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An Exploratory Study on Factors Impacting the Public Technology Commercialization in Korean SMEs*

우리나라 중소기업의 공공기술 사업화 영향요인에 관한 연구

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ABSTRACT

This paper investigates the success and failure factors of technology commercialization for SMEs developing public sector technologies. The 2014 Korea Technology Transfer Commercialization Status Report states that only 30% of the technologies that are transferred are being used and the rest are neglected. The objective of this paper is to determine the relationship between quantitative variables and the success rate of technology commercialization of 1,222 SMEs in Korea by using three analyzes (cross tabulation, process and logistic) methodologies to increase the success of public technology commercialization.

The outcome shows that the number of successful technology deployment cases and the number of IPR registration cases have a positive impact on the success rate of public technology commercialization. The statistical outcome also verifies that unnecessary technology development, more attempts and

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failures of technology development, and longer lead time in the planning phase have a negative impact on the success rate of the public technology development and commercialization. For policy implications, the government should be selective in supporting public technology commercialization and development for SMEs as not all technology attempts exert positive effects.

Key Words : Public technology, Technology commercialization, SMEs, Success factors, Technology development success

"본 논문은 다른 학술지 또는 간행물에 게재되었거나 게재신청되지 않았음을 확인함."

I. Introduction

Many previous literatures have focused on technology transfers and commercialization in promoting innovations in countries like Korea and Taiwan. While many have taken an interest in the SMEs performance through R&D outcomes and outputs, such as the number of patents as well as the change in revenues, there is a growing attention to SMEs' technology transfer and commercialization capability. Technology transfer is defined as "*the movement of scientific knowledge from one party to another* (Morberg and Moon, 2000)." According to Mitchell & Singh (as cited by Carvalho, 2015), technology commercialization facilitates the market of technologies and is defined as the "*series of processes in which ideas are acquired and extended to knowledge for the development, manufacturing, and marketing of products*." In other words, technology commercialization is when the transferred technology is involved in making or selling of a product and provides financial return to the inventor (Morberg and Moon, 2000). In many cases, these two words are interchangeable.

Technology commercialization is the last stage of the product and technology development process to transform technology assets, such as patents, designs, and know-how into profits (Park & Ryu, 2015). However, Korean researchers in universities and public institutions tend to focus their R&D on performance based outputs, such as publications and patents over technology commercialization.

This paper examines the factors affecting the technology commercialization process, the overall performance of SMEs' technology innovation. The objective is to determine the factors and characteristics of success technology commercializing firms in the public technology sector using

data from 1,222 SMEs in Korea. The paper utilizes three analysis (cross tabulation, process and logistic) methodologies. In detail, this paper investigates the success and failure factors of technology commercialization for SMEs developing public technologies. This paper also presents literature reviews on the university-industry cooperation, and how good university-industry relationship impacts technology transfer. Also, unlike the prior researches, which focused on the qualitative aspects, this paper presents empirical results using quantitative data.

The rest of this paper is structured as follows. Section 2 looks into the literature review of technology transfer and commercialization and its previous studies. It examines what factors were identified to achieve successful commercialization. It also examines the importance of public technologies, and current status of its support to SMEs in Korea. Section 3 presents the research method. Section 4 presents the results of the logistic analysis, and Section 5 concludes the paper by presenting the outcomes, policy implications, limitations and future work.

Ⅱ. Importance of Technology Transfer/Commercialization

New product development (NPD) is a vital step in the innovation process, even more with the shift into open innovation and active sharing strategy. Many of these creations and innovative ideas are now "*documented*" and are patented, and many countries value these outputs as R&D performances. Many businesses and SMEs want to proceed into the last stage of the product development process, the technology commercialization, a process to transform knowledge into a service or a product. According to Lenagh (2012), technology commercialization "*requires a proactive approach that combines engaging researchers, promoting the technology, and encouraging potential industrial partners to use the technology.*"

The commercialization process is a linear process, where many business functions simultaneously overlap with each other. Commercialization happens after the design, development, and manufacturing of the product or service, and when businesses identify a way to use the technology or creative ideas to meet the market needs.

The technology commercialization purpose is different depending on the type of companies. Large companies and conglomerates rely on timing, rather than competency, while SMEs tend to

focus on the competency. Large companies transfer knowledge and technology only when they do not have the know-how or in need of a technology that they haven't developed. SMEs lack the finances to transfer-in technologies and know-how any time they want.

1. Past Researches and Literature on Technology Transfer/Commercialization

Technology commercialization studies have been of high interest since the 1990s. Nevens et al (1990) conduct a qualitative study on the difference of technology commercialization of leaders and laggards. There was a big difference in the ability to commercialize technologies, and there were some characteristics that successful technology commercialization companies have. Using Hewlett-Packard (HP) as a case study, the study found that 1) leading companies commercialized two to three times the number of new products and processes than competing firms; 2) incorporated two times as many technologies in their products; 3) time to market was almost half; and 4) had wider competition/market. They also found that firms that are good in commercialization have similar processes. Companies need to set clear and actionable objectives, and break their functional barriers.

It is important to understand that technology commercialization doesn't only relate to transfer of intellectual property (IP), copyright, and patents. There are four levels of technology transfer. Level 1 is related to "*black box technology transfer*" or when intellectual property is transferred. Level 2 is the "*know-how transfer*" or when knowledge, know-how and technology decisions are transferred. Level 3 is the "*employee transfer*" or level 2 with one or more employee in the development team are transferred. Level 4 is the "*team transfer*" or the entire development team is transferred. Narasimhalu (2006) conducts a case study on an information security group (ISG) and their technology commercialization activity of 10 companies. Test clustering and internet related technologies are level 1 commercialization; SGML/DMBS, federated database systems, bioinformatics technologies, and mobile IP technologies are level 2; face synthesis technologies, and 4PC environment migration technologies are level 3; and volume interaction – 3D graphical user interface and image recognition technologies are level 4.

