Determinants of Corporate Commercialization of Public Technology Transfer: Evidence in Korea

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Abstract

This study investigates the potential factors that might affect the successful commercialization of public technology transfer (TT), i.e., technology transfer from universities and public research institutions. We conduct an inductive and qualitative approach to identify the key organizational issues in promoting commercialization of public TT with the help of a unique survey data. The important explanatory factors relate to the researcher's technology consultant service, R&D intensity of the company, and the prior experience of TT from the same institution. However, the TT productivity (i.e. royalty income/R&D expenditure) of the universities and public research institutions, and the engagement of technology transfer intermediary appear to be negative to successful commercialization.

Keywords: Public Technology Transfer, Technology Commercialization, Absorptive Capacity

1. Introduction

As technological innovation has been attracting attention as a core means of national competitiveness reinforcement, the government's support for R&D has been continuously increasing. According to a research and development activity survey report (KISTEP, 2012), in the case of Korea, the amount of the government's R&D investments rapidly increased by 14.4% per year on average from KRW 6,632.1 billion in 2006 to KRW 13,003.3 billion in 2011. As a result, the importance of R&D investments in the national economy is very high, to the extent that the ratio of the entire inputted research and development costs to national GDP as of 2011 was 4.03%, which was the second highest in the world next to Israel. A noteworthy part is that public research institutions & Universities (PRI&Us) play very important roles in the national R&D ecosystem to the extent that KRW 10,668.5 billion, which corresponds to 82.0% of the 2011 government R&D finance, was invested into PRI & Us.

To diffuse PRI & Us' research outcomes and promote the commercialization of the outcomes, the government not only established and amended laws such as the Technology Transfer and Commercialization Promotion Act (established in 2000), the Special Act on the Support of Daedeok Special Research and Development Zone, (established in 2005), and the Promotion of Industrial Education and Industry-Academic Cooperation Act (amended in 2003), among others but also has established and implemented diverse support policies such as establishing mid- to long-term technology transfer commercialization promotion plans

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for four times. As a result, organizations dedicated to technology transfer (TLO, Technology Licensing Office[1]) were installed in PRI & Us and diverse technology transfer intermediaries appeared, resulting in increases in activities intended to transact technological assets, such as patents followed by the formation of technology transaction markets in Korea.

As PRI & Us' social responsibility increased, records of technology transfer to enterprises continuously increased. The total amount of technology licensing revenue received by PRI & Us increased by 2.6 times from KRW 49 billion in 2003 to KRW 125.8 billion in 2011 and the number of cases of technology transfer increased by 4.8 times from 1,076 in 2004 to 5,193 in 2011. Nevertheless, when seen from the viewpoint of research fund productivity (the ratio of technology licensing revenue to input research fund), the performance of PRI & Us' technology transfer in Korea was found to be approximately one-third of that in the USA because the productivity in Korea as of 2011 was 1.32%, while the productivity in the USA as of 2010 was 4.06%. Therefore, additional effort for the improvement of technology transfer efficiency is necessary.

Thus far, many studies have been conducted from the viewpoint of enhancement of PRI & Us' technology transfer capacity and performance. Studies on the correlation between diverse factors and PRI & Us' technology transfer performance have been continuously conducted such as those that divided PRI & Us' resources into financial, physical, human, and organizational resources (Power, 2003) from a resource- based viewpoint (Barney, 1991) believing that the sources of competitive advantages are differentiated resources and capacities possessed by organizations, those that considered compensation systems (Siegel, 1999), cooperation systems (Santoro et al., 2002), licensing strategies, and patent application registration speed (Markman et al., 2005) in terms of transferred technology commercialization, and those that considered surrounding enterprises' R&D intensity (Siegel, 2003; Friedman et al., 2003) and venture capital availability (Wright et al., 2006; Lockett, 2005) from the viewpoint of market structures considering industrial environments (Porter, 1979).

From the viewpoint of enterprises that are actual implementers of technology commercialization, open technological innovation through unceasing cooperation with external organizations is indispensable for ensuring continuous growth by responding to environmental changes including intensifying competition resulting from rapid globalization and shortening product life cycles (Chesbrough, 2003). Through diverse studies indicating that cooperation with external organizations positively affects enterprises' performance (Powell, 1996; Ledwith, 2005; Stock, 2012 et al.), cooperation with external organizations has come to be recognized as a mandatory requirement for enterprises' current success. Diverse studies on enterprises' external cooperation have also been conducted such as those regarding the relationship between the selection of effective methods of technical cooperation (outsourcing, joint research, licensing, M&A, and joint venture establishment, etc.) in relation to internal capacity and environments faced and those regarding the effectiveness of vertical cooperation with demanding/ supplying enterprises or horizontal cooperation with non-related enterprises (Podolny, 2001).

In this study, PRI & Us and enterprises will be integrated into one analysis unit to examine whether enterprises that introduced technologies from PRI & Us actually accomplished commercialization success such as sales occurrence and cost saving. Through the foregoing, the scope of technology transfer performance analysis that has been limited to PRI & Us will be expanded and special relationships between enterprises and PRI & Us will be mainly analyzed instead of conducting general comparison and analysis of the relationship between enterprises and organization in diverse cooperation networks in order to find factors for success of public technology commercialization. To this end, the present state of enterprises' commercialization of technologies transferred from 29 institutions in Korea that comprise universities and

1) Pursuant to article 2 of the Technology Transfer and Commercialization Promotion Act, the establishment of a department dedicated to TLO is mandatory to public research institutes.

research institutes with excellent technology transfer performance were examined.

The composition of this paper is as follows. First, in Chapter 2, previous studies related to the analysis of the effects of PRI & Us' technology transfer, enterprises' introduction of external technologies, and technology transfer intermediary on the performance of technology transfer·commercialization are examined and their research hypotheses are presented. In Chapter 3, a research model is presented based on the results of questionnaire surveys about technologies transferred from 29 universities and research institutes and in Chapter 4, success factor hypotheses are verified through regression analysis. In Chapter 5, policy alternatives for enhancing the efficiency of public technology transfer are presented based on the results of verification of the hypotheses.

2. Previous Studies and Research Hypotheses

2.1 Public Research Institutions and Universities Technology Transfer

As the importance of public technology transfer was magnified, the USA acknowledged PRI & Us' ownership of technologies and specified technology transfer as a major duty of them in 1980 through the establishment of Bayh-Dole Act[2] and Stevenson-Wydler Technology Innovation Act[3] so that technology transfer activities began in earnest. In Korea, PRI & Us' technology transfer began to be promoted in earnest in 2000 when the Technology Transfer and Commercialization Promotion Act was established to construct a series of bases for technology transfer such as making the installation of organizations dedicated to technology transfer (TLO, Technology Licensing Organization) mandatory and providing incentives for technology transfer.

