Measures to promote public technology-based startups : Focusing on entrepreneurship for scientists and engineers

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Abstract

Technology-based startups are known to contribute to the growth of national economy by creating high-paying jobs, promoting R&D investment, exporting goods and services, etc. Technology-based startups created by using the outcome of government-sponsored R&D projects, namely, public science and technology-based startups, are particularly considered important as their survival rate is over 80 percent and they continue to operate their business for a long period of time.

The purpose of this study is to provide measures to promote public technology-based startups by revitalizing technology entrepreneurship. After examining a hypothesis on factors affecting startup business based on science and technology, it was confirmed that startup training programs and cooperation with external organizations had a positive impact for scientists and engineers to create companies. This study provides following measures to promote startups based on public science and technology. First, expand a cooperative network with outside specialized agencies and share the information focusing on their competencies. Second, encourage to conclude business agreements with regard to startups and provide related guidelines. Third, operate a startup related consultative body for regular exchanges. Lastly, create and expand startup support projects that both public research institutes and specialized agencies can jointly participate.

Keywords: technology-based startup, scientists and engineers, entrepreneurship, promotion of startups, public technology

1. Introduction

1.1 Purpose and background of the study

Korea and the world's leading countries have begun to emphasize the importance of startups and entrepreneurship as their survival strategies and strived to secure new growth engines for the future by promoting startups since the global financial crisis (Lee Yun-jun, 2013). Countries with the top tech-based startups have recognized their importance and made active efforts to secure and maintain national competitiveness continuously by fostering venture companies with innovative new technologies. Korea has also considered creating tech startups as the essence of strategy from the perspective of market dynamism as well as a new growth engine for sustainable development, and implemented various policies to support the efforts to foster tech-based companies. However, the quantitative growth of tech startups in Korea is far behind qualitative one (Hyundai Research Institute, 2013; 2016).

It is known that tech-based startups contribute to the growth of national economy by creating high-paying jobs, promoting R&D investment,

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exporting goods and services, etc. According to the research on job growth of 14 high-tech industries ('90~'11) conducted by Kauffman Foundation, the employment rate of high-tech companies that continue their business for 1~5 years since their inception was two time higher than general companies that operated for the same period.

Tech-oriented startups based on the outcome of government-sponsored R&D projects are particularly important as over 80 percent of them had survived and they showed a high survival rate for a long time after the foundation.

If a researcher, who leads a R&D activity of public science and technology, creates a company based on the technology concerned, positive effects to the business can be maximized as the researcher is in a position that can easily bring innovation to the product and production process by developing new application technologies and speeding up the product time to market (TTM).

However, scientists and engineers hesitated to challenge to start a new business in reality due to a high opportunity cost as they have to take a risk of failure that is huge compared to the benefits of working at a company including high wages, job security, and others (Korea Institute of Startup & Entrepreneurship Development (KISED), 2017).

In the past, being a specialist who focuses on the given area of research and development only was a sole capacity that was required for R&D staff. However, researchers should be generalized specialists now that have the problem-solving capability with macroscopic and comprehensive approaches to R&D by encompassing the entire process such as R&D related management, maintenance, assessment, and policies (Ministry of Science and Technology, 2006). Namely, scientists and engineers of the 21st century should acquire entrepreneurship skills that can wisely respond and even lead dynamic changes in the surrounding environment.

The entrepreneurship is a critical driver that triggers innovative activities and enables to seize market opportunities and create new products and process by differentiating a company from its competitors by being connected to creation, development, and management activities of resources (Miller, 1983; Dollinger, 1983).

In order to promote entrepreneurship for scientists and engineers, this study explored measures that could solve related problems based on the concepts from institutional and network theory. As researchers are from public research institutes with a high risk appetite, it is considered that providing them with institutional frameworks such as support system or entrepreneurship training programs, etc. would help them realize entrepreneurship. This study also looks into the network theory as it is expected that cooperating with external organizations can be effective to complement lack of capacity in starting a new business as companies are making constant efforts to create a network to maintain their competitiveness and complement core competencies in general.

The purpose of this study is to provide measures to promote tech startups based on public science and technology by revitalizing technology entrepreneurship and it is differentiated from the following points.

First, this study deals with public science and technology-based startups and entrepreneurship for scientists and engineers. There are many studies on startups and entrepreneurship in general. However, there is little that directly conduct researches on public science and technology-oriented startups or the ones created by research personnel of public research institutes.

Second, this study focused on the analysis based on institution and network theory. It is true there is almost no academic approaches on tech startups based on the technologies of public research institutes as most studies of this kind were conducted by related ministries and offices in the form of policy research report. Considering the fact that previous studies mainly focused on analyzing the current status and case study only, this study intended to conduct an in-depth analysis and draw on improvement measures based on the theoretical framework of institutional and network theory.

Third, this study was conducted by using highly reliable data and voice of customer (VOC). Basic data of this study, 「Survey report on technology transfer and commercialization of Korea」, that was issued by the Ministry of Trade, Industry and Energy (MOTIE) each year since 2007 by collecting the data of public research institutes of Korea including universities and their research institutes, is more reliable than other survey results of individual researchers and it is a highly valuable analysis material thanks to its representation. This study also reflected qualitative analysis results by conducting focus group interviews (FGIs) on researchers, members of technology licensing offices (TLOs), and others.

1.2 Contents and composition of the study

This study consists of 6 chapters.

Chapter 1 explains the background and purpose of the study. Chapter 2 relates to a theoretical research that defines the concepts of scientists and engineers, technology-based startups, and technology entrepreneurship and looks into the concepts of institutional and network theory. Chapter 3 explores the status of public science and technology-based startups, emphasizes its significance comparing to general startup businesses, and analyzes the state based on the data surveyed. Chapter 4 examines tech startup support policy of the US, Europe, and Japan to benchmark overseas cases, and explains the result of FGIs conducted on scientists and engineers, members of TLOs, technology trade agencies, and companies specializing in technology commercialization. Hypotheses were established in chapter 5 drawing on concepts of institutional and network theory in order to analyze factors affecting public science and technology-based startups and explained the result of data analysis obtained from the 2016 survey report on technology transfer and commercialization of Korea. Lastly, chapter 6 summarizes key findings of this study and provides policy recommendations to promote public science and technology-oriented startups based on the result.

2. Theoretical Review

2.1 Definition of scientists and engineers

An official definition of scientists and engineers of Korea can be found in 「Special Act on Support of Scientists and Engineers for Strengthening National Science and Technology Competitivenes s」 (hereinafter referred to as 'Special Act on Support of Scientists and Engineers') that was established in March, 2004. The term "scientist and engineer" means persons, who have majored in the fields of natural science and engineering, and of interdisciplinary convergence relating thereto, who have a degree in the fields of science and engineering at a two-year bachelor course college or higher education institution or industrial engineers and technicians in accordance with the National Technical Qualifications Act or ones of having equal to or higher than the concerned qualifications (Lee Jung-jae et al., 2008).

