경제학석사학위논문

Determinants of PRO(Public Research Organization) – Industry Cooperation and its Impact on Firm Performance

– Comparison of Manufacturing sector with Service sector in Korea–

기업과 공공연구기관 협력의 결정요인과 협력이 기업 성과에 미치는 영향

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Abstract

Determinants of PRO(Public Research Organization) – Industry Cooperation and its Impact on Firm Performance

– Comparison of Manufacturing sector with Service sector in Korea –

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This paper employs the Korea Innovation Survey data which were issued in 2010 and 2011. KIS2010 is for manufacturing firms and KIS2011 is for service firms. Using these data, I analyzed determinants of industry– public research institutions cooperation and its impact on firm's performance. First, in the manufacturing sector, determinants of industry–PRO cooperation are firm size and government support regardless of cooperation mode, and in service sector, only government support is a determinant to firm–government research institutions cooperation. Second, impact of industry–PRO cooperation on firm's innovation is not significant in both industry sectors. Lastly, I identified the impact of industry–PRO cooperation on firm performance. I defined firm performance as three ways – the number of patents, the ratio of innovative outcomes' sales to total sales and labor productivity. In the manufacturing sector, only the number of patents has a significant impact from industry–PRO cooperation, however, in the service sector, firm's cooperation with

universities has a significant impact only on the number of patents, and firm's cooperation with GRI have significant impact on both the number of patents and sales ratio. From these results, I concluded when service firms cooperate with GRIs, there occurs knowledge industrialization, and when manufacturing firms cooperate with PRO, the accumulated patents do not link to firm's sales, which means that knowledge industrialization is hard to occur in the manufacturing sector, yet. This difference between the two industries comes from each industrial characteristics, in that production and sales occur simultaneously and processes reaching to customers are relatively shorter than in the manufacturing sector. And difference resulted from cooperation partners, is because of readiness of knowledge transfer and knowledge industrialization. Technology Licensing Office plays an important role in knowledge industrialization, and TLO in the GRI has better quality than TLO in universities so that knowledge industrialization occurs when a firm cooperates with GRI. These results show that in Korea, there need more practical policies or supports to make the accumulated knowledge reach to firm's sales.
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keywords : Firm, Innovation, Cooperation, Universities, Government Research institutions, Public Research Organization, Technology Industrialization

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Ⅰ. Introduction

Technological innovation is an important source of developing new firms and industries, and growth of existing firms and industries (Utterback, 1971). As transition of factor driven economy into innovation driven economy came, attention to National Innovation System has increased. NIS is a system consisting of organizations creating, diffusing and utilizing economically useful knowledge or information and their network. NIS in Korea has developed in the late 1980s to early 1990s in the way of following the advanced countries' system[1]. In the NIS, government, business and Public Research Organization including universities and government research institutions are key players. I wanted to study those players' relationship, especially, in terms of determinants of firm's R&D cooperation with PROs, impact of the cooperation on firm's innovation, and impact of the cooperation on firm performance using the latest Korean Innovation Survey data – KIS2010 for manufacturing sector and KIS2011 for service sector.

In the service sector, innovation had received little attention in terms of government supports, policies or regulations. As Korea's economic growth has been oriented from manufacturing sector, R&D investment for service firms has been of lowness. (Kim and Yoon, 2010) Early researches on service firm's innovation argued that innovation in service sectors was not different from that in manufacturing sector, so that they considered service firm's innovation as an extension of manufacturing firm's innovation (Pavitt, 1984; Miozzo and Soete, 2001). Some studies recognized that innovation in service sector has different characteristics with that in manufacturing sector, and they characterized service firm's innovation as heterogeneity, customer-oriented, importance of non-technology innovation and high dependency on external resources for information. Service sector includes heterogeneous industries than manufacturing sector, so that there exists various innovation patterns

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[1] Song W. J., et al. (2004), A study on the Development Strategy for Korean National Innovation System, *Policy Research, 1-215.*

depending on the business types. In the service sector, it is important characteristics of direct correspondence to customers' demand, and there are more customer interfaces than in the manufacturing sector. While technology innovation is the leading innovation in the manufacturing sector, non-technology innovation such as marketing innovation and organizational innovation is important as well in the service sector. Lastly, in the service sector, to provide services, there are lots of transactions using technologies or products produced in the manufacturing sector, and in the innovation process, it shows high dependency on the external information or technology (Kim and Yoon, 2010).

As economy turned into knowledge-based society, creation, acquisition and utilization of new product become major sources for national competitiveness (Bettis and Hitt, 1995; OECD, 2003). Knowledge industrialization is also an important issue as a role of economic development. Korean government's interest toward knowledge industrialization has begun since 2001 with enactment of "Technology Transfer Promotion Law". As the history of knowledge industrialization is not long compared to the advanced countries, I wanted to investigate whether there is any improvement in knowledge industrialization in Korea compared to Eom and Lee(2010) result. Although service sector keeps expanding nowadays, and its value added consists of almost 60% of GDP in Korea, [2] studies on cooperation, innovation or knowledge industrialization in the service sector are not sufficiently researched so far. Therefore I researched on service sector as well.

Section Ⅱ describes three hypotheses I set, and previous literatures regarding our hypotheses. In section Ⅲ, I explain what data and variables I used in this study. Section the Ⅳ shows the models concerning my subjects. The fifth section consists of empirical results from my study using the models and hypotheses I set, analyzes the results. In the last section, I summarized my results and concluded what further researches are needed.

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[2] World Bank, 2017, http://data.worldbank.org/indicator/NV.SRV.TETC.ZS?locations=KR

Ⅱ. Previous Literatures

1. Hypothesis 1 : What factors determine industry-PRO cooperation? Do firm size, R&D intensity and government support have a significant effect to the cooperation?