As shown in Figure 1, general procedures for public technology transfer can be divided into reporting of invention, evaluation of invention, applications for patents, technology marketing for discovery of subject enterprises, transfer contracts, and licensing management stages. To overcome the problem of limited capacity of TLO organizations, technology marketing works such as the discovery of demanding enterprises are entrusted to external technology transfer intermediary when necessary. When a researcher has

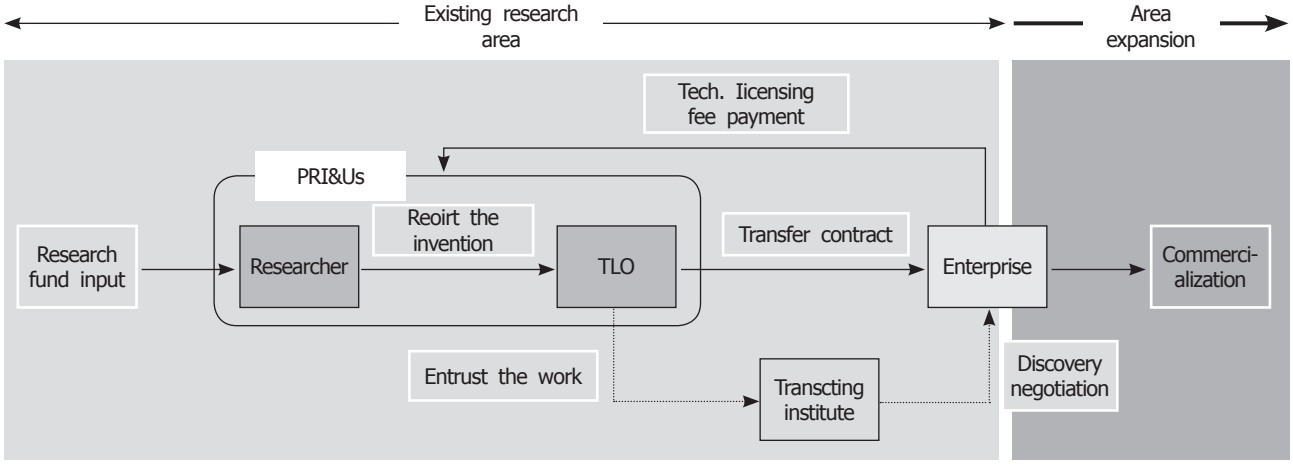

Figure 1 Technology transfer process of PRI & Us

2) Bayh-Doyle Act (P.L. 96-517, 1980): Based on the judgment that there should be no effort for commercialization without ownership and protection of invention, universities' and non-profit institutions' acquisition of ownership for inventions made by the federal government was allowed

3) Stevenson-Wydler Technology Innovation Act (P.L. 96-480, 1980): specified government departments' technology transfer and related effort as major duties such as mandatory technology transfer budget allocation to departments having research institutes (at least 0.5% of R&D budgets), mandatory establishment of technology transfer offices (ORTA: Office of Research and Technology Applications) in research institutes

reported an invention as an outcome of technology development to an organization dedicated to technology transfer (TLO), if the TLO judges that the invention should be protected because it has business value, the TLO will apply for a patent to obtain intellectual property rights. Thereafter, the TLO publicly promotes the technology or searches for enterprises that require the relevant technology to make a technology transfer contract to transfer the intellectual property rights or permit the right of implementation, or elect to found a business firsthand with the technology as an investment in kind as an alternative.

Previous studies on PRI & Us' technology transfer can be largely divided into those with the viewpoint of the inside of organizations, those with the viewpoint of external environments, and those with the viewpoint of dynamic relations to review the studies. From the viewpoint of the inside of organizations, Power (2003) divided factors that affect patent creation, technology licensing, etc. into financial, physical, human, and organizational resources based on the resource based theory (Barney, 1991) to conduct a comprehensive analysis. To review those studies in more details, there are studies on the effects of different attributes of input research funds (government fund, private funds, etc.) on transfer performance (Foltz et al., 2000), the relationship between the scales of organizations dedicated to technology transfer and business history (Di Gregorio et al., 2003; Markman et al., 2005; Lockett and Wright, 2005), distribution of researcher resources (Thursby, 2002), the efficiency of technology licensing compensation systems (Siegel, 1999), study outcomes such as papers (Santoro, 2002; Di Gregorio, 2003), and the speed of technology transfer processes (Markman et al., 2005). From the viewpoint of environments, some studies examined the relationship between external environmental factors and the performance of public technology transfer based on the industrial organization theory (Porter, 1979) emphasizing that external environments surrounding organizations are important factors. Major contents of study results presented include the relationships between surrounding enterprises' R&D intensity and regional economy's GDP (Siegel, 2003), high-tech enterprise density (Friedman, 2003; Audretsch, 2005), and venture capital availability (Di Gregorio, 2003; Wright et al., 2006) and the performance of technology transfer. Major studies from the viewpoint of dynamic relations examined the relationships between smooth communication between organization members (Smiler, 1991; Greiner, 2003; Santoro et al., 2002), ties between researchers, TLO organizations (Siegel et al., 2003), etc. and technology transfer performance. In Korea too, studies on public technology transfer mechanisms have been actively conducted including those that examined research fund finances, research manpower, internal capacity of institutions such as TLO (Cho, 2012), cooperation with external organizations and external environments such as social capitals (Kim, 2011), the effect of consortiums among technology transfer related parties (Park, 2007), incentive distribution methods and technology information management (Ok, 2009), and marketing activities, educational systems, and technology transfer efficiency (Lee, 2012).

This study will begin from the viewpoint that the ultimate objective of PRI & Us' technology transfer is transferred technologies' market entry. That is, the focus of analysis was moved from the technology licensing revenues of PRI & Us to the successful commercialization of transferred technologies for the reinforcement of national competitiveness. Therefore, the subjects of analysis were increased to include enterprises to which PRI & Us' technologies were transferred with a view to verifying whether PRI & Us' activities actually positively affected successful commercialization through follow-up surveys of transferred technologies. To verify whether the PRI&Us' technology transfer performance supported in previous studies actually affected enterprises' commercialization performance, the first and second hypotheses were established as follows.

Hypotheses 1. Public research institutions and Universities that have higher technology transfer performance will positively affect enterprises' commercialization success.

Hypotheses 2. Additional researchers' support after technology transfer will positively affect enterprises' commercialization success.

2.2 Enterprises' Introduction of External Technologies

Due to rapid increases in the speed of technological innovation and shortening of product life cycles, the necessity to cooperate with external organizations along with in-house research and development has become larger (Hagedoorn, 1994; Chesbrough, 2003). Risks and costs involved in research and development can be reduced by quickly acquiring diverse knowledge and ideas through external research and development while reinforcing core capability through internal research and development (Laursen & Salter, 2006) General processes for enterprises to introduce external can be divided into the stages of defining necessary technologies, decision making on technology introduction, negotiation and contract, and additional development. When necessary in order to overcome the problem of enterprises' limited capability to search for external technologies, works such as searching for institutions having necessary technologies and negotiations are entrusted to external technology transfer institutions.

Enterprises' absorptive capacity was defined as the ability to commercialize external knowledge by evaluating and utilizing the external knowledge using the prior knowledge and experience accumulated in the organization (Cohen & Levinthal, 1990). That is, some studies regarded absorptive capacity as a means to effectively utilize introduced technologies and measured human resources' technology levels, the ratio of skillful R&D manpower, and the amounts of R&D investment from the viewpoint of country units (Mowery & Oxley, 1995) and some other studies argued that high absorptive capacity could be possessed if amount of prior knowledge was large and the intensity of effort was high from the viewpoint of learning ability and problem solving ability (Kim, 1998). Zahra and George (2002) expanded the existing absorptive capacity to Dynamic Capacity, divided it into Potential Absorptive Capacity and Realized Absorptive Capacity, and concretized them as a series organization routines and process stages to recognize, assimilate/digest, transform, and exploit necessary knowledge.