Amadi-Echndu & Rasetlola describe two technology commercialization model frameworks using three firm-level case studies. First is the linear model that follows a sequential and chronological process, and the second is the functional model that shows the continuous linkages of networked

agents and stakeholders. The three case studies are integrated gasification combined cycle (IGCC) technology applied in coal-based electricity power generation; lithium battery technologies; and diesel particulate filter (DPF) technologies. Using a Delphi questionnaire, the paper collected data on influencing factors in the order of priority: 1) commercialization environment issues, 2) intellectual property issues, 3) technology management issues, 4) marketing strategy issues, 5) innovation development issues, and 6) financial issues.

In the context of Korea, Park & Ryu (2011) classify different funds and activities in the business life cycle. Under development phase and technology acquisition, some key activities are feasibility assessment and basic/original technology R&D. The technology commercialization phase consisted of three steps: 1) implantation step, 2) nursery step, and 3) demonstration step. Implantation step required designing of technology-based projects. Nursery step required embodiment of commercialized technologies through prototyping and detailed business plans. Demonstration step required implementation of commercial products through establishing market plan, and manufacturing products.

In the business life cycle, commercialization process is one of the most critical phases as it defines a performance and an outcome. 2014 Technology Transfer Commercialization Status Report states that only 30% of the technologies that are transferred are being used and the rest are neglected. According to the Industrial-Educational Cooperation Survey, only the conditions of technology transfer are reviewed. If original and practical technologies can be deployed and be utilized through transferring public technologies, it would reduce time and costs in product development for SMEs. Successful technology commercialization contributes to the economic development by increasing productivity and provides an opportunity for high-tech products to enter the world market.

Furthermore, Park (2015) examined the transfer of convergence-type technology from SMEs, and compared how it differs with technology transfer in general. The author stated that technology transfer in SMEs was extremely important in the policy level, and was possible to compare the number of cases and funds for different technology classifications over 3 years (2010 ~ 2012). Only 4.4% of the technology transfer cases in Korea dealt with convergence-type technology, and electronics, machine, chemical, medical and food sectors have shown more cases of convergence technology transfer. Despite the importance of technology transfer in SMEs, convergence-type technology transfer have not impacted the growing sectors. In addition, the author suggests that

Korean SMEs tend to favor non-convergent type of technology patents and it is easier to transfer technologies with a higher possibility of usage to SMEs.

Past technology transfer and commercialization research have been focusing on several areas. Some examples are the collaboration of universities with industries; policies and policy paradigms; and the success and failure factors of technology commercialized firms

1) Cooperation between Universities and Industries for Technology Transfer and Commercialization

One of the most important factors in technology commercialization is the cooperation between universities and industries. Many universities have their own university technology transfer office to manage the activities involved in commercializing university research and inventions. In the US, prior to 1980s, the national government had the ownership of all university inventions, but after the Bayh-Dole Act was enacted to grant permission to university to own their inventions to license or to create a startup venture (Morberg & Moon, 2000).

According to Wong & Singh, the collaboration with universities is a desirable factor in technology transfers because the firms know that researches and technologies developed by the universities can improve their products and improve their R&D. The number of co-publications is positively related to the university technology commercialization outputs as in number of patents and spin-off formations. Despite the importance of technology transfers from university to industry collaboration, relatively little research ideas are actually commercialized and placed on the market (Patton & Kenney, 2010).

Phan & Siegel (2006) look at the effectiveness of university technology transfer by doing a literature review of quantitative and qualitative studies in the US and the UK. A total of 40 articles are reviewed; 12 journal articles on the effectiveness of licensing of university-based inventions, a total of 8 journal articles on science parks and 24 journal articles on entrepreneurial activity. They come up with several conclusions. First, despite the rapid increase in technology commercialization in universities, universities in the UK are hesitant in commercialization due to lack of endorsements and funding. Second, not many universities have a successful commercialization process; therefore, the paper offers several recommendations. One recommendation is that despite that institutional, organizational and individual factors are common among universities; the importance and

effectiveness of these factors are different across universities due to history and technological depth.

Rothaermel, Agung, & Jiang (2007) did a literature review on the topic of university entrepreneurship. Analyzing articles from 1981-2005 shows a continuous increase in the articles published per year related to university entrepreneurship; there is a rapid increase from 2000. Interestingly, the ratio of qualitative and quantitative research of university entrepreneurship has changed over time; from 41% qualitative (22% were quantitative, and 37% used no data analysis, but theoretical treatments and commentaries) in 1980-1985 to 75% quantitative (11% qualitative) in 2000-2005 (Rothaermel et al., 2007). Despite the low qualitative researches, these articles provide important contributions. For example, many qualitative articles identify commercialization options, the importance of technology transfer from university to industries, and effects of entrepreneurship in universities.

After analyzing 173 articles published in various journals, there are four common research areas: 1) entrepreneurial research university, 2) productivity of technology transfer offices, 3) new firm creation, and 4) environmental context including networks of innovation. Universities in developed countries have increased their entrepreneurial activities, such as developing patents and licenses; creating incubators, science parks, and university spin-outs; and even investing and creating startups. All these four areas are interconnected. Entrepreneurial university "*generates technology advances and facilitates technology diffusion process through technology transfer office and creates science parks and incubators that span startups*" (Rothaermel et al., 2007). These literature reviews do not only provide guidance to policy makers and practitioners, but also shows there needs to be more work to be done in the areas of university entrepreneurship, especially in the capabilities and network context of university inventions.

Patton & Kenney (2010) states that universities play a key role in industry formation, and the interaction between startups and university-community is vital to both actors. To understand the cluster and the university-industry community better, the paper examines two university clusters, UIUC and UW-M. For UIUC, and 117 startups that were found from 1958-2006. 46 of them were in the area of information technology, 28 of them were in the engineering sector and 23 in physical sciences. 61 or 52% were founded by university faculty/staff, and 13 or 11% were found outside of the university community. UW-M, who has a longer history in promoting startups, has 200 startups (65 in biological science, 54 in information science, and 26 in medical sciences).