Previously, there were several studies regarding determinants of R&D cooperation. Tether (2002) estimated determinants of cooperation in both manufacturing and service sector, he concluded large firms have a tendency to cooperate with universities not with GRIs more than small firms and R&D intensity is another factor that positively affects to firm' s cooperation with partners. Mohnen and Horeau (2003) said R&D intensive firms tend to obtain knowledge from universities or government research institutions, however, they do not have a direct connection to the two organization. Also firm size and government support have a significant and positive influence to R&D cooperation with universities than other types of cooperation. Capron and Cincera (2003) considered universities are a potential source of information that firms can access so that they researched on what factors lead to collaboration between firms and universities. In their result, firm size and government support are significant factors to industry-universities cooperation. In their other results, universities do not seem to be the most important information source for firm's innovation activities at the Belgian aggregate level, however, in terms of collaboration, universities are the second important actor to the firms as a cooperation partner.

In case of Korea, Eom and Lee (2010) investigated determinants of industry-PRO cooperation using 2002 Korean Innovation Survey data.[3] Their result is that firm size and firm's R&D intensity has no statistically significant affect to both industry-universities and industry-GRI cooperation, and on the other hand, firm's participation in national R&D projects which was defined as a government support in the research, has a positive and significant influence to the both types of cooperation.

I assumed that determinants of manufacturing firms-PRO

[3] Korean Innovation Survey 2002 targeted only Korean manufacturing firms which had done business activities in the survey period, 1999~2001.

cooperation in my research are similar with those in Eom and Lee (2010), because manufacturing firms' cooperation environment had not changed compared ton Eom and Lee(2010). As there are not enough studies regarding cooperation in the Korean service sector, I studied the determinants of PRO cooperation in the service sector as well, and the ratio of service firm's cooperation with PRO are much lower than manufacturing firms' cooperation with PRO so that determinants of service firms–PRO cooperation would not be clear.

2. Hypothesis 2 : Impact of industry–PRO cooperation on firm's innovation

Industry–PRO cooperation plays an important role in innovation process (Perkmann and Walsh, 2007). Firms gain expert knowledge from cooperation and utilize it for their innovative activities. There are several studies on firm's innovation and impact of R&D cooperation on firm's innovation. Monjon and Waelbroeck (2003) said R&D cooperation with universities, especially with foreign universities, promotes firm's innovation. Teece (1990) showed that to be successful, innovative firms needs any kinds of alliances including horizontal, vertical, upstream or downstream type. These alliances can facilitate innovation, and they become important sources of innovation. Perkmann and Walsh (2007) and Becker and Dietz(2004) also emphasized the importance of R&D cooperation in innovative process. In Korea, Eom and Lee (2010) investigated this subject, and in this case, considering possible endogeneity issue, they estimated cooperation's effect to innovation, controlling endogeneity using instrument variables. In this paper, different from the researches mentioned above, firm's R&D cooperation with PRO is not a significant factor in the firm's innovation in Korea and they concluded that already innovative firms do cooperate with PRO to use external knowledge in Korean manufacturing sector. Sung (2006) compared determinants of firm's technological innovation activities between manufacturing firms and service firms using KIS2002 for manufacturing sector and KIS2003 for service sector without controlling possible endogeneity. The result is that in both sectors, cooperation had a significant and positive impact on the firm's innovation. Kwak and Choi (2009) studied determinants of technological innovation in Korean service sector in the perspective of resource-based theory and industrial organization theory using KIS(Korean Innovation Survey)2006. I studied on the impact of industry-PRO cooperation on innovation, in comparison with Eom and Lee (2010), whether there is any change since then, and particularly I compared manufacturing firms with service firms using data of Korean service sector as well. As in Eom and Lee(2010), I presume that in case of manufacturing firms, the results would not be different from those in Eom and Lee(2010), because firms' cooperation and innovation environment have not changed much compared to Eom and Lee (2010). When I do not control the possible endogeneity, manufacturing firm's cooperation with PRO would have a significant and possible effect to the firm's innovation, otherwise, the cooperation would not have a significant impact on firm's innovation. The ratio of innovative firms among total service firms is much less than manufacturing firms – 15.72% of total service firms are innovative service firms and 74.63% of total manufacturing firms are innovative manufacturing firms, and cooperation ratio in service sector is also much less than in manufacturing sector. If environments for innovation or cooperation in service sector has not progressed as much as in manufacturing sector, industry-service firms cooperation would not significantly affect the firm's innovation.

3. Hypothesis 3 : Impact of industry-PRO cooperation on firm performance – sales, patents, and labor productivity

Some studies proved that R&D cooperation enhances firm performance. Belderbos et al. (2004) researched on firm performance depending on firm's R&D cooperation type – cooperation with universities, GRIs, clients, and suppliers – using Belgian CIS-Ⅰ and CIS-Ⅱ. R&D cooperation has a significant and positive impact on firm's labor productivity, however, cooperation with universities and research institutions does not play a significant role for productivity. In terms of growth of innovative sales, industry-universities cooperation significantly and positively affects to sales growth. However, Eom and Lee (2010) estimated industry−PRO cooperation on firm performance – sales ratio of innovative products, the number of patents, and labor productivity in Korean manufacturing sector, however, the cooperation with PRO had no significant influences to all 3 kinds, and has an impact only on the number of patents associated with new product innovation. They explained this result that knowledge is accumulated as Korean government enacted law for invigorating knowledge industrialization, however, it leads to the expansion of the number of patents only, and do not resulted in firm's sales. I also estimated the impact of industry−PRO cooperation on firm performance as defined in the Eom and Lee (2010), both in manufacturing and service sector, compared to the previous studies, and found whether there are different results between manufacturing and service sector. I hypothesized that if government policies or regulations has advanced since Eom and Lee (2010) research, industry−PRO cooperation has a significant and positive impact on firm's performance. Especially in the service sector, as services are produced and consumed simultaneously so that the processes of businesses are short comparing to the products in the manufacturing sector, technological industrialization may occur better than in the manufacturing sector.