According to the definition of Organization for Economic Cooperation and Development (OECD), scientists and engineers (S&E) refer to persons who have completed a higher education in the fields of science and engineering or ones who are engaged in professional work on science and technology

(S&T) without completing such education (Byun Soon-chun et al., 2013).

United Nations Educational, Scientific and Cultural Organization (UNESCO) defines S&E as persons who are directly engaged in S&T activities in certain organizations or fields by being paid for the service they provide (Byun Soon-chun et al., 2013). As for the definition of National Sanitation Foundation (NSF), S&E refer to persons who have majored in science or engineering with a bachelor's or higher degree or ones aged under 75 who are working as scientists or engineers. The definition of NSF encompasses more comprehensive areas of studies than those of OECD or UNSECO. Such comprehensive definition of scientists and engineers could be more desirable considering recent trends of converging S&T, humanities, and social science (Jin Mi-seok & Um Mi-jeong, 2007). The scope of S&E is classified differently according to the academic background, occupation, and related tasks. However, they refer to persons who are working at (or having occupation) in the fields of science, engineering, and R&D (Kim Hong-young et al, 2015).

Table 1. Comparison of international standards on S&E

Item	OECD	UNESCO	NSF	Korea
Title	HRST	STP	S&E Workforce	S&E personnel
Classification	Degree, Major, Occupation	Occupation	Degree, Major, Occupation	Degree, Major, Technical Qualification
Academic attainment	2-year bachelor's or higher degree	X	Bachelor's or higher degree	2-year bachelor's or higher degree
Major	Natural science, Engineering, Medical science, Agricultural science, Social science, and Humanities	X	Natural science, Engineering, Medical science, Agricultural science, and Social science	Natural science, Engineering, and Interdisciplinary convergence relating thereto
Occupation	Professional work on S&T activities	Scientists, engineers, technicians, and assistant staff	Scientists and S&T related occupation	X
Remarks	(Degree ∩ Major) ∪ Comprehensive scope of occupation and major	Focusing on the engagement in S&T activities	(Degree ∩ Major) ∪ Unique occupation classification system	Degree ∩ Major

Source: Byun Soon-chun et al., (2013); Kim Hong-young et al, (2015), cited

Table 2. Definitions of technology-based startups

Researcher	Definition
Samsung Economic Research Institute (2004)	• Starting a business that creates innovative technologies • Creating a venture, technology innovation, innovation leading, and technology-intensive business are also included comprehensively
Kim Dae-ho·Kim Hong (2009)	• Starting a business of creating innovative technologies • Starting a technology intensive company that creates jobs and high value-added business such as venture company, INNO-Biz, etc.
Korea Business Incubation Association (2015)	• Technology intensive startup that creates a new market based on innovative technologies and entrepreneurship
Jelinek (1996)	• Refers a series of consistent approaches that are aligned with common understanding to continue joint and technological efforts to interpret undefined data and materials to keep up with technological changes
The Canadian Academy of Engineering (1998)	• Innovative application of scientific and engineering knowledge by an individual or multiple person who create and operate a business and take financial risks to achieve a goal and vision
Garud and Karnøe (2003)	• Play a role of an agency that connects actors with various capabilities, increase the involvement of technology and process, and help to provide more input during the process of changing new technologies
Liu (2005)	• A method of relying on resources and structures for an entrepreneur to pioneer emerging technology opportunities
Dorf and Byers (2005)	• A type of business leadership with capabilities of identifying a high potential and commercialization opportunity of technology intensive products, collecting resources such as talents and financial supports, and solid decision-making skills that manage rapid growth and risks

Source: Kim Yong-jeong (2014); An Seung-gu (2017), cited

2.2 Definition of the concept of technology-based startups

2.2.1 Definition of technology-based startups

The dictionary definition of startup is to initiate a business or the formation of a company. There are many definitions of technology-based startups at home and abroad (Table 2).

2.2.2 Characteristics of technology-based startups

The characteristics of technology-based startups are clearly defined by comparing them with general ones. According to Korea Technology Finance Corporation (Kibo), technology-based startups have different characteristics in terms of types of business, forms of business implementation, and general characteristics as follows.

Table 3. Comparison between tech-based and other startups

Classification	Types of business	Forms of business implementation	Characteristics
Tech-based startups	Manufacturing Professional service (specialization,science,technology) Cultural and knowledge-based business	Produce goods (and services) and engages in sales activities based on new ideas or technologies	Must take a high risk for a high return, if successful Start small with a potential to become an established company through rapid growth
Startups in general	General service Wholesale and retail business (construction)	General forms of business such as restaurants, beauty-related business, and simple product distribution process	A low barrier to entry and frequent creation and extinctions of startups Small business with small budget in general and creates low added-value

Source: Korea Technology Finance Corporation (www.kibo.or.kr)

Academically, Klofsten & Jone-Evans (2000) defined characteristics of research-based spin-offs or technology-based startups, objective of this study, as follows.

First, a research-based spin-off is a new company as a legal entity. It is a company of a legal status with an autonomous structure of its main activities are generating income. Second, it is created based on a parent organization. In general, a spin-off has its root on a public research institute, universities, and other research-oriented organizations and it can be specialized as a research-based spin-off. Third, it utilizes the knowledge generated as a result of academic activities. Here, the knowledge includes technologies, patents, know-how, etc. that are amassed during the process of academic activities.

2.3 Definition of the concept of technology entrepreneurship

The terms of entrepreneurs and entrepreneurship were popularized by Austrian economist J. A. Schumpeter. In 1934, he said that the capitalism progressed based on a new combination of elements such as manufacturing of new goods, quality improvement of existing products, adoption of new manufacturing methods, advancement of new markets, acquisition of new sources of parts and raw materials, and formation of new industrial organizations. He also defined an entrepreneur as a person who is engaged in innovative activities that trigger such 'creative destruction.'

Since then, entrepreneurship had cited and expanded by various researchers through researches and in many cases. However, most definition of entrepreneurship that came after Schumpeter include activities that 'accept uncertainties,' 'conduct innovative activities,' and 'seize opportunities' in general.

Technological entrepreneurship that emphasized the importance of technology innovation activities in tech-based industries has emerged as a new concept, while studies on entrepreneurship required according to the functional elements of an organization along with the determination of its concept.

For instance, Globe et al., (1973) first used the term of 'Technology Entrepreneur' in their study on critical elements of certain complex activities determining the success of technological innovation and defined the person who led an organization for the success of scientific or technological activities. Since then, researchers are taking different views on technological entrepreneurship from various perspectives.