59% or 117 startups were founded by the university faculty/staff, and only 4 or 2% were found outside of the university community (Patton & Kenney, 2010). Unlike the UIUC cluster, the UW - M cluster has two features that make them successful in capturing knowledge locally. First, the UW-M cluster is involved in a bigger cluster and has relationships with "*long-standing organizations*", such as WARF and Office of Corporate Relations. Second, networks and relationships among private entrepreneurs and university organizations are deeply rooted (Patton & Kenney, 2010).

2. Technology Transfer and Commercialization Policies and Programs

There are various levels of technology transfer and commercialization policies. First, there are policies at the national and in the state government level. These policies are related to patent, intellectual property and copyright laws. There are also policies in universities and in research institutes. For example, the University of Rochester (2016) has its own policies related to ownership, copyright, patents, licensing and the costs of commercializing their own innovations. Similarly, Vanderbilt University (2016) has their own center for technology transfer and commercialization (CTTC) and return of rights, conflict of interest, and federal policies.

West suggests policy implications and operational changes to improve university technology transfer and commercialization process. These are some of the suggestions. First, it is to provide better information and more accountability on commercialization process details like the revenue, expenditures, investment decisions and financial risks to help shareholders and policymakers to understand the different activities taking place. Second, there needs to be more equity investments. Universities tend to focus on the short-term revenues, and shy away from investing and taking a 5% equity stake that may end up generating billions of dollars. Lastly, encouraging university innovation through compensation and coaching/ mentoring. Universities can generate more revenues and become an entrepreneurial university by compensating to licensing officers and hiring people with financial backgrounds. Also, by coaching and mentoring to faculties and students how to market and attract venture capital, it would create more opportunities for spin-off businesses and startups (West, 2012).

Park (2012) examined the relationship between the policies that support technology and the

technological competitiveness for Korean SMEs. There were two major outcomes; first, the policies that impacted the technological competitiveness of SMEs were polices that directly supported R&D, such as the technology fund support policy and technology infrastructure support policies. In addition, innovative SMEs in the manufacturing sector with the size of 5 to 49 employees showed high correlations between technology support policies and their technology competitiveness. Therefore, there is a need to increase support through funding policies, and more opportunities for investment and loan for these innovative SMEs.

According to OECD – World Bank (2013), technology commercialization policy assist in five ways: 1) assist in funding, 2) support science-industry cooperation, 3) provide information, 4) improve intellectual property and copyright, and 5) provide education to businesses and entrepreneurship. Many of the commercialization policies are related to protecting patents, and intellectual properties. There are also educational policies to assist and train business and entrepreneurial skills and better integrate university and industrial cooperation.

In Korea, despite the Ministry of Science & Technology emphasizing the proliferation of R&D over technology commercialization, the Korean government suggested that SMEs need to utilize local university and form a joint technology development system to overcome technical barriers. Therefore, Korea Technology Transfer Center (KTTC) was established, following the enactment of Technology Transfer Promotion Act, in 2000 . There are also 40 commercialization related policies and acts in Korea, but most of them are related to technology development/promotion (KIAT, 2014).

As the Korean policy focus shifted to high-tech innovation and technology commercialization in the 1990s and 2000s, the government started to offer diverse programs to commercialize and transfer technologies; one example would be inducing university and industry research centers to cooperate and participate in different projects (Kim, 2001). Patented technology transfer promotion and R&D support programs are all examples to promote and assist the commercialization and transfer activities in government research centers, universities, non-profit research entities, and even SMEs. There is also the technology transfer subsidy program to provide loans with low interest and contributory funds to assist in technology commercialization activities.

3. Success and Failure Technology Transfer and Commercialization Factors

The innovation was a different game than a decade ago; the speed from idea creation to commercialization can hardly catch up with the demand. To achieve a higher level of success and catching up with the demand, technology commercialization plays an important role. With a higher rate of successful technology commercialization, corporations can innovate at a faster rate.

Success and failure factors for technology commercialization have been a research interest in Korea as well. There have been many qualitative studies to relate to the successful technology commercialization. Park & Ryu (2005) conducted a meta-analysis to review all of the various factors and capabilities of technology commercialization. The influencing factors can be classified into four areas: 1) technical properties, 2) technology developer, 3) technology consumers, and 4) external environment. Technical properties include technical maturity, technology reliability, and relation to existing technology. Technical developers include experience of commercialization, awareness of commercialization, and university-industry cooperation. Technology consumers include executives' willingness, risk management, commercialization expertise, and commercialization funding procurement capabilities. Finally, external environment includes commercialization network, IP protection, government policies and market characteristics.

Park & Ryu (2005) carried out a 40 publications meta-analysis related to SMEs' technology innovation; they used DBPia and Korean Studies Information Service System (KISS) databases and searched for "SMEs", "Technology Commercialization" and "Technology Innovation" as keywords. The analytical framework was separated by impact and performance variables. Impact variables included internal factors, such as organizational and innovation factors, and environmental factors. Performance variables included financial and non-financial factors.

〈Table 1〉 Factors Related to Technology Commercialization from Past Literatures (KBIZ, 2013)

Factor Classification		Details	Measurement Techniques	Relation
Internal Factors	Organizational Factors	Business Characteristics	Size of Enterprise - Number of Employees	+
			Corporate Competency Level - Knowledge Assets (Master's Degree or Higher Holders) - Training Investment	+ +
			Age of Enterprise	+
			Innobiz Business Certification Status	+
			Marketing Concentration	+
			Industrial Sector	+
			Trade Union Presence	-
		CEO's Characteristics	Executive's Personality - Directional Innovation - Management Competency Factor - Executive's values Executive's Experience - Marketing Experience - Knowledge - Management and Business Skills - HR Capabilities	
		Organizational Procedures and Cultural Characteristics	Procedural Justice	+
			Leveraging Strategic Methodology	+
			Sensitive to Change in the customer and environment	+
	Innovation Factors	Technology Innovative Activities	Number of R&D Personnel	+
			R&D Investment	+
			Presence of Research Institutions	+
			Technology Commercialization Capacity	+
			Innovation Management Skills	+
			Number of Product Innovations	+
			Development Lead time	+
			Equipment	+
			Technology Innovation Strategy	+
			Absorptive Capacity	+
			Intellectual Property	+
		Management Innovation Activities	Institutional Innovation	+
		Collaboration Activities	External Collaboration Experience	+
			Size of Collaboration Activity	+
			Level of Information Network	+
			Effectiveness of External Collaboration	+