In the case of technologies developed by PRI & Us, channel type transfer without any particular subjects is universal (Podolny, 2001). That is, since technologies developed by PRI & Us have the nature of public goods, they are not delivered to certain subjects but correspond to the type of sowing the seeds of technologies. Therefore, differences in the performance of technological innovation are assumed to be very big between enterprises with high absorptive capacity and those with low absorptive capacity. In this study, absorptive capacity is divided into Potential Absorptive Capacity and Realized Absorptive Capacity applying the study conducted by Jansen (2005) and the effects of these absorptive capacities on commercialization success after public technology introduction will be figured out.

Hypotheses 3. Enterprises' high technology absorptive capacity will positively affect public technology commercialization success.

Hypotheses 3-1. Enterprises' high potential absorptive capacity will positively affect commercialization success.

Hypotheses 3-2. Enterprises' high realized absorptive capacity will positively affect commercialization success.

2.3 Technology Transfer Intermediary

In compliance with the transaction cost theory (Williamson, 1979), which argues that market activities evolve toward cost saving, technology transfer organizations that conduct business activities through the reduction of transaction costs existing in the market appeared. These organizations have been naturally settling as an axis of the technology transfer market through the role of reducing the cost to obtain reliable information in the complicated technological innovation system and finding appropriate enterprises

to link necessary technologies to them.

In the case of Korea, a 'technology transfer intermediary' designation system was made under the former Technology Transfer and Commercialization Promotion Act established in 2000 and has been operated so that the government has been designating technology transfer intermediaries firsthand, based on work contents such as grasping those technologies that are to be transferred or commercialized, technology demand surveys, analysis, and evaluation, information establishment/management/distribution, construction of related information networks, and technology transfer mediation/conciliation. Thus far, 61 institutions (as of the end of 2012) have been designated and are currently active. These institutions can be divided into 38 private institutions and 23 public institutions (regional technopark, etc.). The government organized cooperation networks among technology transfer intermediaries to strengthen their capacity in order to promote technology transactions thereby implementing projects to support region based technology enterprises' growth (Technology Transfer Promotion Network Projects).

Studies conducted on these intermediaries include those that presented core functions divided into information retrieval, knowledge processing, mediated negotiation, and approval standardization (Howells, 2006), those that proved that among the forms of intermediaries, patent firms have positive effects of making environments in which researchers can be immersed in research and development by reducing transaction costs (Lamoreaux, 2002), and those that indicated that venture capitals are creating outcomes by expanding the scope of their works from those of simple investors to those of the functions of intermediaries such as participating in technology and management support (Kirk & Pollard, 2002). Other studies verified the effect of the composition of technology transfer consortiums among intermediaries (Park, 2007).

In this study, whether those intermediaries that are playing the role of activating technology transfer markets by reducing transaction costs actually have positive effects on public technology transfer's actual commercialization success will be verified.

Hypotheses 4. Public technology transfer made through technology transfer intermediaries positively affect commercialization success.

2.4 Cooperative Partnership

R&D cooperation refers to the formation of special relationships between at least two parties surpassing the simple market transactions made for creation, acquisition, exchange, and utilization of technical knowledge (Hagedoorn et al., 1994), and enterprises' R&D cooperation refers to the formation of cooperative relationships between enterprises for joint research and development and technology transfer, etc. in order to consolidate their positions in the market. To create competitive advantages in the management environment where competition between enterprises is intensified, the speed of changes in technologies is increasing, and product life cycles are shortened due to globalization, enterprises are increasing not only their own efforts but also cooperation with external enterprises in order to effectively utilize external knowledge and technologies (Verspagen, 2004) and some studies indicated that differences in, performance between enterprises that were conducting R&D cooperation and those that did not conduct R&D cooperation increased gradually (Powell, 1996; Laursen & Salter, 2006). R&D cooperation is being made because of diverse motives such as R&D cost reduction, technological risk sharing, market entry acceleration, technical standard creation, and linkage to innovation processes (Dodgson, 1993). R&D cooperation can be divided based on the subject of cooperation into vertical cooperation such as product development outsourcing within demand and supply value chain and horizontal cooperation made by relationships with competitors, supplementing businesses, research institutes, and universities, etc. based on the subject of cooperation and into cooperation for the same resources that mainly pursues the economy of scale and cooperation for supplementary resources that pursues economies of scope based on the types of resources that are the subjects of cooperation (Ireland, 2002).

Some studies pointed out that measuring technology

cooperation success factors is very difficult work.(Hamel, 1991; Khanna, 1998). There are studies conducted on the relationship between the frequency of interactions between cooperating parties (Ledwith, 2005) and new product development performance and other studies conducted on the relationship between effective communication, adjustment, cooperative relationships with those who have technology sources and successful technology acquisition (Stock & Tatikonda, 2008). In particular, a study indicated that trust between cooperating institutions is a core factor that determines sucess (Lado, 2008) and there is a study case where the relationship between the concentrating power of cooperation, whether cooperated previously, technology similarity and enterprises' performance (Arbor, 2009).

Since the technologies developed by universities and research institutes which are the subject of this study are relatively low in the degree of completion and are not for certain enterprises but are for public interests, continuous cooperative activities for overcoming large gaps between enterprises and suppliers will be addressed as an important factor. Some studies indicated that if research organizations such as enterprises and research institutes have experience of past cooperation, results would be better not only in the frame of the relationships between enterprises (Levinthal & Fichman, 1988; Hakanson, 1993) but also in the cooperative relationships between enterprises and public research institutes (Cyert & Goodman, 1997; Davenport., 1999a). In particular, from the viewpoint of enterprises, cooperation activities with universities or research institutes are regarded as acting as a very important actor in overcoming cultural heterogeneity and establishing trust because universities will become to well understand the characteristics of enterprises (Jeong, 2008) and positively affecting enterprises' commercial performance. (Oh, 2006). That is, enterprises' and universities' experience of cooperation will enable relatively reducing necessary costs incurred in the process of transfer by enhancing mutual understanding of each other's organization characteristics.

Hypotheses 5. Partnerships between enterprises and public research institutions and universities have positive regulation effects on public technology commercialization success.

3. Study Method

3.1 Data

3.1.1 Survey Subjects

Questionnaire surveys were conducted about the present state of commercialization of 5,411 technologies transferred from a total of 29 public research institutes comprising 16 universities and 13 research institutes that had participated in the 'leading TLO[4)] support project (Connect Korea support project)' jointly planned by the former Ministry of Knowledge Economy and the former Ministry of Education, Science and Technology from 2006 through 2010 to enterprises. Since the TLO support project was implemented with selected public institutions with relatively excellent technology commercialization capacity and performance with a view to strengthening the TLO organization's capacity, the implementing institutions can be said to be major institutions that can represent Korean PRI & Us from the viewpoint of technology transfer. Among a total of 1,589 questionnaires collected from enterprises that received technologies from the foregoing institutes, 1,087 questionnaires with faithful responses to survey items from enterprises of which the financial information could be secured were finally analyzed.