Table 4. Definitions of technology entrepreneurship

Researcher	Definition
Rothwell & Zegveld (1982)	A person who is interested in commercializing the potential of technologies in long-term
The Canadian Academy of Engineering (1998)	Innovative application activities of scientific and technological knowledge by persons who operate a business and assess financial risks to achieve technology goals and visions
Shane & Venkataraman (2003)	A process of integrating resources and technological structure of an organization that is conducted by an entrepreneur for innovative companies to pursue commercial opportunities
Dorf & Byers (2005)	Business style encompassing activities to manage rapid growth and risks by identifying technology-oriented business opportunities with a high growth potential by using decision-making capabilities based on principles and by creating resources and capital that are needed

2.4 Review of related theories

2.4.1 Institutional theory

The essence of institutional theory is that a corporate should achieve and maintain an environmental legitimacy, which refers to a general recognition or assumption that determines whether corporate behaviors are desirable, righteous, and proper with regard to the norms, values, beliefs, and justice established in a system of a social structure (Suchman, 1995). Namely, a corporate is required to comply with the rules and belief system that exist in the surrounding environment for its survival according the institutional theory (DiMaggio and Powell, 1983). Therefore, companies that share the same environment select the same practices and strategies, and undergo isomorphic changes (DiMaggio and Powell, 1983). It means that main reasons for having the same corporate practices are closely related to the surrounding managerial environment or institutional norms of a social structure (Rudolf Sinkovics and Byung Il Park, 2017).

DiMaggio and Powell (1983) clarified the meaning of institution by providing a definition on new institutionalism. In the fields of organization and social theory, a new institution is an independent variable that excludes a theoretical behavior model and includes an individual property or direct interest to motive that cannot be defined as a group in institutional interest, changes in cultural-cognitive aspects, or properties of analyzing ultrafine units. They are forced and supported by the establishment and reproduction of an institution and actors serving as a board of directors (including organizations and individuals). One explanation of the theory from cognitive orientation perspective is that a given institution is encoded by actors through a social process and internalized societal attitudes are transformed into scripts. An institution is taking place when actors take actions according to the scripts and the institution is constantly reproduced following such mechanism. The establishment of institution externalizes or objectifies the institution and other actors witness that the institution is implemented and a new phase of socialization begins. As time passes by, the institution submerges and is considered as natural. After that, actors barely recognize the fact that their actual behaviors are partially controlled by the institution as taking actions following the institution is considered as rational based on the shared institution (Lee Chang-Kuk & Kim Yong-jin, 2015).

With the emergence of neo institutionalism starting from the study of Meyer & Rowan (1977), the significance of institution has been particularly emphasized in organizational studies and studies on institutions and relationships between institution and organization are actively carried out. The emergence of neo institutionalism in organizational studies has its root in the recognition that an institutional environment of which scope is wider than that of task or technological environments significantly affect the structure and operation of an organization (Kyungmook Lee, 1999).

2.4.2 Network theory

A network refers to a ‘connection system of various relations’ and it is commonly used as a general term with a high interest by many areas of studies. Recently, efforts are made to interpret and analyze social and economic symptoms based on the network theory in various forms (Barnes, 1979).

The network theory is mainly used to the research on relations between organization and the inside of the market as discussions on traditional relations between actors can be carried out by including both economic and non-economic activities. Hence, the network theory provides a comprehensive explanation on a network based on values of both utilitarian or exchange theory, and non-utilitarian perspective. According to the network theory, as a result, an efficiency and network value of an actor through exchange is specified through the network structure (Mizruchi, 1994). A network communication structure that strikes its balance by rational choices of individual actors is structured by combining both rational choices of humans and social values (Jackson and Rogers, 2007). Evaluation, acquisition, integration of a new knowledge and whether it can be commercialized are greatly affected by close and frequent interactions with other companies (Cohen & Levinthal, 1990; Dyer & Singh, 1998; Lane & Lubatkin, 1998). Also, most knowledge and capabilities created through such network are implicit intangible assets and close and frequent interactions between the members of network are needed to create a new knowledge and capability (Kogut & Zander, 1992, Hallėn et al, 1991; Hakansson & Snehota, 1997). It means that companies interact with many actors of innovation and they have closer relations and conduct relation-specific investments on certain actors (Andersson et al, 2001). Therefore, a possibility of creating a new knowledge increases according to the embeddedness between partners who more closely interacts with each other than other network partners (Eung Sok Lee, 2007).

Table 5. Previous studies on public S&T based startups

Author	Level of analysis	Data/methodology	Key findings
Louis et al. (1989)	Faculty of Life Science	Regression analysis on 788 professors at 40 colleges and universities	Determinants of faculty-based entrepreneurship: standards of local groups; policies and structures of universities have little impact
Zucker et al. (1998b)	Relations in which ‘star’ scientists and US biotech companies are included	Academic journal of science containing the discovery of sequencing and related data of a biotech company from North Carolina Biotechnology Center (1992) & Bioscan (1993)/ Count model analysis	The status of star scientists can predict the entry of biotech companies into the market

Zucker et al. (2000)	Relations in which 'star' scientists and US biotech companies are included	Academic journal of science containing the discovery of sequencing and related data of a biotech company from NCBC (1992) & Bioscan (1993)/ Count model analysis	Cooperation between a star scientist and corporate researchers lead to a better achievement of US biotech companies and the achievement can be measured by: number of patent registration, product developed, and products on the market
Audretsch (2000)	Biotech entrepreneurs	101 founders of 52 biotech companies / Hazard function used for regression analysis	University-based entrepreneurs tend to have more scientific experiences as they get older
Zucker and Darby (2001)	Relations in which 'star' scientists and Japanese biotech companies are included	Biotech companies and Nikkei biotech directory data	Cooperation between a star scientist and corporate researchers lead to a better achievement of Japanese biotech companies and the achievement can be measured by: number of patent registration, product developed, and products on the market
Franklin et al. (2001)	Relations in which 'star' scientists and US biotech companies are included	Quantitative survey of British TTOs by the author	Universities intend to transfer their technologies to startups successfully apply both academic and proxy entrepreneurship
Lockett et al. (2003)	TTOs and university-based startups	Quantitative survey of British TTOs by the author	Universities where startups are created mostly have transparent and well-defined venture strategies, entrepreneurship experts, and large social networks
Di Gregorio and Shane (2003)	University-based startups	AUTM survey/ count regression analysis on determinants by the number of startups	Two determinants of creating startups: capacity of universities and investors that can improve the professor quality and share of startups instead of license royalty fees; royalty distribution methods that are favorable to professors serve as a factor negatively affecting to startup creation
O'Shea et al. (2005)	University-based startups	AUTM survey/ count regression analysis on determinants by the number of startups	Successful technology transfer of university is a critical factor affecting the startup rate
Lockett and Wright (2005)	TTOs and university-based startups	Quantitative survey of British TTOs by the author/ count regression analysis on determinants by the number of startups	The ratio of university-based startups from the total has a positive relation to the amount of investment on IPR protection, project development capacity of TTOs, and the amount of royalty distribution for the faculty