Ⅲ. Data and Variables

1. Data

I used *KIS2010* (Korea Innovation Survey) and *KIS2011* for manufacturing and service sector respectively and *KIS* followed the definition of *Oslo Manual* from OECD and its sample was all the manufacturing and service firms which were founded before 2007 and 2008, with more than 10 employees, respectively. KIS(Korean Innovation Survey) has been conducted by Science and Technology Policy Institute since 1996. In the manufacturing sector, firms which are included in the Korean Standard Industrial Classification 10 to 33 are defined as manufacturing firms and in the service sector, firms which belong to KSIC 45 to 96 are defined as service firms. The sample firms were those that answered the survey and had standard financial statement in Korean Investor Service VALUE database. The number of total sample firms I used was 1206 in the manufacturing sector and 527 in the service sector. The technological innovation defined in *Oslo Manual* is new product innovation, product-improving innovation, and process innovation.

2. Variables

(1) Firm characteristics

Firm size (SIZE)

Firm size is measured in log value of the average number of employees during survey period – in case of manufacturing sector, the survey period is from 2007 to 2009 and for service sector, the period is from 2008 to 2010 for the manufacturing sector.

R&D intensity (RD_INT)

R&D intensity is used as a proxy for firm's absorptive capacity. Absorptive It is calculated by the average of R&D expenditures from 2007 to 2009 divided by the amount of sales in 2009 for the manufacturing sector, and for the services sector, the average of R&D expenditures from 2008 to 2010 divided by the amount of sales in 2010.

Reasons for Cooperation (COST and RISK)

Firms have several reasons to cooperate with external partners, among them, I selected cost-reducing objective and risk-sharing objective. *COST* variable is the average point of the answers from the question "what is the importance of the following factors as a barrier to technological innovation?" and *RISK* variable is the average point of the answers from what is the importance of the following factors as a barrier to technological innovation?" *COST* variable includes excessively high cost for excessively high cost for innovation or industrialization among 23 hindrance factors to innovation and *RISK* variable includes excessive risk or uncertainty among 23 hindrance factors to innovation.

Affiliation to Business Group (GROUP)

Tether(2002) had two different opinion on this issue, he argues that if a firm is affiliated to a group, the firm less tends to cooperate with PRO, because it can earn knowledge or resources inside of the group. On the other hand, a firm do cooperate with PRO using the group's assets such as its brand name, resources, and network.

Belderbos et al. (2004) found firms belonging to a business group have a tendency to cooperate with universities. There is also the opposite opinion. According to Mohnen and Hoareau (2003), affiliated firms have a negative impact on the industry-universities cooperation probability. As Korean industry structure consists of a small number of conglomerates, whether a firm is an affiliate to business group might affect to firm' s decision to cooperate with PRO. *GROUP* is a dummy variable indicating whether a firm is an affiliate to domestic or foreign business group, or a firm is an independent firm. The variable equals 1 when a firm is affiliated to domestic or foreign business group, and equals 0, when it is independent firm.

Firm Location (Regional dummies)

As communications technology has developed, the meaning of local boundary is weaker and weaker. Nevertheless, proximity of firm and PRO is yet important for knowledge spillover and cooperation. Geographic proximity matters when knowledge is transferred through informal linkage, however, when the knowledge spillover occurs through formal linkage, it is not necessary. Also, proximity matters when a firm cooperate with university-based scientists, however the influence is not tremendous (Audretsch and Stephan, 1996). Acs et al. (1994) found that firms within the same region with university researches tend to do more innovative activity. I generate 5 regional dummies - Metropolitan region, Gyeongsangbuk-do, Gyeonsangnam-do, Chungcheongbuk-do and Chungcheongnam-do - using 17 Korean provinces. O firms are located in Metropolitan region including Seoul, Incheon and Gyeonggi-do.

<Table 1> Regional component ratio

	Manufacturing sector	Service sector
	N(=1206)	N(=527)
Metropolitan region	622 (52%)	351 (67%)
Gyengsangbuk-do	226 (19%)	43 (11%)
Gyengsangnam-do	125 (10%)	57 (8%)
Chungcheongbuk-do	61 (5%)	8 (2%)
Chungcheongnam-do	106 (9%)	20 (4%)

In the parenthesis, it shows the percentage figure.

(2) Sectoral Characteristics

Legal protection is an industry variable rather than firm-specific characteristics and it has a positive impact on the cooperation with research institutions. I choose intellectual property right as a sector variable, IPR (*IN_IPR*) is measured by the average point of the answers of patent to the question "How important is each of the following methods as a means to protect IPRs of your innovation outcomes?" among 4 possible answers.

< Table 2 > Descriptive Statistics

Variables			Manufacturing sector		Service sector	
			Obs	Mean	Obs	Mean
Firm characteristics	Firm size	size	1206	5.17	527	4.47
	R&D intensity	rd_int	1206	0.14	496	0.0049
	Cost-sharing objective	cost	1206	1.81	495	0.19
	Risk-sharing objective	risk	1206	1.89	498	0.22
	Affiliates Of business groups	group	1206	0.77	524	0.15
Sector characteristics	Intellectual property	in_ipr	1206	1.04	525	0.13
Government policy	Government support	g_sup	1206	0.39	525	0.10

(3) Government policy

Government policy is a factor on facilitating industry-PRO cooperation (Capron and Cincera, 2003; Mohnen and Hoareau, 2003). I select participation in national R&D projects as a government support, the answer to the following question "Which government's support measure does your firm use or participate?" *G_SUP* is a dummy variable indicating whether a firm participates in the national R&D projects or not, equals 1 if a firm participate in the national R&D projects, and equals 0, otherwise.

(4) Cooperation probability (*Coop*) - cooperation with universities, cooperation with GRIS

Probability of cooperation is a dummy variable indicating whether a firm cooperates with universities or GRIs when it pushed forward technological innovation. Coop equals 1 if a firm cooperates with PRO, and equals 0, otherwise. In this study, both manufacturing and service sector, customers, suppliers and competitors are top 3 partners those who a firm collaborates with.