3.1.2 Survey Item

Whether the enterprises that received technologies from PRI & Us succeeded in commercialization was surveyed to divide the levels of success into three (success,

4) Technology Licensing Office (TLO): Pursuant to article 11 (Public research institutes' organization dedicated to technology transfer) of the Technology Transfer and Commercialization Promotion Act, public research institutes in Korea should install an organization dedicated to technology transfer mandatorily.

in progress, postponed/failed) and technology transfer related items divided into three categories; technology supplier, technology demander, and transferred technologies, as shown in Table 1, were surveyed.

3.1.3 Survey Result

The present state of enterprises that received public technologies by scale based on the number of employees and research and their development costs concentration levels (research and development costs/ total sales) at the time when the technologies were introduced are as shown in Table 2 set forth below. Whereas the large enterprise group accounted for 146 cases (13.9%), the small and medium enterprise group accounted for most of technology transfer cases at 941 (86.1%). In particular, small and medium enterprises with the number of employees in a range of 10-299 accounted for 764 cases (70.3%) indicating that most technologies were transferred to small and medium enterprises. In the case of R&D intensity that indicate the ratios of R&D investment amount to enterprises' sales, where as the 2011 average of Korean enterprises was 2.56%, and the average of enterprises high ranked in sales was 4.04% (KISTEP, 2012), among enterprises that received public technologies, 670 ones or 61.6% showed 5% or higher R&D intensity which are relatively very high (20.6% on average). Whereas 20.5% of enterprises in the large enterprise group showed 5% or higher R&D intensity, 68% of

Table 1 Major questionnaire survey items

Category	Item	Content
Technology supplier	• Licensing revenue (A)	• Licensing revenues received from 2006 through 2010
	• Input research and development costs (B)	• R&D investment from 2006 through 2010
	• Research fund productivity (A/B)	• Ratio of technology licensing revenues to input research funds
	• Degree of ex post facto support	• Whether the developer taught the technologies and supported the development of additional technologies
Transferred technologies	• Technology area	• Korea Standard Industry Classification System (medium classification)
	• Technology Readiness Level (TRL)	• Technology readiness level based level 1(basic)- level 9 (commercialization)
Technology demander	• Present state of implementation of commercialization	• Three levels; success, in progress, postponed/failed
	• Technology introduction channel	• Researcher, organizations dedicated to technology transfer, private intermediary, online market
	• Major business type area	• Korea Standard Industry Classification System (medium classification)
	• Number of employees	• Number of regular employees as of the end of 2011
	• Motive of introduction of technologies	• Advancement into new business, new product development, new process improvement, IP response
	• Number of times of public technology introduction	• The number of times of contract execution with public institutions before the technology introduction
	• Distance from the supplier	• The same/adjacent region, distant region

Table 2 Present state of research fund concentration ratios by scale of enterprises that introduced technologies

enterprise scale \ R&D intensity		-1%	1-5%	5-10%	10-50%	50%-	total
Large enterprises (1,000-)	Frequency	32	52	10	5	0	99
	%	32.3%	52.5%	10.1%	5.1%	0.0%	100.0%
Medium large enterprises (300-999)	Frequency	14	18	7	8	0	47
	%	29.8%	38.3%	14.9%	17.0%	0.0%	100.0%
Medium enterprises (50-299)	Frequency	51	122	95	83	10	361
	%	14.1%	33.8%	26.3%	23.0%	2.8%	100.0%
Small enterprises (10-49)	Frequency	28	71	73	181	50	403
	%	6.9%	17.6%	18.1%	44.9%	12.4%	100.0%
Micro enterprise (-10)	Frequency	7	22	26	83	39	177
	%	4.0%	12.4%	14.7%	46.9%	22.0%	100.0%
Total	Frequency	132	285	211	360	99	1,087
	%	12.14%	26.22%	19.41%	33.12%	9.11%	100.0%

enterprises in the small and medium enterprise group showed 5% or higher R&D intensity thereby showing a tendency for research fund concentration ratios to grow as enterprise scales decrease. Therefore, it can be seen that mainly enterprises with high R&D intensity received public technologies.

The average R&D productivity (the ratio of total technology licensing revenues to input research funds) of the 29 public research institutes for five years was identified to be 1.8% in the survey results. This shows higher performance than the average from entire Korean PRI & Us at 1.32% (KIAT, 2012). Research institutes showed higher R&D productivity levels compared to universities in general. This seems to be attributable to differences in focus areas by technology development stage between universities focusing on basic research and research institutes focusing on applied research. The productivity is below that of the universities, research institutes at 4.06% in the USA in particular among major advanced countries. In the case of individual institutes, whereas the value shown by the research institute (ETRI) with the highest R&D productivity was 7.2%, the average value of productivity of ten highest ranked institutes was 20.9% (AUTM, 2011). Therefore, the fact that Korea PRI&Us should make continuous effort to improve technology transfer performance could be identified.

The results of survey of whether enterprises' public technology commercialization was successful are as shown in Table 4 set forth below. Here, commercialization success refers to the results of qualitative responses to questions asking whether the initial purpose has been achieved such as cases where introduced technologies were utilized to launch products thereby contributing to sales increases if the purpose of introduction was product development and cases where introduced technologies were utilized to reduce costs and shorten working time to achieve the initial purpose if the purpose of introduction was process improvement. The commercialization success rate of the entire public technologies transferred was 15.1% which was relatively higher compared to general enterprises' commercialization success rate at 6.8% (Park et al., 2011). The state 'in progress' in which success or failure is not yet certain accounts for 35.0% of the entire cases. The reason for this seems to be the fact that time to market entries or failure is long because public technologies' readiness levels are low.

Table 3 Present state of public research institutes'(29) research fund productivity

Category \ R&D productivity		~-1%	1-3%	3-5%	5%-	Total
Universities	Frequency	9	7			16
	%	56.3%	43.7%			100.0%
Research institute	Frequency	1	7	4	1	13
	%	7.7%	53.8%	30.8%	7.7%	100.0%
Total	Frequency	10	14	4	1	29
	%	34.5%	48.3%	13.8%	3.4%	100.0%

3.2 Research Model and Definition of Variables

3.2.1 Research Model

A research model prepared to verify the research hypotheses presented earlier based on previous studies is as shown in Figure 2. Whereas many studies conducted thus far have been limited to technological innovation activities of individual parties, this study included all suppliers and demanders in the scope of analysis to examine the entire cycles of public technology transfer and commercialization, ranging from public technology development to market entry through transfer to enterprises to pursue differentiation and tried to draw persuasive results by analyzing data on all representative institutes in Korea. Variables were divided into categories of transferred technology commercialization related parties, that is, suppliers, introducers, and intermediaries. The effects of the capacity of individual elements on technology commercialization success were utilized as independent variables and partnership, which corresponds to a relational factor between the parties, was utilized as

Table 4 Present state of commercialization of transferred technologies

Category	success	in progress	Postponed/failure	Total
Number of cases	164	380	543	1,087
Ratio(%)	15.1	35.0	49.9	100