Nerkar and Shane (2003)	MIT startups	Longitudinal data of MIT startups/ Hazard function used for regression analysis	'Fundamental character' of new technologies and their scope of patent application increases more in concentrated businesses than in distributed industries in terms of survival rate; effectiveness of technology strategy of startups is reflected by depending on the environment surrounding the industry
Meseri and Maital (2001)	TTOs and university-based startups	Quantitative survey of Israel TTOs by the author	To assess startup entrepreneurship, Israeli TTOs use standards that are similar to those that venture investors apply
Markman et al. (2004)	TTOs and university-based startups	AUTM survey/ survey by the author/ lineal regression analysis	Equity or licensing, and startup have correlations to the payment of TTOs; they do not have a correlation to royalties paid to the professors or have negative relations
Markman et al. (2005b)	TTOs and university-based startups	AUTM survey/ survey by the author/ lineal regression analysis	Three determinants of speeding up TTM; TTO resources, capability to identify licenses, involvement of faculty inventors during the licensing process
Markman et al. (2005a)	TTOs and university-based startups	AUTM survey/ survey by the author/ lineal regression analysis	It is highly likely that universities prefer an attractive combination of technology development phase and licensing strategy of a venture startup (licensing on initial state technology and its value) as it maximizes short-term profits and due to the fear of taking risks

Source: Siegel (2007), S&M Business Administration· Korea Institute of Startup & Entrepreneurship

2.5 Analysis on precedent studies and oversea cases

2.5.1 Analysis on precedent studies

Table 5 indicates previous studies on public S&T based startups.

2.5.2 Analysis on overseas cases[1)]

2.5.2.1 USA

The Bayh-Dole Act of 1980 was one of the most important measures that allowed public research institutes to actively engaged in the creation and management of intellectual property rights (IPRs) and the act permitted public research institutes to pursue a patent registration and license fee of inventions they made using federal funding.

Later, the US has implemented various policies to promote the technology transfer and commercialization of public R&D achievements for the growth of national economy based on technology innovation. Former president Obama sought the 'Startup America Initiative' to promote startups and emphasized the importance of commercializing public R&D inventions (Jan, 2011), and pursued the 'Lab-to-Market' policy to support major public agencies to commercialize their inventions they own and promote their technology transfer.

1) KISED (2017), Measures to promote strategic tech-based startups for the development of research institutes

Table 6. Main contents of Lab-to-Market

Dept./Institute	Description
Dept. of Energy (DOE)	Sponsored the National Incubator Initiative for Clean Energy (NIICE)
Dept. of Defense (DOD)	Sponsored the Pracademic Center of Excellence in Technology Transfer (PACE/T2), a center for commercialization and technology transfer of Arizona State University
National Health Institute (NIH)	Implemented the Breast Cancer Startup Challenge
National Science Foundation (NSF)	Provided entrepreneurship training programs to researchers through the Innovation Corps (I-Corps)

The US government has set cross-agency priority goals to manage the outcome of lab-to-market initiative in order to encourage related activities. When requesting the congress for the 2015 federal spending, the government stressed the significance to speed up the implementation of 'Lab-to-Market' initiative and provided related plans through President's Management Agenda (PMA).

A representative case of Lab-to-Market is collaboration between NIH and NSF to encourage entrepreneurship for scientists. The NIH plans to induce researchers and corporates supported by the small business innovation research (SBIR) and small business technology transfer (SBTT) programs to participate in NIH Innovation Corps (I-Corps) program, an adjusted version of NSF's I-Corps for biomedical technology. NSF has been operating NSF I-Corps that provides researchers funded by NSF with training programs and consulting services since 2011.

2.5.2.2 Europe

France, a traditional science and technology powerhouse, has institutionalized the establishment of a company and participation of management by public research institutes since 1982. The French Institute for Research in Computer Science and Automation (INRIA) and the French Alternative Energies and Atomic Energy Commission (CEA), and other public research institute has established subsidiaries to commercialize the inventions with ownership by themselves. The increase of portfolio companies that public R&D institutes are directly and indirectly involved in the management leads to the foundation of a specialized company for commercialization (or technology holding company) with expertise in effective investment and performance management, and promotion of activities related to the foundation of new companies.

Sweden, a country that is constantly ranked among the highest in national competitiveness and innovation indicator, has a characteristic of university-centered technology commercialization policy. At first, there were many restrictions as they were managed as a public sector under the influence of the government. For example, they were not allowed to establish a company by themselves. Also, the startup rate of universities based on the inventions they owned was low compared with other OECD companies as the supporting structure and incentives for new technology-based startups were relatively weak, despite university-centered public R&D structure. However, the country allowed universities to establish technology holding companies in 1994 based on the decision that innovating its economic structure through startups was needed. As a result, many technology holding companies, of which stakes were owned by universities, were founded by 11 universities including GU Holding by University of Gothenburg and Uppsala universitets Utveckling AB (UUAB) by Uppsala University in 1994 and 1995.

Denmark, a small but strong country, established related laws in 2004 and began to encourage activities to promote technology transfer, establish companies, and invest on existing companies of public research institutes. At the same time, the country has provided clear principles on the scope of (capital) investment and area of business of public research institute. For instance, where a public research institute establishes or takes part in the establishment of a company, there should be no conflicts to its public duty, and the equity value or and amount of investment for starting a business should not excess 3% of R&D budget or about $75,000. It was designed to contain concerns about decreasing publicness while realizing expected effect when public research institutes participate in technology commercialization by establishing subsidiaries and with other methods.

3. Status of public technology-based startups

Although the ratio of creation and extinction of startups in Korea is at high class among OECD countries as of 2013 and Korea is a very active country in both emergence and collapse of new companies, it is difficult to evaluate that startups in Korea bring fruitful results. As for the ratio of startup creation, the UK showed the highest score with 15.4% and Korea was in the upper ranks with 13.8%. However, its rate of startup extinction is also relatively higher than that of other countries with 12.1% (2nd place) (National Assembly Secretariat, 2017).

As of 2014, the survival rate of startups in Korea was less than 50% and about 27% after 3 years and 5 years from their inception, respectively, and the figure decreases as the years of survival extend. However, the survival rate of public technology-based startups is higher than the total number of companies. Over 80% of public technology-based startups survive after 1 to 5 years from their inception and showed a high survival rate even if the period of operation gets longer. It can be said that public technology-based startups are created by having their roots in technologies that are developed through government-led efforts and they are usually related to big science and technical skills that civilians are hard to get access to. Hence, public technology-based startups have a huge growth potential in the future for a long period of time.