<Table 3> Cooperation partners

	Manufacturing sector (2010) (n=1206)	Service sector (2011) (n=471)
Universities	96 (7.96%)	16 (3.40%)
GRIs	94 (7.79%)	18 (3.82%)
Affiliates	70 (5.80%)	17 (3.61%)
Suppliers	173 (14.34%)	22 (4.67%)
competitors	140 (11.61%)	20 (4.25%)
Private service agents	110 (9.12%)	16 (3.40%)
Customers	189 (15.67%)	28 (5.94%)

<Table 4>

Variables	Service (n=527)	Manufacturing (n=1206)
Cooperation with PROs	20 (3.80%)	382 (31.67 %)
Cooperation with Universities	16 (3.37%)	366(30.35 %)
Cooperation with GRIs	18 (3.42%)	375(31.09 %)
Innovative firms	83 (15.75%)	900 (74.63 %)
Government support	53 (10.10%)	474 (39.30%)
Patents	0.2675522	24.07

*Among 527 service firms, 2 firms have missing values in the data.

(5) Innovation Probability (*P_INNO*)

Innovation Probability is a dummy variable which equals 1 when a firm has tried to perform technological innovation including new product innovation, product-improving innovation and process innovation and equals 0, otherwise. In my study, all the companies that cooperate with universities are innovative firm in both manufacturing and service sector.

(6) Innovation Outcomes : Sales, Patents, and Labor productivity.

As a measure of firm performance regarding innovative activities, *SALES* is a variable measuring the ratio of sales revenue associated with product innovation which is new to the market, to total sales in the last year. *PATENT* variable is the number of patents filed during the survey period from the three kinds of innovation taken together – new product innovation, product–improving innovation, and process innovation. *PROD* variable indicates a firm's labor productivity calculated by the average value added during the survey period divided by the average number of employees during the survey period. Value added data are sourced from standard financial statement in the KIS VALUE database.

Ⅳ. Models

(1) Determinants of cooperation with universities or PROs

$$\text{Coop}_i = \alpha_0 + \sum_{k=1}^{n} \alpha_k x_{ki} + u_i$$

x = {size, rd_int, cost, risk, group, regional dummies (r_), in_ipr, g_sup}

"*Coop*" is a dummy variable which equals 1 when a firm cooperates with PRO and 0, otherwise. I estimated this model using probit estimation method. In this model, I estimate PRO cooperation on exogenous variables – firm size(*size*), R&D intensity(*rd_int*), cooperation objective (*cost* and *risk*), affiliation to business groups(*group*), firm location(*r_*), IPR variable(*in_ipr*) and government support(*g_sup*).

(2) Impact of cooperation with universities or PROs on firm's innovation.

$$Coop_i = \beta_0 + \sum_{k=1}^{n} \beta_{1k} x_k + \sum_{l=1}^{n} \beta_{2l} z_{li} + u_{i1} \quad (2-1)$$

$$p\_inno_i = \gamma_0 + \sum_{k=1}^{n} \gamma_{1k} x_{ki} + \gamma_2 \widehat{Coop_i} + u_{2i} \quad (2-2)$$

z = {regional dummies (r_)}

x = {size, rd_int, cost, risk, group, g_sup, d_pull, c_push, age, exprt, industry dummies}

In the second model, I analyzed impact of PRO cooperation on firm's innovation. *p_inno* is a dummy variable which equals 1 when a firm succeeds in technological innovation and 0, otherwise. Including exogenous variables, other 3 variables are additional in this model. *Demand-pull* variable (d_pull) and *Cost-push* variable (c_push) indicate objectives for innovation. Those variables are answers to the following question "What are the objectives of your firm to do technological innovation?" Demand-pull variable is an average point of the answers such as product substitutions, market share increases and improvement in quality in the product innovation and process innovation. Cost-push variable is an average point of the answers such as material costs reduction and labor cost reduction in the product innovation and process innovation. "*Age*" is a logarithm value of firm's age and *EXPRT* is a dummy variable indicating whether a firm exports abroad or not. It equals 1 if a firm exports during the survey period and 0, otherwise. Industry dummies are included to control industry effect.

In this model, there is an endogeneity issue. Firm's characteristics have an influence to R&D cooperation, and then this affects to the firm's innovation probability. Therefore, using regional dummies as instrument variables, the model control the possible endogeneity issue. After regressing PRO cooperation on exogenous variables and instrument variables, I regressed innovation probability on exogenous variables and predicted value of PRO cooperation, $\widehat{Coop}$, instead of *Coop* using probit estimation method.

(3) Impact of cooperation with universities or PROs on firm's performance - sales, patents and labor productivity

$$p\_inno_i = \delta_0 + \sum_{k=1}^{n} \delta_{1k} x_{ki} + \delta_2 Coop_i + u_{1i} \quad (3-1)$$

$$Perfrom_i = \theta_0 + \sum_{k=1}^{n} \theta_{1k} x_{ki} + \theta_2 Coop_i + u_{2i} \quad (3-2)$$

x = {size, rd_int, group, d_pull, c_push, age, exprt, industry dummies}

In the third model, I analyzed how PRO cooperation affects to firm performance using sample selection model. Sample selection bias is caused by the survey itself, because only innovative firms could answer to the questions about *sales* and *patents*. To correct sample selection bias, I used *Heckman's 2SLS*. Heckman's 2SLS consists of two stages. In the equation (3-1), I estimated innovation probability and got predicted value of it using probit estimation method. With the predicted value of innovation probability, I calculated inverse Mill's ratio(*invmills*), after that, I estimated firm performance with exogenous variables I set and inverse Mill's ratio using OLS estimation.

Ⅴ. Empirical Results

(1) Determinants of R&D cooperation with universities or GRIs.

In <table 5>, in the manufacturing sector, larger firms have a tendency to more cooperate with both universities and GRIs, and if a firm participates in the national R&D projects, it is more likely to cooperate with universities and GRIs. R&D intensity does not have significant impact on the firm's cooperation as in Eom and Lee (2010. In the service sector, both firm size and R&D intensity is not significant factor to firm's R&D cooperation with both universities and GRIs, however, government support have significant and positive impact on the cooperation with GRIs, not on the industry-universities cooperation. Comparing the participation rate in the national R&D projects, manufacturing firms have higher rate than service sector. Among 1206 sample firms in the manufacturing sector, 39.30% of the firms participated in the national R&D projects from 2007 to 2009, on the other hand, among 525 service firms, 10.10% of the firms participated in the national R&D projects from 2008 to 2010. As service firms tend to less participate in the national R&D projects than manufacturing firms (Eom and Choi, 2004) and universities have less accessibility to the government R&D projects than GRIs, there is different result between manufacturing sector and service sector.