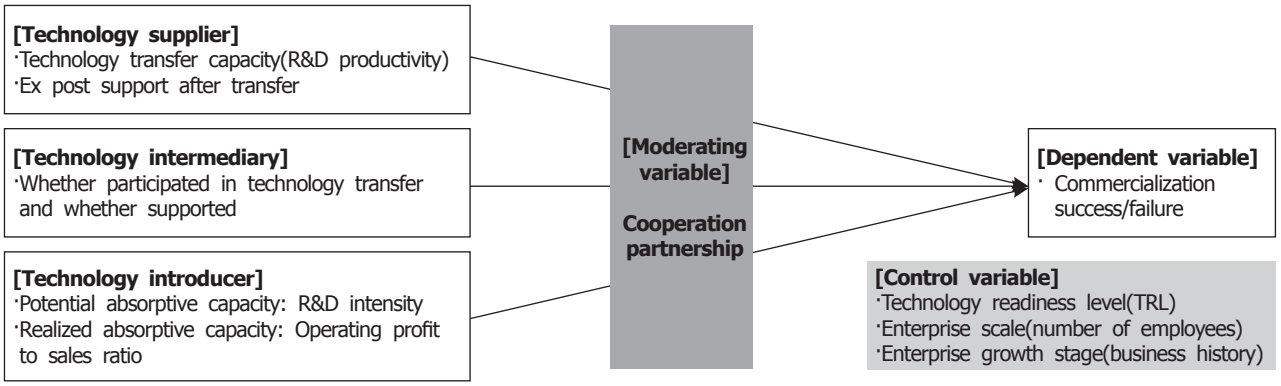

Figure 2 Analysis model

a moderating variable to analyze moderating effects between the capacity of the parties, in particular, the capacity of enterprises and partnership.

3.2.2 Definition of Variables

To test the effects of commercialization party variables that are to be examined in this study, technology readiness levels, enterprise scales, and enterprise growth stages were controlled in the research model. Conflicting study results have been presented for enterprise scales for long. That is, there are arguments indicating that the larger enterprise scales are, the more actively technological innovation occurs because abundant resources are held such as research manpower and research and development funds along with the acquisition, management, and utilization of external technology information (Cooper, 1964; Graves & Langowitg, 1993; Simonin, 1997; Becherer et al., 1999) and arguments contrary to the foregoing indicating that more active innovation occurs in smaller enterprises because smaller enterprises can obtain many things through active technology cooperation with external parties since smaller enterprises have limited resources and access to markets (Horowitz et al., 1981; Rothwell et al., 1994; Huizin, 2011). Technology readiness levels were controlled because their effects on transferred technologies' commercialization were considered very large since even public technologies may be diverse in technology readiness levels.

With regard to technology suppliers' technology transfer capacity, the results of studies that utilized diverse variables such as internal factors, environmental factors, and relational factors were presented in section 1. Since the scope of analysis was limited to PRI & Us, previous studies utilized papers and patents (Di Gregorio, 2003; Santoro, 2002), the number of cases of technology transfer and the amount of technology licensing revenue (Markman, 2005; Powers, 2003), or the number of cases of business founding (Lockett & Wright, 2005) as dependent variables. However, in the case of this study, since the scope of analysis includes transferred technologies' commercialization success, various factors identified through studies conducted thus far were integrated to select R&D productivity that means the ratio of earned technology licensing revenue to input research funds as an indicator that can represent PRI & Us' technology transfer capacity; provided that, to reduce the variability of annual technology licensing revenues resulting from large technology transfer cases occurring irregularly, data accumulated for three years were utilized. In addition, attempts were made to grasp the effects of whether or not researchers provide ex post facto support as supplying institutions' transfer capacity such as active technology guidance after the execution of contracts so that technologies can be actually transferred to enterprises instead of just making technology transfer contracts on commercialization performance.

Enterprises' technology absorptive capacities were divided into potential absorptive capacity and realized absorptive capacity (Jansen, 2005). Since enterprises'

R&D investments are one of essential components for improving the ability to understand, assimilate, and internalize external knowledge (Zhao, 2005), R&D intensity (the ratio of the amount of R&D investments to sales) were regarded as a variable that represents potential absorptive capacity. Since realized absorptive capacity refers to commercial applications of acquired external knowledge (Lane & Lubatkin, 1998), the operating profit to sales ratios obtained through enterprises' own activities were regarded as a variable that represents realized absorptive capacity. Whether intermediaries participate in the process of technology transfer to perform supporting works such as finding out technologies and demanding enterprises, marketing, negotiations, and contracts was utilized as a dummy variable to figure out the effect of intermediary participation on commercialization success. In the case of partnership between cooperating institutions (Lado, 2008) as a variable that moderates effects on the performance of technology transfer between suppliers and demanders, the result of checking of whether the enterprise had experience of technology transfer with the relevant PRI & Us in the past was utilized as a dummy variable.

Finally, determining whether commercialization was successful or not was already pointed out as a very difficult study although diverse forms of measuring methods were utilized (Hamel, 1991; Khanna, 1998, Laursen, 2006). Commercialization success might be measured utilizing financial indicators such as sales, growth rates, and profitability in some cases (Lumpkin & Dess, 1996; Bantel, 1998) and be qualitatively measured using the number of new products launched and commercialization speed (Zahra & Nielsen, 2002; Ledwith & Coughlan, 2005). In this study, commercialization success was simplified and measured utilizing the results of intuitive responses of respondents to questionnaires asking whether original purposes of technology introduction have been achieved such as sales, cost saving, and technological power internalization. The definition and details of the aforementioned variables are as shown in Table 5 set forth below.

3.2.3 Analysis Method

In the case of the analysis model to be used for estimation in this study, applying general standard linear models is not desirable. Since the dependent variables use dichotomous nominal scales composed of 'success(1)', 'failure(0)', the assumption of normality is not satisfied. Therefore, if standard linear models

Table 5 Operational definition of the variable and evaluation indexes

Variable name		Operational variable	Proxy variable
Control variable	Technology readiness level	technology Readiness Level: level 1(experiment)-level 9 (commercialization)	ordinal scale (1-9)
	Enterprise scale	natural logarithm of the number of employees	ratio scale
	Business history	natural logarithm of year of survey (2012) -year of establishment value	ratio scale
Independent variable	Technology transfer capacity	three-year (`09-`11) average research fund productivity (%) = technology licensing revenue/research and development costs	ratio scale
	Supplier ex post facto support	whether supplying institute provided ex post facto support after technology transfer	yes(1), no(0)
	Potential absorptive capacity	R&D investment concentration ratio (%) in the previous of technology introduction = R&D investment amount/sales	ratio scale
	Realized absorptive capacity	operating profit to sales ratio (%) in the previous of technology introduction = operating profit/sales	ratio scale
	Intermediary support	whether intermediaries intervened in technology transfer processes	yes(1), no(0)
Moderating variable	Cooperation partnership	experience of introducing technologies from the relevant public institute before the technology introduction	yes(1), no(0)
Dependent variable	Commercialization success	whether original purposes were achieved such as sales increase and cost saving	success(1), failure(0)

are applied, estimating parameters will be difficult due to inappropriate model setting. Therefore, binomial logistic regression models to fit data to logit curves between 0 and 1 in order to estimate event occurrence were used to conduct analyses.

4. Analysis Result

4.1 Basic Statistics and Correlation Analysis

A total of 686 responses that comprise 'commercializa -tion success' and 'commercialization postponed/failed' excluding 380 cases of 'commercialization in progress' and cases with omissions of responses for some items out of the 1,087 responses in the entire questionnaire survey were finally analyzed. To review basic statistics of the variables, in the case of technology readiness levels, the average is 4.2 which corresponds to the stage of experiments according to technology development stages (baseline→experiment→prototype f abrication→manufacturing→commercialization). This seems to be the level of technologies introduced from PRI & Us recognized from the viewpoint of enterprises. The average value of experience of introduction was 0.44 indicating a little fewer than a half of the enterprises have experience of receiving technologies from PRI & Us in the past. The value of intermediary intervention was below 10% indicating that most technology transfers were made through direct transactions between suppliers and demanders. Therefore, the fact that the roles of intermediaries in the market were insignificant.