Table 7. Survival rate of public technology-based startups in South Korea

Classification	2011	2012	2013	2014	2015
1-year	100.0%	94.3%	96.0%	89.3%	98.3%
2-year	81.8%	100.0%	94.3%	96.0%	83.9%
3-year	77.%	81.8%	100.0%	85.7%	92.0%
4-year	-	77.8%	81.8%	93.1%	74.3%
5-year	-	77.8%	77.8%	68.2%	89.7%

Source: National Assembly Research Service (2017)

Table 8. Classification of public technology-based startups

(unit: Number of cases)

Organization		Startups created by concerned researchers and institutes	Companies established through technology transfer	Total
	Public research institute	48	7	55
	Universities	171	33	204
	Others	6	1	7
Total		225	41	266

Source: Survey report on technology transfer and commercialization of Korea (2017)

As of 2017, a total number of 266 startups was created based on public technologies owned by public research institutes (including public research institutes and universities). Among them, 225 cases were directly created by the researchers and institutes, and 41 companies were newly set up through technology transfer.

4. FGI analysis

4.1 Respondents and methods of FGIs

Focus group interviews (FGIs) on experts of concerned areas were made for reference to the analysis on issues for scientists and engineers to start a new business and development of improvement measures. Some of them were used to solidify the validity of hypotheses developed in chapter 5 and others were used as grounds for policy establishment in chapter 6.

The FGI was conducted on 8 persons including 3 researchers, 3 TLO members, and 2 employees of a technology trading association and company specializing in technology commercialization in order to reflect opinions of various fields. The years of service of selected respondents were over 5 years in an effort to ensure their expertise.

Also, S&E respondents who actually try to realize entrepreneurship were selected among the ones who had experienced to start a business or ones who were preparing to start a new one in order to collect the information that is needed for startups in reality.

TLO members of public research institutes frequently communicate with researchers for technology transfer and play leading roles in carrying out commercialization activities. Hence, their opinions were collected from the perspective of overseeing the entire process. Technology trading association and commercialization expert companies were chosen as interviewers as they could provide their opinions as the technology market participants. Face-to-face interviews were made in principle and additional opinions were often reflected via e-mail and on the phone.

4.2 Result of FGI analysis

The following table provides a summary of opinions collected from the FGIs. They were classified into four categories of institution, training, cooperation, and organization.

Table 9. Result of FGI analysis

Respondents	Opinions	Type
Scientists & engineers	There is a less chance to get access to technology entrepreneurship and startups created by researchers. It would be better to have an opportunity to learn about them in depth.	Training
	Comparing to incentives provided after conducting government funded R&D project on a stable basis, conditions to compensate the difficulties and uncertainties of startups (concurrent position, reinstatement, winning R&D bidding, etc.) are insufficient and not unattractive	Institution
	There are not many successful cases of tech-based startups created by S&Es	Training
	Many have little knowledge of detailed procedure or support projects to start a business based on the inventions with ownership	Training
	It is difficult to prepare startups in reality due to complex startup application and deliberation process, and too many documentation works	Institution
	There are many irrational terms and conditions of agreement between a researcher and institute that would break one’s will to start a business	Instituion
	Lack of training and education programs related to corporation establishment, taxation, and accounting for startups built by researchers	Training
TLO	Strategic directions of an agency or department goals are focused on technology transfer and it is difficult for researchers to make efforts for tech-based startups	Organization
	It is difficult to actively promote successful cases of tech-base startups built by researchers as they are rare except but Kolmar BNH Co., Ltd.	Training
	Organizational culture of public research institutes does not encourage researchers to start a business directly and they do not have sufficient organizational capacities to support the operation from the initial stage of startups	Organization
	Most TLO resources are concentrated on technology transfer that take the largest part of its business due to manpower shortage and it is difficult to inject the resource to commercialization or startup phase in reality	Organization
	It is difficult to find out external organizations specializing in startups built by researchers	Cooperation
	For a researcher to start a business, much support is needed. Lack of feedback from TLO members may lead to lack of drive	Instituion
Technology trading agencies and commercialization expert company	As for startups by a researcher, it is difficult to share the information as most projects were conducted within the public research institute. Hence, joint participation from the initial period can be hard	Cooperation
	Relationships to public research institutes are related to inquiry on relatively stereotypical business such as technology licensing, valuation, etc. and are mostly about outsourcing requests. Therefore, complex issues such as startups are difficult areas of collaboration	Cooperation
	Difficult for employees to acquire expertise in concerned areas as startup by researchers are not many	Organization
	There are no mandatory rules for private institutes get a separate stake or royalty even when a startup built by researchers were established successfully and there was a fruitful result	Institution

4.3 Problems and improvement measures

The FGI analysis was carried out and identified issues were summarized by classifying them into 4 categories (including institute, training, cooperation, and organization).

As for institution, internal regulations related to startups were established in favor of the institution and which makes researchers difficult to prepare new business and run a company. Lack of incentive systems that may induce cooperation from the inside and outside of an institution was also identified. As for training, learning opportunities for scientists and engineers to cultivate entrepreneurship are basically insufficient as well as the ones to experience practical business related to startups. As for cooperation, lack of mutual information for cooperation between public research institutes and private companies (such as technology trading association and companies specializing in commercialization, etc.) is considered as a problem and they do not well aware of the need to share the information. As for organization, lack of ability to set up management goals, supporting organization, and resources for startups make researchers difficult to get the support they need to prepare for starting a business or carrying out following process.

To come up with improvement measures to resolve issues listed as above, first, there is a need to revise or establish internal regulations related to startups and establish an incentive system for startup contributors (including TLO members, external agencies, etc.). Second, include and operate startup related courses to the job training programs and install regular online/offline programs in Korea Institute of R&D Human Resource Development (KIRD) which is in charge of government-funded training so that researchers can access to various startup related training programs. Third, there is a need to frequently hold meetups and work meetings between public research institutes and private companies before they enter into agreement officially in order to increase mutual understanding on their business, and prepare standard contract forms of each type of business cooperation. Lastly, public research institutes by themselves should make efforts to create a mood for startups by including starting a business as a work task and actively support startups built by research teams by increasing the number of experts in TLO.

5. Analysis on factors affecting public technology-based startups

5.1 Hypothesis establishment

As for market-friendly advanced countries, public research institutes are easy to engage in activities to start a business with their own strategies. However, in Korea, activities related to starting a business are affected by internal regulations established in line with upper levels of government legislation. Also, it is true that startups involving in direct market participation activities, rather than traditional R&D business are taking passive approaches to startups from the institutional level as it has an impact on both the individual and the reputation of the institution concerned. Hence, it is expected that reviews on hypothesis related to the training system to activate startup support system and startups that regulations of institutions are directly applied.

The role and importance of innovative network for a company to maintain its competitiveness continuously in uncertain management environment have been stressed out. An innovative network helps to acquire new knowledge from partners, share risks and uncertainties with them, and provide effective mechanisms in order to respond to organizational innovation (Gilsing & Nooteboom, 2005; Rampersad et al., 2010). Companies are well aware that it is impossible to provide all resources required to obtain and maintain their competitive edge and innovation with internal resources only and are making many efforts to secure measures to utilize resources from external networks to overcome such disadvantages (Yu et al., 2004). Cooperation between internal and external members of network is considered to have a positive impact on startups of scientist and engineers working at public research institutes.