<Table 5> Determinants of PRO cooperation

	Manufacturing sector		Service sector	
	cooperation with universities	cooperation with GRIs	cooperation with universities	cooperation with GRIs
size	0.099** (0.01)	0.11*** (0.00)	0.116 (0.20)	0.359 (0.89)
rd_int	0.065 (0.94)	0.064 (0.95)	16.16 (1.45)	5.078 (1.17)
group	−0.15 (0.14)	−0.20** (0.04)	0.311 (0.19)	−0.0262 (−0.02)
cost	0.043 (0.35)	0.032 (0.49)	0.393 (0.33)	−0.0479 (−0.05)
risk	0.095** (0.03)	0.089** (0.05)	0.946 (1.04)	1.932* (2.15)
r_s	−0.15 (0.40)	−0.21 (0.24)	−0.894 (−0.53)	−0.774 (−0.49)
r_cb	−0.54** (0.04)	−0.62** (0.02)	1.784 (0.86)	3.219 (1.43)
r_cn	0.12 (0.58)	−0.061 (0.77)	0.818 (0.40)	2.123 (0.98)
r_kb	−0.28 (0.20)	−0.31 (0.14)	−0.262 (−0.12)	0.656 (0.35)
r_kn	−0.14 (0.47)	−0.20 (0.29)	−0.948 (−0.44)	−0.628 (−0.32)
g_sup	0.53*** (0.00)	0.55*** (0.00)	0.226 (0.16)	2.928** (2.82)
in_ipr	0.22*** (0.00)	0.21*** (0.00)	1.361 (1.74)	−0.320 (−0.63)
_cons	−1.55*** (0.00)	−1.47*** (0.00)	−4.712 (−1.70)	−6.995** (−2.65)
N	1206	1206	455	471

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

(2) Impact of cooperation with universities or PROs on firm's innovation.

<Table 6> shows the results of regression of hypothesis 2 and the results are estimated separately in case of controlling endogeneity and not controlling endogeneity. In the manufacturing sector, when I did not control endogeneity, industry−universities and industry−GRIs cooperation does affect significantly and positively to firm's innovation. However, when controlling endogeneity, cooperation does not have significant impact on the firm's innovation probability. On the other hand, in the service sector, regardless of controlling endogeneity, cooperation with universities or GRIs does not

statistically significantly affect to firm's innovation probability. This means that cooperation is not a driving force to technological innovation, but already innovative firms have a propensity to collaborate with universities or GRIs in Korea in both sectors. Besides industry−PRO cooperation, in the manufacturing sector, highly motivated firms to innovation, in either demand−pull factor or cost−push factor, are more likely to be innovative. However, in the service sector, nothing has significantly impact on firm's innovation. These results show coincidence with my hypotheses regarding impact of firm's cooperation on firm's innovation.

(3) Impact of cooperation with universities or PROs on firm's performance – sales, patents and labor productivity.

<Table 6> Impact of PRO cooperation on innovation

	Endogeneity controlled					Endogeneity not controlled			
	Manufacturing sector		Service sector			Manufacturing sector		Service sector	
	Innovation probability	Innovation probability	Innovation probability	Innovation probability		Innovation probability	Innovation probability	Innovation probability	Innovation probability
size	0.34 (0.52)	0.34 (0.55)	0.0855 (0.12)	−0.0194 (−0.03)	size	0.52 (0.36)	0.44 (0.42)	−0.00196 (−0.00)	0.218 (0.32)
rd_int	17.7 (0.13)	17.1 (0.14)	−8.087 (−0.88)	−4.717 (−0.77)	rd_int	19.0 (0.18)	30.1 (0.41)	−1.185 (−0.05)	−3.359 (−0.59)
cost	−0.38 (0.27)	−0.35 (0.34)	−0.606 (−0.44)	0.506 (0.43)	cost	−0.60 (0.20)	−0.56 (0.25)	1.048 (0.35)	−0.109 (−0.11)
risk	0.28 (0.48)	0.30 (0.44)	2.470 (1.40)	1.963 (1.29)	risk	0.35 (0.40)	0.28 (0.47)	−0.0260 (−0.02)	2.326 (1.32)
group	2.47 (0.21)	1.99 (0.23)	1.268 (0.64)	2.361 (0.85)	group	1.43 (0.35)	1.46 (0.35)	0.897 (0.48)	0.730 (0.47)
g_sup	−1.20 (0.53)	−1.34 (0.51)	1.513 (1.05)	0.186 (0.09)	g_sup	−1.10 (0.42)	−1.24 (0.47)	0.501 (0.29)	1.285 (0.70)
d_pull	6.54** (0.03)	6.74** (0.03)	0.213 (0.11)	−0.400 (−0.17)	d_pull	5.00** (0.03)	4.48*** (0.00)	1.018 (0.21)	1.736 (0.88)
c_push	3.51** (0.02)	5.34* (0.07)	−0.137 (−0.05)	0.554 (0.22)	c_push	4.79** (0.02)	4.88** (0.03)	1.055 (0.26)	−0.193 (−0.09)
age	0.11 (0.88)	0.21 (0.77)	−1.254 (−0.64)	−0.986 (−0.60)	age	0.11 (0.90)	0.36 (0.72)	0.340 (0.20)	0.00765 (0.01)
exprt	−0.038 (0.96)	−0.19 (0.83)	−0.205 (−0.08)	1.613 (0.70)	exprt	1.61 (0.22)	1.83 (0.16)	1.659 (0.89)	1.859 (1.04)
Industry dummies	Included	Included	Included	Included	Industry dummies	Included	Included	Included	Included
phat_u	1.70 (0.59)		0.697 (0.71)		univ	6.63*** (0.00)		0.732 (0.21)	
phat_g		1.50 (0.65)		0.734 (0.88)	gri		6.71*** (0.00)		0.566 (0.22)
_cons	−3.72 (0.61)	−3.73 (0.61)	1.170 (0.16)	1.373 (0.23)	_cons	−7.76** (0.04)	−8.22** (0.03)	−5.084 (−1.13)	−5.161 (−1.36)
N	1183	1183	470	470	*N*	1183	1183	454	470

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In this section, I used only innovative firms so that there is a problem of sample selection bias. First, I calculated inverse Mill's ratio using the predicted valued from the regression of equation (3-1) in model 3. By adding the term, *Invmills,* I corrected sample selection bias.