Before regression analysis, the Pearson correlation analysis was conducted first to figure out independent variables', control variables', and moderating variables' basic statistics and multicollinearity. The results as shown in Table 6 set forth below were obtained and since the correlations between the variables were not high in general, it was assumed that no multicollinearity existed between independent variables.

4.2 Regression Analysis Result

According to Table 7, Model 1 includes control variables and independent variables, Model 2 verified main effects of moderating variables, and Model 3 verified moderating effects between enterprises' absorptive capacity and moderating variables. With regard of the goodness-of-fit of entire models, the Chi-Square values that show model explanatory power increased toward Model 3 at significance levels below 0.01 and -2logL(deviance) decreased thereby showing increases in the goodness-of-fit of models in general.

According to Model 1 in Table 7, as research institutes' R&D productivity increased, enterprises' commercialization success rates statistically

Table 6 Basic statistics and analysis of correlations between variables

	Mean	S.D	1	2	3	4	5	6	7	8	9
1. Number of employees(person)	1,504.34	8,887.22	1								
2. Business history (year)	16.69	13.07	0.405***	1							
3. Technology readiness level(TRL)	4.20	1.84	0.019	0.078**	1						
4. Technology transfer capacity	3.67	2.62	-0.048	-0.169***	0.004	1					
5. Potential absorptive capacity	20.57	53.05	-0.053	-0.184***	-0.031	0.044	1				
6. Realized absorptive capacity	-3.78	67.89	0.021	0.068**	0.029	0.012	-0.678***	1			
8. Supplier ex post facto support	0.46	0.50	-0.092***	-0.112***	-0.016	0.099***	0.031	-0.018	1		
9. Intermediary support	0.09	0.29	-0.051	-0.055	-0.106***	0.112***	0.010	-0.001	0.232***	1	
7. Cooperation partnership	0.44	0.49	0.064**	0.104***	0.115***	0.121***	-0.056	0.071*	-0.040	-0.012	1

*** significant at 1%; ** significant at 5%* significant at 10%,

Table 7 Results of logistic regression analysis

Variable	Model 1	Model 2	Model 3
Control variable			
Number of employees(log)	-0.225(.076)***	-0.233(0.077)***	-0.215(0.077)***
Business history(log)	0.222(.220)	0.194(0.221)	0.217(0.223)
Readiness level	0.380(.058)***	0.374(0.058)***	0.382(0.058)***
Independent variable			
technology transfer capacity	-0.177(0.041)***	-0.182(0.041)*	-0.178(0.041)***
potential absorptive capacity	0.004(0.002)*	.004(.002)*	0.003(0.002)
realized absorptive capacity	0.001(0.002)	0.000(.002)	0.001(0.002)
supplier ex post facto support	0.611(0.203)***	0.681(0.204)***	0.566(0.206)***
intermediary support	-1.088(0.425)**	-1.078(0.426)**	-1.088(0.431)**
Moderating variables' main effect			
cooperation partnership		0.410(0.205)**	0.144(0.253)
Moderating variables' moderating effect			
potential absorptive capacity×cooperation partnership			0.012(0.007)*
realized absorptive capacity×cooperation partnership			-0.003(0.008)
N	684	684	684
-2logL	633.346	629.348	623.731
Nagelkerke R2	0.217	0.225	0.235
Chi-squared	106.024	110.022***	115.639***
Correct classification %	80.2	79.8	80.1

*** significant at 1%; ** significant at 5%; * significant at 10%. Standard errors are in parentheses.

significantly decreased. That is, despite that PRI & Us were earning relatively large amounts of technology licensing fees from enterprises through the establishment of effective technology transfer processes and active support activities of TLOs, etc,, the situation had negative effects on enterprises' commercialization success. Therefore, the initial Hypotheses 1 was dismissed. However, the effects of researchers additional effort after technology transfer such as ex post facto support for complete teaching of technologies on enterprises' commercialization success were shown to be statistically significant in Model 1. Therefore, Hypotheses 2 was adopted.

Enterprises' technology-absorptive capacity showed statistically different results. In Model 1, whereas potential absorptive capacity (R&D intensity) and enterprises' performance showed statistically weak positive (+) correlations, realized absorptive capacity(operating profit to sales ratio) did not showed significant correlations with enterprises' performance. Therefore, Hypotheses 3-1 was supported and Hypotheses 3-2 was dismissed. That is, it was proved that public technologies introduced brought about effective performance to enterprises that prepared technologies rather than contributing to enterprises' performance in a short time.

In cases where technologies were transferred through the intervention of diverse commercialization intermediary organizations such as technology transfer intermediaries, negative effects on enterprises' commercialization success were identified. (Model 1) Therefore, Hypotheses 4 was dismissed.

The main effect of experience of introduction of technologies from PRI & Us in the past on enterprises' commercialization success was identified to be significant through Model 2. Moderating effects between enterprises' commercialization success and enterprises' potential absorptive capacity (R&D intensity) were significant in Model 3 but moderating effects between enterprises' commercialization success and realized absorptive capacity(operating profit to sales ratio) were identified not statistically significant. Therefore, in the case of Hypotheses 5, only the main effect and moderating effects with potential absorptive

capacity could be adopted.

5. Conclusion

In this study, the determinants of technology commercialization that were transferred from PRI & Us were examined. This study can be said to be different from previous studies and meaningful in that, while many previous studies have been conducted by analyzing data on PRI & Us from the viewpoint of technology transfer performance, this study expanded the subjects of analysis to include enterprises that introduced public technologies and analyzed whether the transferred technologies were actually made into products and successfully commercialized utilizing factors such as suppliers' technology transfer capacity, enterprises' absorptive capacity, mutual cooperation partnership, and transfer intermediaries' intervention effects.

Unlike initial expectations, even when universities' and research institutes' technology transfer capacities (=R&D productivity) were high, transferred technologies' commercialization success was not affected at all. That is, although PRI & Us' licensing revenues were increasing through efforts for effective technology transfer system such as establishing organized processes and increasing manpower in TLO, enterprises' actual commercialization success was not promoted. This results should be reviewed in terms of the technology licensing contract system and practice in government R&D projects in Korea. That is, because technology licensing contract have been institutionalized to be called at specified fixed ratios of the amounts of the government's R&D investments, in the case of technology transfer of the government R&D project outcomes, licensing contracts are made based on the sizes of input funds regardless of transferred technologies' commercialization performance. On reviewing the contents of a survey of the form of technology licensing contract of PRI & Us in 2012, it can be seen that revenues earned as running royalty based contracts are only 9.5% of the entire technology licensing revenues (Korea Institute for Advancement of Technology, 2012 technology transfer commercialization survey analysis data). However, the fixed amount technology licensing contract regulations were amended in 2012 to specify that licensing contracts for the results of joint research with universities or research institutes should be collected according to autonomous contracts with enterprises. Therefore, future changes in progress should be examined. .