However, it turned out after reviews on precedent studies that there are not ones analyzing factors affecting startups of scientists and engineers from the perspectives of institution and cooperation. Hence, 2 hypotheses were established based on institutional and network theory for each.

5.1.1 Institutional aspect

As for institutional aspect, an analysis was made on determinants of creating research-based spin-offs and their outcome focusing on research institutes such as technology transfer organizations of public research institutes, and unofficial institutions including policies, procedures, practices with regard to commercialization of public research institutes (Kim Yi-soo, 2009).

Public research institutes have unique culture, inducing systems, and rules and procedures (Moray & Clarysse, 2005). Therefore, impacts posed by policies, procedures, and practices of research institutes regarding the commercialization of their research outcome are significant to the achievement of research-based spin-offs and they can serve to trigger more entrepreneur activities (Kim Yi-soo, 2009).

Considering that researchers of public research institutes relatively more tend to avoid risks and hesitate to engage in challenging activities to start a business (KISED, 2017) as they are highly paid and due to a high job security, it is expected that providing programs from the institute level that support startups of researchers will promote more creation of startups.

(Hypothesis 1) A startup support program would have a positive impact on startups of scientist and engineers.

Firms' ability to constantly acquire intellectual resources (such as technology, knowledge, know-how, and skill) is considered as a factor creating their competitive edge (Wernerfelt, 1984;, Teece et al., 1997; McGrath, 2001) and it is an important determinant that maintains their such capability. Hence, the importance of training program to enhance the learning capability of the inside of organization is stressed. Phan et al. (2006) said that training programs for researchers serve as a positive factor in increasing the effectiveness of technology transfer of universities, and Lee Seung-keun et al., (2005) argued that education and training during the process of technology transfer provide a positive impact on the performance. Therefore, it is expected that running training programs for researchers such as technology commercialization, entrepreneurship, startups, etc. will be helpful in promoting activities with regard to startups.

(Hypothesis 2) Training programs will have a positive impact on startups of scientists and engineers

5.1.2 Network aspect

Many research findings confirmed that a network capability is important to both technology transfer and commercialization. In particular, Santoro and Chakrabarti (2002) emphasized the importance of communication between members of technology transfer-related organizations, and they said that free and flexible exchanges between researchers and engineers of universities, and research staff of companies promote the technology commercialization as the technology transfer takes place through a close and individual network between them. In addition, external cooperation among various external partners, customers, experts, etc. (Laird & Sjoblom, 2004) and use of a close external cooperative network are significantly important for the success of technology commercialization (Santoro & Chakrabarti, 2002).

When it comes to startups of researchers, cooperation with TLOs is necessary and it is expected that continuous efforts to create a network with various external actors (such as VCs, RTTCs, and technology commercialization companies, etc.) will play a critical role.

(Hypothesis 3) Regular exchanges between researchers and TLOs will have a positive impact on startups of scientists and engineers.

(Hypothesis 4) Work exchanges with external organizations will play a positive role for scientists and engineers to start a business.

5.2 Methods of analysis and its design

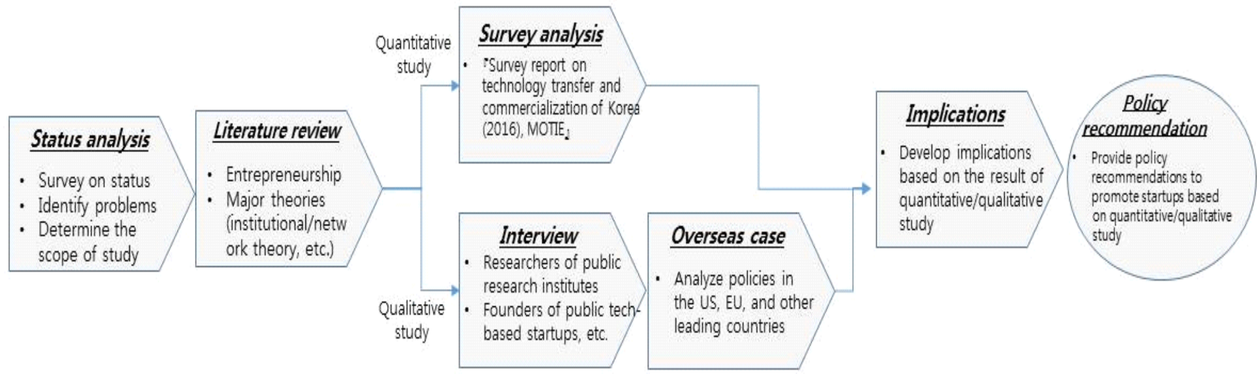
5.2.1 Data and analyzing methods

This study used 「Survey report on technology transfer and commercialization of Korea」, as a basic material. MOTIE releases the survey each year on public research institutes of Korea (including universities and research organizations) since ’07. It is an official survey conducted on public research institutes defined in 「Technology Transfer and Commercialization Promotion Act」 according to KOSTAT approved statistics (Government approved statistics No. 11522) and highly reliable compared with other surveys conducted by individual researchers. It has high analytical values from its representativeness as it surveyed all public research institutes of Korea. This study used the 2016 data that surveyed on 250 public research institutes with smallest missing values for the analysis.

The subjects of analysis were public research institutes, representative public research organizations. Universities carry out education and training activities to nurture research talents and mainly conduct researches on the fields of basic science (Cho Hyun-dae, 2007). University professors work within an academia group where they belonged, and their research activities are mostly taking place by presenting thesis on academic journals (Kim Hyung-joo et al., 2013). However, research institutes are given tasks to conduct public R&D projects that are difficult to be carried out by corporates and universities, assigned such identity within the framework of national innovation system, and they are operated as leaders in implementing national R&D projects to prevent market failures and fill the institutional loopholes in national R&D (Lee Jang-jae et al., 2011).

A general regression analysis can not be applied to the study as the data on the existence of startup support system and internal cooperation used for the study were nominal scales and only two dependent variables were generated. Also, count data such as the number of programs provided, number of agreements signed, etc. cannot have positive values. It was discrete and showed a skewed distribution. Therefore, a negative binomial regression analysis that used a non-linear model based on a probability distribution function, which was proper to be applied to a count data, was adopted in order to develop the most appropriate model to the characteristics of distribution of dependent variables or count data, and relations between dependent and independent variables.

Figure 1. Research model



5.2.2 Variable measurement

As for dependent variables, a number of startups, result of entrepreneurship of scientists and engineers (researchers) was calculated. The number included startups by individual researchers based on the invention owned by public research institute and ones created directly by the concerned institute.

As for independent variables, the existence of system that supports startups by researchers, and the number of training programs for researchers such as entrepreneurship, technology commercialization, startup, etc. were measured. Also, whether researchers and TLOs were having regular exchanges and the degree of cooperation with external organizations were checked and measured from the network perspective.