<Table 7-1> and <Table 7-2> represents the results that the impact of cooperation with universities or GRIs on firm's performance indicated by 3 ways – the number of patents filed associated with innovation, sales ratio of innovative outcome new to the market, and labor productivity. In the manufacturing sector, the coefficients of collaboration with universities or GRIs have significant and positive affect to patents among three firm performance variables I established. In the paper of Eom and Lee (2010), cooperation with universities or GRIs has statistically significant effect to patent in case of the firms where implemented new product innovation. Eom and Lee (2010) accounted for these results as Korea industry only has accumulated patents from PRO cooperation, and this knowledge does not link to firms' sales, which means knowledge industrialization is not prevalent yet in Korean manufacturing sector. In the service sector, on the other hand, R&D cooperation – with both organizations – have a significant and positive impact on the number of patents firms filed. Furthermore, cooperation with GRIs has a significant and positive effect to firm's sales ratio. This shows in the manufacturing sector, still knowledge/technology industrialization does not occur whereas it seems that there is knowledge industrialization in the service sector. According to <Table 4>, cooperation rate is bigger in the manufacturing sector than in the service sector. On average, manufacturing firms have more patents regarding innovation, than service firms. In spite of these manufacturing-oriented environments, the reason why knowledge industrialization occurs in the service sector rather than in the manufacturing sector, seem to result from intrinsically different characteristics between manufacturing sector and service sector. Rogers et al. (2000) argued that the number of start-up firms from universities spin-off is one indicator, measuring outcome of universities' technology transfer. Founding start-ups supported by venture capital is a good method to commercialize technologies in the early stages of knowledge industrialization (Lerner, 2005). In the service sector, the length of

process connecting outcome of innovation (in this case, patents) to firm's sales is relatively shorter than that in the manufacturing sector. Referring to those two literatures, I used start−up rate [4] for measuring the level of knowledge transfer or knowledge industrialization. Start−up rates in the service sector are larger than in the manufacturing sector (the differences are statistically significant). This indicates circumstantial evidence for occurrence of knowledge transfer and knowledge industrialization in the service sector.

<Table 7−1> Impact of cooperation on firm performance− manufacturing sector

	Manufacturing sector					
	Cooperation with universities			Cooperation with GRIs		
	sales	patents	productivity	sales	patents	productivity
size	0.0012 (0.72)	1.31*** (0.00)	−0.030** (0.04)	0.00087 (0.79)	1.43*** (0.00)	−0.029* (0.05)
rd_int	0.40*** (0.01)	103.4*** (0.00)	−0.63 (0.29)	0.39*** (0.01)	110.4*** (0.00)	−0.61 (0.30)
group	0.0042 (0.59)	0.13 (0.90)	−0.065* (0.07)	0.0028 (0.72)	0.043 (0.97)	−0.065* (0.08)
d_pull	0.019*** (0.00)	1.28** (0.02)	0.010 (0.55)	0.019*** (0.00)	0.88 (0.11)	0.011 (0.52)
c_push	0.0045 (0.41)	−0.34 (0.64)	0.0061 (0.79)	0.0059 (0.29)	0.43 (0.57)	0.0012 (0.96)
age	−0.0062 (0.20)	0.22 (0.73)	0.020 (0.35)	−0.0061 (0.21)	0.11 (0.87)	0.018 (0.39)
exprt	−0.0013 (0.82)	−0.043 (0.96)	0.018 (0.49)	−0.0026 (0.66)	−0.10 (0.90)	0.018 (0.50)
Industry dummies	Included	Included	Included	Included	Included	Included
univ	−0.017 (0.25)	5.05** (0.01)	−0.040 (0.53)			
gri				−0.022 (0.13)	4.90** (0.01)	−0.028 (0.66)
invmills	−3.2e−40 (0.42)	−1.6e−38 (0.77)	3.7e−41 (0.98)	−1.5e−39 (0.88)	−2.0e−36 (0.14)	−9.7e−40 (0.98)
_cons	0.0071 (0.82)	−7.45** (0.04)	0.18 (0.25)	0.010 (0.74)	−6.83 (0.10)	0.18 (0.25)
N	388	389	298	387	387	296

p−values in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

[4] $start\text{-}up\ rate = \frac{the\ nuber\ of\ start-up\ firms}{the\ \ number\ of\ active\ firms} \times 100$

I followed the definition of start-up rate in Statistics Korea.

<Table 7-2> Impact of cooperation on firm performance- service sector

	Service sector					
	Cooperation with universities			Cooperation with GRIs		
	sales	patents	productivity	sales	patents	productivity
size	-0.0067^{***} (0.00)	-0.0030 (0.90)	-0.029^{***} (0.00)	-0.0029 (0.36)	0.0088 (0.77)	-0.030^{***} (0.00)
rd_int	-1.86^{***} (0.00)	-5.83^{**} (0.02)	10576.7 (0.37)	-0.18^{*} (0.06)	11.2^{***} (0.00)	-0.96 (0.48)
group	0.0010 (0.90)	-0.022 (0.80)	0.15 (0.18)	-0.0053 (0.64)	-0.061 (0.59)	0.049^{**} (0.03)
d_pull	0.26^{***} (0.00)	-1.47^{***} (0.00)	-48.3 (0.37)	0.100^{***} (0.00)	0.31 (0.13)	0.051 (0.26)
c_push	-0.17^{***} (0.00)	2.08^{***} (0.00)	26.6 (0.37)	-0.054^{**} (0.02)	-0.25 (0.26)	-0.046 (0.42)
age	0.0014 (0.74)	-0.042 (0.34)	0.023 (0.22)	-0.0083 (0.14)	-0.030 (0.58)	0.016 (0.25)
exprt	-0.0014 (0.89)	0.0012 (0.99)	0.15 (0.21)	0.018 (0.18)	0.16 (0.21)	0.043 (0.17)
Industry dummies	Included	Included	Included	Included	Included	Included
univ	-0.0095 (0.75)	2.95^{***} (0.00)	195.5 (0.37)			
gri				0.072^{**} (0.02)	1.53^{***} (0.00)	-0.0058 (0.92)
invmills	-0.0000020^{***} (0.00)	-0.0000038^{**} (0.05)	-1.72 (0.37)	$-6.8e-29$ (0.93)	$-6.1e-27$ (0.41)	8.5e-19 (0.32)
_cons	0.022 (0.11)	0.099 (0.51)	0.51 (0.21)	0.023 (0.23)	0.034 (0.86)	0.14^{***} (0.00)
N	458	459	96	486	487	102

