developed, and industry-university cooperation positively affects sales as well as patents. In Korea, due to the weak systems of knowledge commercialization, the impact is reveled only in patent, the prior stage of knowledge commercialization. In particular, this is significant for product innovation rather than product-improving or process innovation, implying the characteristics of the research of public research organizations as being useful or appropriate for the former neither just nor short-term based .

This paper has two contributions. One is that this is the first empirical study on IUG linkages in Korea, which is discriminated from previous studies in the form of surveys or case studies. Particularly, it deals with GRI, in which previous study is totally lacking. The other contribution is that this thesis explains the difference in the role or impact of IUG cooperation between Korea and advanced countries, in terms of the level of development in knowledge commercialization systems. That it, due to the underdevelopment of commercialization systems, the knowledge from this cooperation is revealed in patent, without being able to shift commercially, in Korea. This paper points out this as a weakness in the NIS of Korea.

In this respect, this paper suggests two points. One is that the IUG linkages in Korea should go beyond patent to reach commercialization. In the NIS, efficient knowledge flow is essential among institutional actors, but the commercialization, but not creation, of knowledge does not work well in Korea. So, new knowledge is shared or utilized by limited firms, eventually not contributing to the competitiveness of a nation as a whole. Therefore, we cannot overstate a need for establishing the NIS in which public research organizations play a central role in knowledge flows. The other is that the government's policy should be streamlined for knowledge commercialization. The government's support measures, e.g., some projects of National R&D Programs, evaluate firms based only on patent filed or registered rather than commercialization performance. Accordingly, incentives are too small for firms to endeavor to commercialize their technology. Moreover, they focus on the number, rather than quality, of the patents, leading them in a hurry to produce a low-level of patents that finally cannot be commercialized. Therefore, the Korean government needs to diversify the ways of evaluation and management of knowledge generated from the linkages as well as to focus on the formation of it.

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