As for control variables, the number of research personnel working at research institutes were measured.

The operational definition of variables is summarized as follows.

Table 10. Operational definition of variables

Classification	Variable name	Operational definition
Dependent variable	Number of startups	Number of startups directly created by researchers or institutes based on the technologies they owned
Independent variable	Startup support system	Existence of system that supports startup by researchers based on the technologies they owned
	Startup training program	Number of training programs for researchers with regard to startups
	Cooperation within the organization	Existence of regular exchanges with TLOs
	Cooperation with external organizations	Number of business agreement signed with external organizations
Control variable	Number of research personnel	Number of research staff working at research institutes

Table 11. Elementary statistics

Variable name	N	Mean	Standard deviation	Minimum value	Maximum value
Number of startups	112	0.3392857	1.527841	0	14
Number of research personnel	94	254.234	480.0404	0	3802
Startup support system	109	1.642202	0.4815664	1	2
Startup training program	112	2.053571	3.405981	0	20
Cooperation within the organization	109	1.53211	0.5012726	1	2
Cooperation with external organizations	112	0.5625	1.393558	0	9

Table 12. Result of correlation analysis

Variable name	1	2	3	4	5	6
1. Number of startups	1					
2. Number of research personnel	0.3993	1				
3. Startup support system	-0.2907	-0.2671	1			
4. Startup training program	0.431	0.2796	-0.5804	1		
5. Cooperation within the organization	-0.1936	-0.1343	0.4508	-0.3946	1	
6. Cooperation with external organizations	0.3242	0.1785	-0.4428	0.4776	-0.3083	1

* P<0.01

5.3 Result of analysis

5.3.1 Elementary statistics

A total number of 146 public research institutes in Korea was surveyed and 139 institutes answered the questionnaire. The following table indicates the basic statistics that were obtained by analyzing 112 institutes excluding the ones of which data was difficult to be used due to missing too many data.

5.3.2 Correlation analysis

A correlation analysis is a method of statistics used to analyze close linear relations between two variables and it can evaluate correlation between the measurement levels by analyzing the correlation between the concepts injected. The following table indicates the result of correlation analysis of this study. The results showed correlation between variables were not high as all values were relatively low below 0.5. Hence, it is expected that they would not compromise the purpose of estimation significantly to identify influencing factors.

5.3.3 Result of regression analysis

In this study, a negative binominal regression analysis was conducted in order to verify hypotheses on influencing factors affecting startups of scientists and engineers and the results were as follows.

First, an integration model 4 was developed by combining each factor and three individual models (model 1, 2, and 3) were made to identify each factor in detail.

Other than model 4 (integrated model), model 1, 2, and 3 have the number of startups as dependent variables, and contain the number of researchers as control variables. When control variables are excluded, model 2 and model 3 show explanatory power for startups by including institutional factors and network factors only as independent variable, respectively.

To proof the compatibility of models, the Wald Chi-Squared Test was used and the result found that each model held a sufficient explanatory power.

In order to identify the impact of individual independent variables on startups, startup training program among institutional factors had a positive impact in 10% level of significance and startup support system had no impact in model 2.

In model 3, cooperation with external organization among network factors had a positive impact on startups in 5% level of significance and cooperation within organization showed no statistical significance.

In model 4, only cooperation with external organization was appeared to have a positive impact on startups in 5% level of significance.

Overall, startup training program and cooperation with external organizations were accepted and cooperation within organization was rejected.

Table 13. Result of regression analysis

Variable name		Model 1	Model 2	Model 3	Model 4
Number of research personnel		0.003**	0.001	0.002***	0.002***
		(0.001)	(0.001)	(0.001)	(0.001)
Institutional factors	Startup support system		-18.334		-18.639
			(1981.804)		(1322.604)
	Startup training program		0.150*		0.079
			(0.091)		(0.073)
Network factors	Cooperation within the organization			-0.484	0.390
				(0.792)	(0.765)
	Cooperation with external organizations			0.491**	0.292**
				(0.211)	(0.129)
Constant term		-2.319***	16.562	-2.153*	15.907
		(0.577)	(1981.805)	(1.295)	(1322.604)
Chi2		10.551	33.180	21.339	38.083
N		94.000	91.000	91.000	91.000

* $p<0.1$, ** $p<0.05$, *** $p<0.01$

Table 14. Result of hypothesis testing

	Operational definition	Accepted/rejected
Hypothesis 1	Startup support system will have a positive impact on startups	Rejected
Hypothesis 2	Startup training program will have a positive impact on startup of scientists and engineers.	Partially accepted
Hypothesis 3	Regular exchange between researchers and TLOs will have a positive impact on startup of scientists and engineers.	Rejected
Hypothesis 4	Business cooperation with external organizations will have a positive impact on startup of scientists and engineers.	Accepted

6. Policy recommendations and conclusion

Now is the time that public research institutes that conducted government-funded R&D projects only on a stable basis in the past should play an important role by bringing outstanding outcomes and effectively discovering seeds of technologies they owned, and commercializing and starting a business based on them to increase their social and economic use, and creating a virtuous circle.

Hence, this study intended to identify positive factors triggering entrepreneurship for scientists and engineers, main actors of R&D, by applying both qualitative analysis based on FGIs and quantitative statistical analysis on survey data. The result showed that cooperation between public research institutes and external expert organizations is the most critical determinant for startup of scientists and engineers. Hence, this study suggests following policy recommendations to promote startup of scientists and engineers through cooperation between public research institutes and outside specialized agencies.

First, expanding a cooperative network with outside specialized agencies and share the information focusing on their competencies.

Technology trading agencies, TLOs, RTTCs, and technology valuation agencies are considered as the third actors of utilizing and commercializing the result of R&D by playing the role of messengers that link the creation, use, and commercialization of R&D achievement (Yang Seung-woo et al., 2013). In 2010, the government adopted a system of designating an entity that meets certain standards such as dedicated talents, facilities, etc. among companies specializing in technology commercialization to provide financial support for commercialization activities and a preferential right to participate in technology transfer and commercialization projects to promote technology commercialization of private sector. Companies specializing in commercialization engages in business activities such as collection, analysis, and provision of commercialization-related information, support for the exploration, development, convergence, etc. of technologies to advance commercialization, counseling and consulting for commercialization, and invitation and investment of funds necessary for commercialization. As of July, 2018, 29 companies specializing in commercialization are operating their business in Korea.

With regard to startups of scientists and engineers, cooperation with companies specializing in commercialization is needed. However, it was difficult to gather the information on them including their precise size, main areas of activities, status of startup supporting persons, startup reference, etc. Hence, there is a need to provide detailed information on such private specializing companies so that public research institutes can select a partner that is optimal to the areas concerned, size, and type of tech-based startups that they intend to pursue.