p-values in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Next, what I focused on is a different result in the service sector when a firm cooperates with universities and cooperates with GRIs. As I mentioned earlier, in the service sector, firms where cooperate with government research institutions have a significant and positive affect the number of patents and further, the cooperation affects statistically significantly to the firm's sales. However, industry-universities cooperation have significant and positive affect on the number of patents but have a statistically insignificant result in firm's sales. One of possible explanation of this different result between cooperation with universities and GRIs is that there exists a different level of readiness of knowledge industrialization between the two organizations.

To facilitate knowledge industrialization, several factors are necessary. First, it is an important factor whether organizations – universities or GRIs – have their own Technology Licensing Office where conducts overall knowledge industrialization works. According to Kim and Hyun (2006), factors for knowledge industrialization divide into institutional environments and strategic environments. In strategic environments, human capital and workers' education level who work in TLO are positive and significant factors to knowledge industrialization. While 109 universities have their own TLOs out of 141(77.3%), 60 GRIs have their own TLOs out of 107(56.1%) in 2009.[5] Despite universities have quantity of TLOs over GRIs, in the perspective of quality, GRIs are better than universities. Government research institutions have more total cumulative technologies than universities, and they have more average of cumulative technologies than universities. Considering interior capacity, TLO in the GRIs have better condition than TLO in universities <Table 10>. As a result, GRIs–based TLOs are prior to universities–based TLOs in the aspect of quantity, industry–GRIs cooperation have a significant effect to firm's knowledge industrialization than industry–universities cooperation. TLOs are key to knowledge transfer and knowledge industrialization. Although GRI–based TLOs have a better condition than universities–based TLOs, still, there is a huge gap comparing to the advanced countries so that we need more supports to develop TLOs increasing experts related to knowledge transfer and knowledge industrialization such as patent attorneys, technology transfer agent and technology valuation specialists, and structuring the programs fostering those experts.

<Table 8> Current state of TLO in 2009

	Total	TLO	ratio(yes)	No TLO	ratio(no)
GRIs	107	60	56.1%	47	43.9%
Universities	141	109	77.3%	32	22.7%

Source : Ministry of Knowledge Economy and Korea Institute for Advancement of Technology(2011), *A source book of analysis on technology transfer and industrialization in 2010*.

[5] Ministry of Knowledge Economy and Korea Institute for Advancement of Technology(2011), *A source book of analysis on technology transfer and industrialization in 2010*.

<Table 9> Current state of technologies possessed by PROs in 2009

	Total number of Cumulative technologies	Average number of Cumulative technologies
Public research institutions	73,967	348.9
Government research institutions	39,489 (53.39%)	443.7
Universities	34,478 (46.61%)	280

Source : Source : Ministry of Knowledge Economy and Korea Institute for Advancement of Technology(2011), *A source book of analysis on technology transfer and industrialization in 2010*

Ⅵ. Summary and Conclusion

As knowledge becomes an important source to economic growth, and innovation is another important factor to economic growth, National Innovation System plays an important role to facilitate knowledge industrialization for economic growth. The history of Korean National Innovation System is not long, compared to the advanced countries. For more than 20 years, Although Korean NIS has progressed, it is immature and imperfect yet. In the national innovation system, networks of those actors are also important. The objective of this study was to discover whether what determines industry-universities and industry-GRIs cooperation, whether the cooperation affects firm's innovation, and finally whether there is improvement in NIS of Korea, in comparison with the results of Eom and Lee (2010).

In the Korean manufacturing and service sector, factor for activating industry-GRIs cooperation is government support participating in the national R&D projects, however it is not significant when a service firm cooperates with universities. In the second model, what I found is that industry-PRO cooperation is not a driving source to firm's innovation in both manufacturing and service sector. Already innovative firms do cooperate with PRO in Korea. In the perspective of firm performance, different results of knowledge industrialization between for manufacturing firms and for service firms, come from different industrial characteristics that manufacturing and service have, respectively. In the service sector, there is a different result between industry-universities cooperation and industry−GRIs cooperation. When a firm cooperates with GRIs, it has a significant influence to both patents and sales, which indicates knowledge industrialization. As GRIs have more experts in TLO for knowledge industrialization than universities, industry−GRIs cooperation is more likely to transform accumulated knowledge into firm's profit than industry−universities. My hypotheses does not changed comparing with Eom and Lee(2010). Even though more than 10 years has passed since 2002, the reason why the results have not changed is that policies for technology transfer and industrialization have focused on the expansion of quantity not quality and government supports also have concentrated on monetary supports.

In order to invigorate knowledge industrialization, expansion of professionals regarding technology transfer and industrialization is preferentially necessary. As far, government support for TLOs focuses on financial support, however, to facilitate knowledge transfer and industrialization, expansion of regarding knowledge transfer and industrialization plays a key role as well. Therefore, to expand professionals in TLOs, systematic programs for fostering experts such as patent attorneys, technology transfer agent and technology valuation specialists are necessary. Although GRI−based TLOs are better than university−based TLOs, still, there is a huge gap comparing to the advanced countries, therefore, to invigorate knowledge industrialization, we need more supports to develop TLOs increasing experts related to knowledge transfer and knowledge industrialization such as patent attorneys, technology transfer agents and technology valuation specialists. Also, we need to develop programs to foster those professionals (Park, 2008).