<Table 2> Continued Factors Related to Technology Commercialization from Past Literatures (KBIZ, 2013)

Factor Classification	Details	Measurement Techniques
Environmental Factors	Market Environment	Strength of Market Competition Market Attractiveness Industrial Properties (Growth stage, industry type, R&D Intensity)
	Conglomerate Dependence	Subcontract with Conglomerates
	Location	Interregional Classification Regional Technical Cooperation Geographical Proximity Psychological Proximity Regional Environmental Level
	Government Policy	Size of Technology Development Funding Presence of Government Funding Proportion of Government Funding Government Support Efficiency+ Utilizing Policy Tools Commercialization Support Financial Support Marketing Support
	Private Funding Attraction	Size of Private Funds

Organizational factors are related to size, age, marketing level, industrial classification of the enterprise, as well as the CEO's characteristics, such as the experience, and personalities. Innovation factors are related to investment, the number of workers, commercialization capabilities, R&D strategies, and absorptive capacity level. For the environmental factors, enterprise market environment, location, government funding, and policy advantages are considered. Table 1 and 2 show both the internal and environmental factors of technology commercialization from past literatures.

1) Lack of Quantitative Research on Technology Transfer and Commercialization

Most of the technology commercialization researches are done as qualitative studies, since quantitative data are corporate privacy, and know-hows/competitive edges. There have been very few studies using qualitative data. Kang, Gwon, Hong, Kim & Cho (2011) investigate the

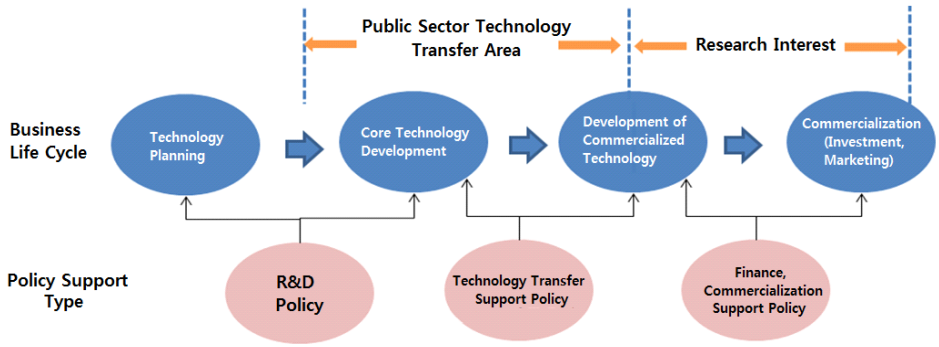
commercialization of government-supported firms by analyzing their performance and internal/external capabilities. Using 1192 Korean manufacturing firms' data from 2005-2007 by the Korean Innovation Survey (KIS), three logistic regression models are used to come up with five major findings. First, appropriability didn't affect the technology commercialization in big firms, but had a positive effect on SMEs. Second, process, organizational, and marketing innovation capabilities have a positive effect on success of technology commercialization. Third, rate of external R&D investment had a positive effect on the success of technology commercialization. Fourth, government supports on R&D had a positive effect on the success of technology commercialization. Fifth, R&D investment and firm size don't have a significant effect.

Similarly, according to the SME's Technology Survey Report (as cited by Kang et al., 2011), in the last two years, there were 5.7 cases of technology development attempts, 2.2 cases were successful in being commercialized and created profit (while 3.7 cases were successful in technology development). This shows only 57.1% of success rates of technology developments, and only 37.7% of success rates of technology commercialization.

The rate of successful technology commercialization also varies among different types of enterprises. For example, for innovative companies, the success rate of technology commercialization was 58%, opposed to 55.4% for standard enterprises. Also, intermediate technology (58.8%) and general purpose technology industries (56.9%) have a higher success rate of technology commercialization than high-tech industries (54.7%) (Kang et al., 2011).

Technology Survey Report (as cited by Kang et al., 2011) also identified bottlenecks and failure factors of technology commercialization. Top three bottlenecks for technology commercialization after technology development were 1) lack of commercialization funds, 2) high price levels for developed products, and 3) difficulties in securing raw materials and equipment. Many SMEs face difficulties in finding funds and supports for technology commercialization, lack of support for selling new technology products, and lack of support in market analysis consulting.

4. Research Gap



<Figure 1> Business Life Cycle of Public Sector Technology Development and the Different Types of Policy Support (KBIZ, 2013)

Figure 1 shows the business life cycle of technology development, and the supporting policies for different phases. R&D policy supports the diverse activities in the technology planning and core technology development phase; technology transfer support policy in the development phase; and finally, finance and commercialization support policy in the commercialization phase. The paper's research interest is in the transition stage from the development phase to the commercialization stage.

As noted in the literature review section, there have been many researches done on technology commercialization and transfers in the development phase of the business life cycle. Much of the prior literature focused on identifying the drivers for technology commercialization like entrepreneurial, resources, manufacturing, and innovation characteristics (Park & Ryu, 2015). Other studies have used hypothesis testing to study the relationship between technology commercialization and businesses' performances on conglomerates and other successful cases. However, few studies have focused on the factors of success and failure factors of technology commercialization and its policy measures for small and medium enterprises (SMEs) and universities in one specific sector.

Despite the increased quantitative research in the university-industry cooperation, not much research on the success and failure factors of technology transfer and commercialization have been qualitative, and even less from the perspective of SMEs. To address these gaps, this paper

conducted a survey and a logistic analysis on data collected from 1,222 companies and universities that carried out public technology research and development in Korea. The purpose of this paper is to review and examine the full impacting factors influencing the technology commercialization as the overall performance of SMEs' technology innovation in the public technology. It assesses the factors of both successful and failed cases of technology commercialization; factors like market conditions, technical characteristics, and firm characteristics have a big influence, while the characteristics of technology providers do not affect the outcome of commercialization.