However, enterprises that introduce public technologies also want to determine technology licensing fee amounts in advance (=fixed amount licensing fee), rather than dividing profits that may occur in future through current technology licensing contracts in many cases because they do not want future uncertain profit dividends. In particular, larger enterprises show this tendency more clearly. Although this is to be autonomously selected in terms of enterprises' technology introduction strategies, given the low technology commercialization stages despite that the ripple effects of technologies developed by PRI & Us are large, the fact that the effects of researchers' continuous help on commercialization success are very large should be considered. As shown in the results of analysis, the fact that researchers' ex post facto support after technology transfer significantly affect enterprises' commercialization success was verified. That is, technologies are different from products. Due to their implicit nature, for technology transfer to be actually complete, the participation of original technology developers in technology transfer processes is very important. In particular, changes in paradigms are in progress in relation to the responsibility of PRI & Us' researchers who make public goods and deliver the goods to markets. Along with basic research and applied research, active technology transfer and diffusion is socially required. Although many studies and evaluations have been conducted as the importance of PRI & Us' technology transfer was magnified as a result, the scope of technology transfer should be reviewed again now. That is institutional devices should be prepared at the national level so that the scope of technology transfer is expanded from simple technology transfer contracts to effective implementation of commercialization of the technologies through actual transfer of the technologies

to relevant enterprises after the contracts to ensure that government's R&D funds input into PRI & Us are connected to actual commercialization performance.

When technology transfer intermediaries participated in technology transfer processes through finding technologies to be transferred and institutes that possess the technologies, technology marketing, and negotiation and contract support activities, negative effects on enterprises' commercialization success were identified through the survey. These organizations began to appear when technology transfer organizations and technologies evaluation organization designation systems were promoted in 2000 through the establishment of the Technology Transfer and Commercialization Promotion Act, and have been making effort to become as parties for technology transfer market by expanding their capacity utilizing some support programs. Causes that can explain the commercialization failure after these intermediaries intervention in transfer processes despite the foregoing may include some environmental factors but more fundamental one is considered to be the intermediaries' poor capacity. That is, small private intermediaries with fewer than 10 employees account for 74.1% of all private intermediaries, new organizations that began mediating work in 2005 or thereafter account for the majority of private intermediaries (Park, 2011), and technology transfer related works performed by them were identified to account for less than 20% of all works performed by them. Based on the results of the 2012 survey of private technology transfer institutions (KIAT) their revenues through technology transfer were only KRW 7 million on average and large part of their sales was directly/indirectly connected to government R&D funds. Eventually, the foregoing showed that the transaction market was not activated through enterprises' voluntary demand for technology transfer and that government-led artificial market support has continued.

Along with enterprises' absorptive capacity, mutual partnership and commercialization success were analyzed and according to the results, potential absorptive capacity (=R&D intensity) and partnership positively affected commercialization success. Since the technologies developed by PRI & Us were not made for certain enterprises (Podolny, 2001). Since they have the nature of public goods, they have been developed for public interests targeting many and unspecified entities. Since the readiness level of developed technologies is relatively lower compared to the R&D outcomes of enterprises that pursue commercialization firsthand, relatively more effort and time are required for introducing enterprises to properly internalize and utilized. Eventually, despite that public technologies have technical excellence, because of their low readiness level and the characteristics that they are universal, enterprises' R&D absorptive capacity is very important for enterprises' commercialization success. Furthermore, since the construction of partnership between enterprises and PRI & Us was identified to be an important factor that would lead to the securing of excellent technologies and even to commercialization success, from the viewpoint of enterprises, rather than utilizing PRI & Us single-shot as R&D partners, effort to exchange knowledge through the formation of continuous relationships is considered necessary.

Based on the above-written analysis results, these authors would like to present several policy proposals for improvement of public technology transfer and commercialization success. First, the technology licensing system should be improved so that PRI & Us' technology transfer performance can be interlocked with enterprises' commercialization success. In fact, researchers' cannot guarantee enterprises' commercialization success. However, in the case of licensing fees received by PRI & Us through technology transfer, collecting them based on the act of transfer itself should be reviewed again. Eventually, institutional devices are necessary that can induce increases in the ratio of running-royalty fee collection instead of fixed amount licensing fees occurring at the moment of technology transfer. In addition, transfer processes should be improved so that the scope of technology transfer can be expanded to include technology teaching and technology transfer contracts can be concluded through written technology transfer confirmation when the enterprise has finally

learned the technology. By supporting even digestion and absorption by enterprises instead of simply transferring technologies though such expansion of current technology fees and the scope of the concept of technology transfer, not only the rate of commercialization success of transferred technologies can be enhanced but also the ecosystem of technology transfer and commercialization with virtuous circles can be constructed since incentives will be given to researchers through the foregoing.

The next issue is regarding the dispersed capacities of diverse technology transfer intermediaries. To date, more than 10 years has passed after the beginning of the government's active transferred technology commercialization fostering policies. The situation where technology transactions cannot spontaneously grow in the market in spite of the long period of time should be recognized and the government's effort to continuously expand and develop the market with government intervention should be reviewed again. The effort to expand infrastructures for technology transfer commercialization through increased investments in the areas supported by the government for market activation such as the provision of infrastructures having the attributes of public goods, that is, systematic collection, processing, and provision of national R&D information, the standardization of forms necessary for various transactions such as contracts and marketing, the preparation of stages for periodic networking to expand partnership between transfer/commercialization parties, and the expansion of technology management related education programs. However, the reduction or abolition of various attempts of the government to first compose transaction markets, that is, various certification systems for technology transaction institutions, technology evaluation institutions, technology transfer experts, dedicated commercialization companies, etc. and programs that directly support commercialization parties to activate their operations should be positively reviewed.

Several limitations of this study are as follows. It is true that the characteristics of transferred technology commercialization are very complicated. Therefore, the depth of variables is required along with the expansion of diverse variables because explaining phenomena through several variables. In terms of the expansion of variables, factors for public technology commercialization success may vary with exogeneous variables in industrial environments, that is, diverse characteristics of industries. In addition, the fact that the depth of variable was not fragmented further for measurement is regretful. That is, if the depth of variables such as the strength of partnership, the intensity of commercialization success, and the intensity of researchers' ex post facto support were fragmented further for the approach, more diverse results might have been drawn.

Nevertheless, this study can be considered meaningful in that it widely analyzed data on 1,087 cases of technology transfers from PRI & Us over the last 5 years in order to expand the scope of previous studies limited to PRI & Us' technology transfer and analyze actually how public technologies are actually connected to enterprises' commercialization success and what the affects on commercialization success are. Despite some limitations of the study, these authors hope that public technology commercialization in Korea will be activated further through the enhancement of technology transfer commercialization parties' mind regarding transferred technology commercialization and effort to construct mutual partnership along with the government's policy improvement through the results of this study.

References

AUTM (2012). AUTM Licensing Survey 2010.

Audretsch, D. B., Erik E. L., & Susanne, W. (2005). University spillovers and new firm location. Research Policy, 34(7), 1113-1122.

Ahuja, G., Polidoro, F., & Mitchell, W. (2009). Structural homophily or social symmetry? The formation of allies by poorly embedded firms. Strategic Management Journal 958, 941-958.

Barney, J. (1991). Firm resources and sustained competitive advantage ed. Anonymous. Journal of Management, 17(1), 99-120.