This paper's contribution is that I studied Korean current situation of knowledge industrialization, and while previous studies mainly focused on the manufacturing sector and aggregate sector, my research is a step−ahead to knowledge industrialization in the service sector. It is meaningful in respect that I brought up a necessity of further research on knowledge industrialization in terms of service sector. In the future research, if I used panel data using accumulated data in KIS, that will be more accurate and better analysis for knowledge industrialization.

Appendix

<Appendix 1> Components of innovative firms and cooperative firms.

	Manufacturing sector (2010)				Service sector(2011)			
	Universities		GRIs		Universities		GRIs	
	Cooperators (n=366)	Non−cooperators (n=840)	Cooperators (n=375)	Non−cooperators (n=831)	Cooperators (n=16)	Non−cooperators (n=459)	Cooperators (n=18)	Non−cooperators (n=508)
No. (%) of innovative firms	366 (100%)	534 (63.57%)	375 (100%)	525 (63.18%)	16 (100%)	15 (3.27%)	18 (100%)	64 (12.60%)

<Appendix 2> start−up ratio

	2007			2008			2009			2010		
	In active	Start−up	**Start−up ratio**	In active	Start−up	**Start−up ratio**	In active	Start−up	**Start−up ratio**	In active	Start−up	**Start−up ratio**
Total firms	4,726,221	847,285	**18%**	4,908,035	796,018	**16%**	5,031,599	759,996	**15%**	5,146,659	773,226	**15%**
Manufacturing firms (approximates)[6]	413,292	54,574	**13%**	429,191	51,272	**12%**	439,996	48,952	**11%**	450,058	49,804	**11%**
Service firms	3,996,502	751,090	**19%**	4,150,244	705,643	**17%**	4,254,730	673,711	**16%**	4,352,025	685,439	**16%**

Source : Korean Statistical Information Service

[6] As there are so many missing data of the number of active firms and start−up firms from 2007 to 2010 in both manufacturing and service sector and it shows the total number of firms, I approximated those figures as follows. As there are full data of active firms and new firms in both sectors from 2011 to 2015, I calculated the average ratio of active firms and new firms to the total number of active and new firms for manufacturing and service firms, respectively, using 2011−2015 data. After that, I multiplied those average ratios by the total number of firms, and then had the approximated number of new firms and active firms in both manufacturing and service sector. Using those approximates, I measured start−up ratios from 2007 to 2010 for manufacturing and service sector.

<Appendix 3> Analysis of TLO interior capacity

(unit :%)

	Resourced and Infrastructures					Strategies and practices				Total average
	Type of organization	Human capital	Budget	Regulation and system	Management of information	Industrialization strategy	Assessment of technology	Utilization of networks	Technology industrialization	
GRI-based TLOs	80	70	46	95	65	78	54	53	78	69
University-based TLOs	80	60	49	75	71	76	50	33	44	60

Source : Jung, J. Y., (2011). Current State and Development of TLO in Government Research Institutes. *Science and Technology Policy* (184), 27-37.

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국문초록

이 논문은 2010년과 2011년에 발행된 기업혁신조사를 이용하였다. KIS2010은 제조기업을 대상으로 한 것이고, KIS2011은 서비스기업을 대상으로 한 것이다. 이러한 데이터를 사용하여 기업과 공공연구기관의 협력을 결정요인과 그 협력이 기업 성과에 미치는 영향을 분석하였다. 첫 번째로 제조업에서는 협력 대상과 관계없이 기업 규모와 정부지원이 산학연 협력의 결정요인이고, 서비스업에서는 정부지원만이 기업과 정부출연연구원 간 협력의 결정요인이다. 두 번째로, 산학연 협력이 기업의 혁신에 유의미하지 않은 영향을 미치는 것을 알아냈다. 마지막으로, 산학연 협력이 기업 성과에 미치는 영향에 대해서 알아 보았다. 기업 성과를 기업이 출원한 특허 수, 기업의 전체 매출액에서 혁신적인 상품의 매출액이 차지하는 비중, 그리고 노동 생산성으로 정의하였다. 제조업에서 출원 특허 수만이 기업-공공연구기관 간 협력의 유의미한 영향을 받는 것으로 나왔다. 그러나 서비스업에서는 기업과 대학 간의 협력은 출원 특허 수만 유의미한 영향을 주지만 기업이 정부 출연연구원과 협력을 할 때는 출원 특허 수와 매출비율 두 가지에 유의미한 영향을 주는 것으로 나타났다. 이는 서비스기업이 정부 출연연구원과 협력할 때는 지식산업화가 이루어지는 것을 볼 수 있지만, 제조기업이 공공연구기관과 협력을 할 때, 축적된 특허가 기업의 매출로 이어지지 않았고, 이는 제조업에서는 아직 지식 산업화가 발생하기 힘듦을 의미한다. 두 산업 간의 이러한 차이점은 서비스의 경우에는 제품의 생산과 소비가 동시에 일어나고 고객과 만나기까지의 프로세스가 제조업에 비해 상대적으로 짧다는 점에서 각각의 다른 산업적 특성에서 기인한다. 그리고 협력 파트너에 따른 차이점은 지식의 이전 및 산업화에 얼마나 준비되어 있는지에 따라 발생한다. 기술이전조직은 기술산업화에 중요한 역할을 하는데 정부출연연구원의 기술이전조직은 대학 내 기술이전조직보다 질적으로 더 좋은 평가를 받았다. 따라서 기술산업화가 기업이 정부출연연구원과 협력을 할 때 발생하는 것으로 보인다. 이러한 결과는 한국에서 축적된 지식들이 기업의 매출로 연결될 수 있도록 더 실용적인 정책이나 지원이 필요함을 보여준다.

주요어 : 기업, 혁신, 협력, 대학, 정부출연연구원, 공공연구기관, 기술산업화

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