5. Case Study: Public Technology Commercialization

Public technology R&D has been continually expanding with the support of the government, but use of commercialized public technology in Korean SMEs has been unsatisfying. In 2015, Korea Economic Research Institute (KERI) analyzed the R&D support for SMEs; while successful product development rate was 96%, the successful commercialization rate was only half, 47.2%. In the 2014 commercialization status report, only 30% of the transferred public technologies were being used, and the remaining 70% were unutilized or in a neglected state (KIAT, 2014). Most importantly, there are no investigations and reviews on how the transferred technologies from university to industries are applied or utilized. Transfer Licensing Organization (TLO), a public research institution for technology commercialization, lacks independence due to the lack of budgets, personnel, as well as competence. According to the 2013 university-industry cooperative activity report, budget for technology development & assessment, market & technology research, and commercialization strategy is non-existent. Due to the low competencies of TLO, public technology trading and commercialization are led by researchers themselves, and public TLO plays an insufficient role in technology transfer. Public technology trading and commercialization are done through a technology push process, and thus, private institutes do not take an active role, unless participating through government support projects (KIAT, 2014).

There are other insufficient capabilities in the public technology commercialization/transfer supports. First, there is a lack of diversity in the royalty system for technology commercialization. 88.7% of the royalties are fixed[1], and only 10.7% are running[2] royalties. Second, there is a lack of initial funding required to commercialize associated development, productions, and new

products/services. Third, domestic universities and research institutes put heavy emphasis on R&D outcomes, such as patents and publications over commercialization. Lastly, the networking and the relationships between companies, research institutes, TLOs, private trade associations, financial institutions, and universities need to be improved. There is a lack of connection and cooperation among different constituents during the commercialization process. With poor demand-supply relationship, it is difficult to reflect the market situation, and to identify technology buyers (KIAT, 2014).

The government continues to expand their support for public R&D; however, the technology commercialization process is still insufficient in Korea, compared to foreign countries. There has to be an invigoration of technology commercialization policies in Korea. There needs to be major policy supports for SMEs to take advantage of technology commercialization of the public technologies.

Ⅲ. Research Methodology

The data used in this paper were collected by the Korean Federation of Small and Medium Business (KBIZ) (2013) from 2011 to 2013 to analyze the success and influencing factors for technology commercialization. This raw data consisted of 1,222 SMEs that have collaborated with universities, national and public research institutions on developing public technologies.

KBIZ is investigating the technical situation of SMEs in the manufacturing sector in the biennial basis. In addition, on the basis of the Article 8 of the SME technology innovation promotion act, Small and Medium Business Administration (SMBA) and the Korea Federation of Small and Medium Business (KBIZ) conduct a joint statistical survey to collect the raw data on SMEs in Korea.

In align with the paper's objectives; the paper analyzes the data to find what the factors and characteristics of successful technology commercializing firms using three different analysis methods. First, cross tabulation analyzes the categorical data, such as successful companies' growth stage status or their new technology sector status and provides information about the relationship between factors; second, technology commercialization process analysis determines the technology

commercialization factors for both successful and failure companies; and finally logistic analysis examines the successful companies and how R&D and business factors affect the success rate of commercialization.

Ⅳ. Data Analysis

This section shows the different data description, according to the SME characteristics.

<Table 3> SMEs Characteristics Status

Classification	Innovative Technology SMEs	Venture SMEs	Innovative Management SMEs	Standard SMES
Uncertified Enterprises	330	375	713	574
Certified Enterprises	607	529	76	406
Total	937	904	789	980
Missing	285	318	433	242
Total	1222	1222	1222	1222

Table 3 indicates the classification of the 1,222 SMEs that have collaborated with universities, national and public research institutes in the development in public sector technologies. The raw data classifies SMEs into four (innovative technology, venture, innovative management, and standard) characteristics and two (uncertified and certified) types. There are more certified enterprises for innovative technology and venture SMEs, while there were more uncertified enterprises for innovative management and standard SMEs.

<Table 4> SMEs Growth Stage Status

Classification	Frequency	Percent
Market Entering Phase	79	6.5
Growth Phase	667	54.6
Matured Phase	440	36
Restructuring Phase	36	2.9
Total	1222	100

Table 4 shows the growth stage status for 1,222 SMEs that cooperated with universities, national and public research institutes in developing public technologies. A high number (54.6%) of the SMEs is in their growth phase, while only 2.9% and 6.5% of them are in restructuring and market entering phase, respectively.

<Table 5> SMEs' New Technology Sector Status

Classification	Frequency	Percent
IT, Information Tech	214	17.5
BT, Bio Tech	119	9.7
NT, Nano Tech	40	3.3
ST, Space Tech	14	1.1
ET, Environmental Tech	137	11.2
CT. Cultural Tech	5	0.4
N/A, Not Applicable	693	56.7
Total	1222	100

Table 5 indicates the classification of new technology sectors' status of the SMEs involved in the public technologies. There are six promising technology sectors: information, bio, Nano, space, environmental, and cultural, and are known as the 6T1. The top three sectors of SMEs that participate in developing public technologies are information, environmental and bio.

<Table 6> Main Vendors for SMEs Developing Public Technologies

Classification	Frequency	Percent
Conglomerates	511	41.8
SMEs	415	34
Consumers	167	13.7
Overseas	98	8
Others	31	2.5
Total	1222	100

Table 6 shows the status of the main vendors of the 1222 SMEs developing public technologies. Conglomerates and SMEs are the two highest vendors with 41.8%, and 34%, respectively.

〈Table 7〉 Number of Regular Workers

	N	Min.	Max.	Avg.	SD
Number of Regular Workers	1222	5	299	63.8	69.269

Table 7 shows the number of regular workers in the SMEs developing public technologies. The number of regular employees ranged from 5 to 299, with an average about 64 in the SMEs.