Cho, Hyeon-Jeong (2012). A study on universities' technology commercialization performance influence factors seen from the

viewpoint of resource bases [In Korean]. Intellectual Property Study, 7(3), 217-245.

Cohen, W. M., and Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly, 35(1), 128-52.

Dodgson, M. (1993). Learning, trust, and technological collaboration. Human Relations 46(1), 77-95.

Foltz, J., Barham, B., & Kim, K. (2000). Universities and agricultural biotechnology patent production. Agribusiness, 16(1), 82-95

Freel, M. S. (2003). Sectoral patterns of small firm innovation, networking and proximity. Research Policy, 32(5), 751-770.

Friedma, J., & Silberman, J. (2003). University technology transfer: Do incentives, management, and location matter? The Journal of Technology Transfer 28(1), 17-30.

Di Gregorio, D., & Shane, S. (2003). Why do some universities generate more start-ups than others?. Research Policy, 32(2), 209-227.

Greiner, M. A., & Franza, R. M. (2003). Barriers and bridges for successful environmental technology transfer. The Journal of Technology Transfer, 28, 167-177.

Gulati, R. (1998). Alliances and networks. Strategic Management Journal, 19(4), 293-317.

Hagedoorn, J. (1993). Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences. Strategic Management Journal, 14(5), 371-385.

Hagedoorn, J., & Schakenraad. J. (1994). The effect of strategic technology alliances on company performance. Strategic Management Journal, 15(4), 291-309.

Thomas, H. (2007). The role of patents for bridging the science to market gap. Journal of Economic Behavior & Organization, 63(4), 624-647.

Hoppe, H. C., & Ozdenoren, E. (2005). Intermediation in innovation. International Journal of Industrial Organization, 23(5-6), 483-503.

Howells, J. (2006). Intermediation and the role of intermediaries in innovation. Research Policy, 35(5), 715-728.

Ireland, R. D., Hitt, M. A., & Vaidyanath, D. (2002). Alliance management as a source of competitive advantage. Journal of Management, 28(3), 413-446.

Jansen, J. J. P., Van Den Bosch, F. A. J., & Volberda, H. W. (2005). Managing potential and realized absorptive capacity: How do organizational antecedents matter?. Academy of Management Journal, 48(6), 999-1015.

Kim, Byeong-Geun, Cho, Hyeon-Jeong, & Ok, Ju-Yeong (2011). Analysis of the process and performance of public research institutes' technology commercialization using a structural equating model [In Korean]. Journal of Technology Innovation, 14(3), 552-577.

Kim, Linsu (1998). Crisis Construction and Organizational Learning: Capability Building in Catching-up at Hyundai Motor. Organization Science, 9(4), 506-21.

Korea Institute for Advancement of Technology (KIAT) (2012). 2012 Technology transfer·commercialization survey analysis data book [In Korean].

Lado, A. A., Dant, R. R., & Tekleab, A. G. (2008). Trust-opportunism paradox, relationalism, and performance in interfirm relationships: Evidence from the retail industry. Strategic Management Journal, 29, 401-423.

Laursen, K., & Salter, A. (2006). Open for innovation: The role of openness in explaining innovation performance among U.K. manufacturing firms. Strategic Management Journal, 27(2), 131-150.

Lamoreaux, N. R., & Sokoloff, K. L. (2002). Intermediaries in the U.S. market for technology, 1870-1920. National Bureau of Economic Research Working Paper Series No. 9017.

Ledwith, A., & Coughlan, P. (2005). Splendid isolation: Does networking really increase new product success?. Creativity Innovation Management, 14(4), 366-373.

Lee, Seong-Sang, Kim, Ee-Gyeong, & Lee, Seong-Gi (2012). Analysis of changes in universities' and public research institutes' technology transfer efficiency and efficiency determinants [In Korean]. Intellectual Property Study, 7(3), 163-185.

Lockett, A., & Wright, M. (2005). Resources, capabilities, risk capital and the creation of university spin-out companies. Research Policy, 34(7), 1043-1057.

Malerba, F., & Orsenigol, L. (1996). The dynamics and evolution of industries. Industrial and Corporate Change, 5(1), 51-87.

Markman, G. D., Gianiodis, P. T., Phan, P. H., & Balkin, D. B. (2004). Entrepreneurship from the ivory tower: Do incentive systems matter?. The Journal of Technology Transfer, 29(3/4), 353-364.

National Science & Technology Council (2012). 2011 Research and development activity survey report [In Korean]. Seoul: NSTC.

Ok, Ju-Yeong, & Kim, Byeong-Geun (2009). Analysis of the technology transfer efficiency of domestic public research

institutes [In Korean]. Technological Innovation Study, 17(2), 131-158.

Oh, Jun-Byeong (2006). An empirical study on government supported joint research and development projects: Centering common core base technology development project [In Korean]. Industrial Organization Study, 14(3), 111-146.

Park, Jong-Bok (2011). A study on the effect of strategic environment suitability on technology intermediaries' performance [In Korean]. Industrial Economy Study, 275-302.

Park, Jong-Bok, & Ryu, Tae-Gyu (2007). A study on the effect and characteristics of technology transfer consortiums in the public research sector: Centering on public technology transfer consortium cases [In Korean]. Journal of Technology Innovation, 10(4), 284-309.

Pavitt, K. (1984). Sectoral patterns of technical change: Towards a taxonomy and a theory. Research Policy, 13(6), 343-373.

Podolny, J. M. (2001). Networks as the pipes and prisms of the market. American Journal of Sociology, 107(1), 33-60.

Powell, W. W., Koput, K. W., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. Administrative Science Quarterly, 41(1), 116-145.

Santoro, M. D., & Chakrabarti, A. K. (2002). Firm size and technology centrality in industry-university interactions. Research Policy, 31(7), 1163-1180.

Siegel, D. S., Waldman, D., & Link, A. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory study. Research Policy, 32, 27-48.

Stock, G. N., & Tatikonda, M. V. (2008). The joint influence of technology uncertainty and interorganizational interaction on external technology integration success. Journal of Operations Management, 26(1), 65-80.

Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. Strategic Management Journal 1350(August), 1319-50.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. Strategic Management Journal, 18(7), 509-533.

Thursby, J. G., & Kemp, K. (2002). Growth and productive efficiency of university intellectual property licensing. Research Policy, 31(1), 109-124.

Tyler, B. B. (2001). The complementarity of cooperative and technological competencies: A resource-based perspective. Journal of Engineering and Technology Management, 18(1), 1-27.

Van de Vrande, V., De Jong, J. P. J., Vanhaverbeke, W., & De Rochemont, M. (2009). Open innovation in SMEs: Trends, motives and management challenges. Technovation, 29(6-7), 423-37.

Verspagen, B., & Duysters, G. (2004). The small worlds of strategic technology alliances. Technovation, 24(7), 563-571.

Williamson, O. E. (1979). Transaction-cost economics: The governance of contractual relations. Journal of Law and Economics, 22(2), 233-261.

Zahra, S. A.., & Nielsen. A. P (2002). Sources of capabilities, integration and technology commercialization. Strategic Management Journal, 23(5), 377-398.

Zahra, S. A., & George, G. (2002). Absorptive Capacity: A review, reconceptualization, and extension. Academy of Management Review, 27(2), 185-203.