〈Table 8〉 Development Status of SMEs

Classification	Frequency	Percent
New Product Development	596	48.8
Improving Existing Products	466	38.1
New Process Development	94	7.7
Improving Existing Process	66	5.4
Total	1222	100

Table 8 shows the detailed development status for the SMEs involved in developing public technologies. The status confirms that SMEs are mainly involved in new product development and improving existing products.

〈Table 9〉 Technology Commercialization Success and Failure Cases

Classification	Frequency	Percent
Successful Commercialization	690	56.5
Unsuccessful Commercialization	532	43.5
Total	1222	100

Table 9 presents the outcome of the technology commercialization of the 1,222 SMEs that were developing public technologies. 56.5% of the SMEs succeeded in commercializing their technologies.

1. Analysis and Results

The data is analyzed in three methods: cross tabulation analysis, process analysis, and logistic analysis. Each method

1) Cross Tabulation Analysis of Successful Technology Commercialized SMES

<Table 10> Successful Technology Commercialization SMEs' Cross Tabulation

Classification	Certified or Uncertified	# of Successful SMES	Total	Percent
Innovative Technology SMEs	Uncertified	164	330	49.7
	Certified	381	607	62.8
	Total	545	937	58.2
Venture SMEs	Uncertified	211	375	56.3
	Certified	314	529	59.4
	Total	525	904	58.1
Innovative Management SMEs	Uncertified	410	713	57.5
	Certified	55	76	72.4
	Total	465	789	58.9
Standard SMES	Uncertified	343	574	59.8
	Certified	212	406	52.2
	Total	555	980	56.6

Table 10 displays the cross tabulation analysis of type of SMEs and its' successful technology commercialization cases. In the cross tabulation analysis of key enterprise characteristics and technology commercialization success in the public technology innovation SMEs, technology innovative SMEs and venture SME are the most likely to succeed in commercialization. However, in a detailed analysis, certified innovative technology and management SMEs show the highest success ratio of 62.8% and 72.4%, respectively.

<Table 11> Growth Stage Status and Successful Technology Commercialization SMEs Cross Tabulation

Classification	# of Successful SMEs	Total	Percent (%)
Market Entering Phase	41	79	51.9
Growth Phase	367	667	55.0
Matured Phase	267	440	83.4
Restructuring Phase	15	36	41.7
Total	690	1222	56.5

Table 11 shows the cross-tabulation of growth stage status and the successful technology commercialization SMEs. In this cross tabulation analysis of enterprise growth stage and the

successful cases, SMEs in the growth and matured phase show a higher number of successes. However, in a detailed analysis, matured phase SMEs have the highest success rate of 83.4%.

<Table 12> New Technology Sector and Successful Technology Commercialization SMEs Cross Tabulations

Classification	# of Successful SMEs	Total	Percent (%)
IT, Information Tech	122	214	57.0
BT, Bio Tech	72	119	60.5
NT, Nano Tech	26	40	65.0
ST, Space Tech	8	14	57.1
ET, Environmental Tech	81	137	59.1
CT. Cultural Tech	1	5	20.0
N/A, Not Applicable	380	693	54.8
Total	690	1222	56.5

Table 12 shows the cross-tabulation of new technology sector status and the successful technology commercialization SMEs. In this cross tabulation analysis of new technology sectors and the successful cases, SMEs in information and environmental technology sectors show a higher number of successes. However, in a detailed analysis, SMEs in nanotechnology sector has the highest success rate at 65.0%.

<Table 13> Development Status and Successful Technology Commercialization SMEs Cross Tabulation

Classification	# of Successful SMEs	Total	Percent (%)
New Product Development	358	596	60.1
Improving Existing Products	260	466	55.8
New Process Development	46	94	48.9
Improving Existing Process	26	66	39.4
Total	690	1222	56.5

Table 13 shows the cross-tabulation of development status and the successful technology commercialization SMEs. In this cross tabulation analysis of development status and the successful cases, SMEs developing new products and improving existing products shows a higher number of successes. In a detailed analysis, SMEs in new product development has the highest success rate at 60.1%.

<Table 14> Main Vendors and Successful Technology Commercialization SMEs Cross Tabulation

Classification	# of Successful SMEs	Total	Percent (%)
Conglomerates	277	511	54.2
SMEs	244	415	58.8
Consumers	83	167	49.7
Overseas	69	98	70.4
Others	17	31	54.8
Total	690	1222	56.5

Table 14 shows the cross-tabulation of the main vendors and the successful technology commercialization SMEs. In this cross tabulation analysis of main vendors and the successful cases, SMEs with conglomerates and other SMEs vendors show a higher number of successes. However, in a detailed analysis, SMEs with overseas vendors have the highest success rate at 70.4%.

2) R&D and Technology Commercialization Process Analysis for SMEs in Public Technologies

<Table 15> Development Lead Time by Stages by Months

Classification	N	Min.	Max.	Avg.	SD
Ideation Stage	1222	0	36	5.82	4.323
Development Stage	1222	0	132	9.9	9.024
Commercialization Stage	1222	0	40	7.41	5.613
Total Lead Time	1222	1	168	23.14	15.054

Table 15 shows the lead time of different development stages. Through analyzing the two years R&D lead time for SMEs, the ideation stage takes 5.8 months, the development stage takes 9.9 months, and the commercialization stage takes 7.4 months with a total lead time of about 23 months. The development stage has the shortest lead time, followed by the commercialization stage.

<Table 16> Technology Development and Commercialization Performances

Classification		N	Min.	Max.	Avg.	SD
Technology Development Attempt		1222	0	350	6.55	18.808
Technology Development Performances	In Progress	1222	0	60	2.03	3.842
	Failure	1222	0	90	0.62	3.697
	Successful	1222	0	300	3.9	14.99
Commercialization Performances	In Progress	1222	0	150	1.24	5.148
	Failure	1222	0	40	0.18	1.433
	Successful	1222	0	279	2.48	11.469
Intellectual Property	Applied	1222	0	113	1.23	4.555
	Registered	1222	0	82	0.68	3.176

Table 16 shows the technology development and commercialization performances. Through analyzing the two years R&D lead time for SMEs, there are about 6.6 cases of technology development attempts, 2 cases of technology development in progress, 0.6 cases of technology development failures, and 3.9 cases of successful technology development in average over two years. For commercialized performances, 0.1 cases of failure and 2.5 cases of successes in average over two years. For intellectual property performances, 1.2 cases of application, and 0.7 cases of registration in average over two years. The success rate of technology development is about 60%, and success rate for technology commercialization is about 38%, which is far lower than that of technology development.

<Table 17> Technology Commercialization Failure Factors

Classification	N	Percent (%)
Lack of Technology Development Funds	191	22.9
Lack of Labor	209	25
Low Development Needs	168	20.1
Leading Development by Other Enterprises	86	10.3
Government Regulations	33	4
Technology Development Without Patent Review	62	7.4
Lack of Facility Equipment	79	9.5
Others	7	0.8
Total	835	100

Table 17 shows the technology commercialization failure factors. Through analyzing the two years R&D lead time for SMEs, the top three failure factors are lack of labor, lack of technology development funds, and low development needs.

〈Table 18〉 Technology Commercialization Success Factors

Classification	Frequency	Percent (%)	Valid Percent (%)
CEO's Volition	380	31.1	36.1
Human Resources	209	17.1	19.8
Funding	53	4.3	5
Testing and Inspection Equipment	14	1.1	1.3
Technology Development Experience	164	13.4	15.6
Procuring Information	54	4.4	5.1
External Technical Cooperation	70	5.7	6.7
Scout and Plan	31	2.5	2.9
Self-Technology Development Capabilities	51	4.2	4.8
Industry-University Research Support	24	2	2.3
Others	4	0.3	0.4
Total	1054	86.3	100
Missing Values	168	13.7	
Total	1222	100	

Table 18 shows the success factors of technology commercialization for SMEs developing public technologies. The top three success factors are CEO's volition, human resources and technology development experience.

〈Table 19〉 Causes of Difficulties in Technology Acquisition

Classification	Frequency	Percent (%)
Excessive Technology Acquisition Costs	138	18
Lack of Acquisition Information	91	11.9
Difficulty of Maintaining	74	9.7
Low practicality of Acquisition Technologies	91	11.9
Long time to Acquire Technology	45	5.9
Complexity in Technology Acquisition Process	49	6.4
Difficulty in the fair value assessment of Technology Acquisition	45	5.9
Legal Dispute in Technology Acquisition	5	0.6
Others	227	29.7
Total	765	100

Table 19 shows the cause of difficulties in technology acquisition. The top three causes are excessive cost, lack of information, and low practicality in technologies acquired.

<Table 20> Cause of Difficulties in Technology Commercialization

Classification	Frequency	Percent (%)
Lack of Commercialization Funds	621	28.2
Lack of Securing Raw Materials and Equipment	266	12.1
High Price Level for Product Development	337	15.3
Lack of Product Maturity	265	12.1
Similar Product Emergence	252	11.5
Lack of Market Sales	330	15
Lack of Commercialization Specialists	108	4.9
Others	20	0.9
Total	2199	100

Table 20 shows the cause of difficulties in technology commercialization. The top three causes are lack of funds, high price level of the product development, and lack of market sales.

<Table 21> Technology Commercialization Policy Program Utilization

Classification		Frequency
Funding	Planning Phase	265
	Development Phase	501
	Commercialization Phase	238
Tax Support		490
Outlets Support		161
Personnel Support		194
Information Support		259

Table 21 shows the technology commercialization policy program, and how it is being utilized. There have been many appeals about the lack of supporting policies related to commercialization funds and marketing; it is evident that there is a lack of outlet and personnel supports. It is a mismatch that there are more tax and planning phase fund support as well.

3) Logistic Analysis of Successful Technology Commercialization Factors

In order to do a precision analysis on 690 successful commercialization SMEs, the paper uses quantitative variables related to the technology commercialization success factors of the company as the independent variables to conduct a logistic analysis. This analysis' intention is to extract the common success factors of these 690 SMEs developing public technologies, and see how lead time, sales, and number of technology commercialization promotion factors relate to the technology commercialization success in these 690 SMEs.

<Table 22> Public Sector Technology Commercialization Success Factors Logistic Analysis

		B	S.E.	Wald	df	Sig.	Exp (B)
Number of Employees		-0.001	0.001	0.748	1	0.387	0.999
Lead Time	Planning Phase	-0.038	0.019	4.416	1	0.042*	0.963
	Development Phase	0.006	0.009	0.478	1	0.489	1.006
	Commercialization Phase	0.018	0.015	1.455	1	0.228	1.018
Sales	2 Years Prior	0	0	0.562	1	0.454	1
	Year Prior	0	0	2.479	1	0.115	1
Number of Technology Commercialization Promotion	Technology Development Attempt	-0.094	0.023	17.085	1	0.000*	0.91
	Number of Successful Technology Development Cases	0.862	0.073	140.811	1	0.000*	2.368
	Number of Failed Technology Development Cases	-0.77	0.163	22.298	1	0.000*	0.463
	Number of IPR Pending Cases	-0.113	0.081	1.917	1	0.166	0.894
	Number of IPR Registration Cases	0.441	0.081	10.005	1	0.002*	1.554
Constant		-0.994	0.139	34.854	1	0	0.37

* Statistically Significant difference (P < 0.05)

<Table 23> Public Sector Technology Commercialization Success Factors Model Summary

-2 log likelihood	Cox & Snell R Square	Nagelkerke R Square
1263.718	0.285	0.382

Table 22 and 23 shows the logistic analysis results. Our regression results show the different effects of quantitative factors have on the success rate of technology commercialization. The number of successful technology deployment cases and the number of IPR registration cases have a positive impact on the success rate of technology commercialization; the higher the number of

successful technology development and IPR registration cases, 1.5 to 2 times higher success rate of technology commercialization.

Similarly, longer the technology development attempts, longer the lead time in the planning phase, and higher number of failed technology development cases, the lower the success rate of technology development; all three factors were significant. The result also verifies that unnecessary technology development has a negative impact on the success rate of the public sector technology commercialization.

V. Assumption, Limitations and Future Work

Two assumptions were made regarding the data and the results of the paper. First, due to the nature of SMEs and their technological capabilities being low, this paper assumed that public and joint technical performances would push for technology commercialization. Second, the paper assumed that public technology commercialization can help reduce product development time for SMEs.

This paper has some limitations. First, this is an exploratory research, and therefore, there are a lot of limitations in relation to the statistical results. It lacks theoretical contributions. Second, in relation to the first limitation, the research methodology is mostly data description, instead of statistical analysis using these different quantitative factors. Third, even though the paper targeted SMEs that focused on research and development (R&D) using public technologies, it is ascertained whether the SMEs applied the public technologies in their commercialization process. Fourth, despite 1,222 SMEs participated in developing public sector technologies; only 690 cases have been successfully commercialized. This is a fairly low percentage of success rates.

Despite the lack of statistical contributions, the paper is still meaningful because of the data description it presents. These raw data and their description are not easy to access as they are SMEs' private information. Not only are there information on the number of successful and failed cases of technology commercialization, it also goes deeper in classifying growth stage, sectors, number of employees, main vendor, and firm characteristics in details. Even with these limited statistical results, it could provide meaningful information on technology commercialization cases.

This paper is in the exploratory phase, and therefore, has several areas for future work. First, it is to

collect more data that provide evidence that SMEs applied public technologies in their commercialization process. This can be achieved through qualitative surveys. Second, it is to analyse additional technology commercialization programs to compare whether public technology commercialization and its success factors differ. Third, it is to develop this paper with policy implications, especially in the areas of 1) planning phase to and 2) technology marketing phase enable public sector technology commercialization Policy measures for policy phase might include improving the technology commercialization success rate through expanding support through SME technology development support program; supporting technology management process capabilities; and organization expanded support for public institutions and universities technical skill matching. Policy measures for technology marketing phase might include supporting SME in public technology commercialization and expanding policy support for Korean leading companies; expanding support for public technology startups; and building a financial technology ecosystem and expand investment-linked R&BD projects.

VI. Conclusion

This exploratory research paper investigates the success and failure factors of technology commercialization for SMEs developing public sector technologies. This paper uses 1,222 SMEs participating in developing public sector technologies, and their different quantitative factors to understand the characteristics of successful technology commercializing firms in the public technology sector in Korea. Three different analyses are conducted to see how firm characteristics relate to technology commercialization. The results in this paper are significant because many technology commercialization related papers do not use quantitative data since they are hard to obtain due to the company's privacy. The logistic outcome shows that there is a positive relationship between the success rate of technology development and the success rate of technology commercialization. Higher the number of technology development cases, the higher success rate of technology commercialization. Similarly, the number of IPR registrations has a positive correlation with the success rate of public technology commercialization. Also, higher failure cases of technology development and longer lead time in planning phase have all negative impact on the public technology commercialization.

For policy implications, the paper suggests a different perspective to the current government support on public technology development and commercialization. While current attempts to support SMEs' technology develop was selected by their quantitative dimensions (e.g. number of technology development attempts), but yet, the results show that more attempts for technology development doesn't exert positive results or more successful technology commercialization. In addition, the government should examine the different success factors of public technology commercialization and be selective in finding ones with higher potential of success of technology development and commercialization.

This paper is not without limitations. The paper does not provide significant statistical results. The descriptive statistics of the different SMEs and how different factors impact their commercialization is significant, but it does not provide the depth a linear regression would provide. The second limitation is related to the lack of meaningful statistical results; the paper does not provide a clear conclusion.

With these limitations into account, it is important to improve this current study if it is to be continued on. It would be interesting to gather more data on public technology transfer and commercialization, and conducting a linear regression and hypothesis testing to see whether these different factors do actually affect the success of commercialization in the Korean SMEs. Second, another approach is to add a policy implication section to improve the conclusion of the paper to provide meaningful actions and directions in order to help improve the commercialization of public technology in the Korean SMEs.

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국문초록

우리나라 중소기업의 공공기술 사업화 영향요인에 관한 연구

박문수* · 장순우**

본 연구는 우리나라에서 공공부문으로부터 기술이전을 받은 중소기업에 대한 사업화 성과와 이에 대한 영향에 관한 연구이다. 2014년 기술이전사업화조사분석자료집에 따르면 공공부문에서 기술이전을 받은 기술 중 약30%만이 활용되고 있고 나머지 70%는 미활용되거나 방치상태이다. 상대적으로 대학 및 출연연 등 공공기관의 기술사업화 지원 역량 또한 발전이 더딘 상황이다. 이에 따라 공공부문 기술사업화를 통해 중소기업의 발전을 추동하고, 혁신 성과를 확산하기 위해서는 지속적이고 체계적인 정책적인 지원이 필요한 상황이다.

본 논문에서는 공공부문 기술이전 이후 중소기업의 활용 및 사업화 등에 관한 전주기적 분석을 통해 사업화 성공과 실패 요인을 조사하였다. 최근 3년간 진행된 중소기업기술통계조사를 기반으로 하여 기술사업화 성공기업을 도출하고, 기술사업화의 활용형태에 따라 성과에 어떤 영향을 미치는지 분석을 하였다.

통계 분석 결과, 공공기술을 기반으로 한 사업화 성공 중소기업은 기술개발 성공건수 및 지식재산 등록건수가 많아질수록 사업화 성공률에 긍정적인 영향을 미쳤다. 또한 불필요하게 많은 기술개발, 계획 단계에서 긴 리드 타임 등의 경우 사업화 실패가능성이 높다는 것을 확인했다. 이러한 분석결과는 최근 양적인 차원에서 지원되는 중소기업의 기술개발 시도가 모두 긍정적인 효과를 발휘하기 어렵다는 정책 함의를 도출 할 수 있다. 또한 이를 위해 효율성 및 성공 가능성이 높은 기술사업화에 대한 선택적 지원이 필요하다는 것을 정책 함의로 도출할 수 있다.

주제어 : 공공기술, 사업화, 중소기업, 성공요인, 기술개발 성공

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