Currently, 29 companies specializing in commercialization is concurrently conducting technology trading or brokering business and there are no ones specializing in startups of scientists and engineers only. Hence, there is a need to promote the designation system to include companies with expertise as companies specializing in commercialization, and develop inducements and other measures to expand the pool.

Second, encourage to conclude business agreements with regard to startups and provide related guidelines.

As of 2015, the share of public research institutes that conclude business agreements with universities and research organizations, companies, patent consulting companies, expert technology trading agencies, etc. at home and abroad for technology transfer and commercialization is a 33.3%, totaling 519 cases (1.9 for average)[2]. The number of business agreement signed is increasing each year as 371, 437, and 357 cases in ’12, ’13, and ’14, respectively.

Most of them are related to technology transfer and they are dealing with demand discovery, marketing, brokering, fees, etc. Business agreements related startups of scientists and engineers are difficult to be concluded without willingness of public research institutes and the number of deals completed is not many as well. Hence, it is natural that the private sector reacts passively to sign such agreements. Under such circumstances, the government needs to encourage both parties to conclude business agreements as a position of middleman to coordinate the process smoothly.

Also, creating an agreement by themselves is difficult as it contains many sensitive terms such as states, licensing fees, post-support, etc. compared to general contracts. Therefore, it would facilitate mutual cooperation if the government provides standard business contract samples and guidelines.

Third, operate a startup related consultative body for regular exchanges on information and opinions with regard to startups.

As seen from the result of FGIs, both public research institutes and companies specializing in commercialization face difficulties in the early stage of mutual cooperation as the public research institutes lack of basic information on companies specializing in commercialization when it comes to which company they should contact, and companies specializing in commercialization do not know the status of startups of scientists and engineers working at public research institutes.

Therefore, there is a need to install a consultative body to improve mutual understanding and share their issues all the time. It would be desirable that the promotion agency of each ministry[3] hold such meetings on a regular basis and play the role of facilitator of cooperation between public institutes and companies specializing in commercialization.

Fourth, creating and expanding startup related projects that both public research institutes and specialized agencies can jointly participate.

Currently, public organizations and specialized agencies are partially participating in support projects related to technology transfer and commercialization. Technology transfer supporting projects are conducted to create a network for technology trading promotion, utilize public R&D outcomes, and contribute to the enhancement of technological competitiveness of small and established companies, and joint TLO support projects are exemplary projects. Commercialization projects support additional development of promising technologies or commercialization of ideas owned by companies to facilitate the process, help them enter into markets

2) MOTIE, “Survey report on technology transfer and commercialization of Korea,” 2016

3) Each ministry has a dedicated agency specializing in research management activities such as planning, management, and evaluation of national R&D projects assigned by the government. It plays a role of promotion agency to expand the R&D outcomes and facilitate their commercialization in particular

and create profits stably. Examples of commercialization support projects are commercialization connecting technology development business (R&BD, by MOTIE), and investment-linked public technology commercialization support project (MSIT).

However, there are no projects that directly support startups of scientists and engineers and there is a need to create the concerning support project for the long term. The first step is to officially launch a separate track that supports startups of scientists and engineers with the existing technology transfer and commercialization support projects to promote joint participation of public institutes and specialized agencies.

In line with policies to promote startups of scientists and engineers based on cooperation between public research institutes and private specialized agencies, there is a need to consider startup programs for scientists and engineers. Results of statistical analysis showed its significant effect to startups in part and a necessity of providing startup training was raised several times in FGIs.

Although many organizations provide startup related training programs, there are no ones for researchers working at public research institutes. Similarly, there are training programs that are held on the topic of technology commercialization. However, they are mostly focusing on transfer of technologies with ownership and far from starting a business.

Therefore, scientists and engineers who are interested in starting a business should find and attend such programs provided by other agencies and they are not of a great help as most of them are far from the reality of scientists and engineers.

Hence, the government should create training programs that can help scientists and engineers can start their business based on the technologies they developed in KIRD, an organization that is responsible for government-funded research institutes, and the research institutes by themselves to promote their entrepreneurship.

A limitation of this study is that time series analysis was not made. Variables were extracted from the 2014~2016 DB that was obtained from the planning stage and they were turned out that they contained missing data and incomplete answers of survey respondents. Therefore, the statistical analysis was conducted by using the 2016 DB only. It is impossible to complement the DB of the past. On the contrary, it would be meaningful to follow the trends by conducting a time series analysis, if the DB of 2017 and 2018 can be obtained in the future.

Also, it is possible to carry out an in-depth analysis on government-funded research institutes, technology institute specializing in manufacturing, national and public research institutes, universities, etc. main actors of national R&D projects, by considering their characteristics, if the DB with high completion is secured.

Also, there is a need to study the factors and path of successful startups of scientists and engineers. Of course, it will not be easy and such analysis cannot be carried out right away due to difficulties in obtaining related data and lack of samples. Studies on related fields are necessary to provide guidelines for scientists and engineers who are preparing for startups.

Reference

Ahn Kwang-ho, Yu Chang-jo, Jun Seung-woo. (2008), Kotler’s introduction to marketing, Ggyeongmunsa

Ahn Seung-gu. (2017). A Study on the Factors Affecting the Performance of Technology-based Startups: Focusing on the Analysis of Policy Effectiveness, Korea Institute of S&T Evaluation and Planning

Byun Soon-chun, Kim Jin-yong, Shim Jeong-min, Kim Sung-jin, Kim Yang-jin, Park Jin-woo, Park Se-jin. (2013). Future Direction of HRST Policy: Lessons from History, Korea Institute of S&T Evaluation and Planning

Cho Hyun-dae. (2007). The Evolution of Public Research Systems of Major Countries and Policy Recommendations for Korea, Science and Technology Policy Institute

Eung Sok Lee. (2007). A study of MNE Subsidiary R&D Initiative in Korea: Resource Based and Network Theory, International Business Journal Vol. 18. Issue 1, 59-85.

Hyundai Research Institute. (2013). Creative startups do not exist, Monthly Economic Review, Vol. 534

Hyundai Research Institute. (2016). A need for enhancing the effectiveness of venture promotion support policies. Issues and tasks, Issue 16-13

Jin Mi-seok, Um Mi-jeong. (2007). Future Changes of HRST Policy Environment and New HRST Policy Strategies in Korea, Science and Technology Policy Institute.

Kil Un-kyu·Shim Yong-ho·Kim Sung-kyun. (2014). Literature review to deduce success factors of technology-based startups, Korea Technology Innovation Society academic conference collection of dissertations, 252-260.

Kim Hong-young, Bae Yong-kuk, Choi Moon-young. (2015). Measures to improve the structure of government sponsored R&D projects to foster scientists and engineers, Korea Institute of S&T Evaluation and Planning.

Kim Hyung-joo·JeungMi-ae·UmMi-jeong·SeoHong-yong.(2013).MovingUniversityFaculty'sCollaborationswithIndustriestoPromoteAcademicKnowledgeTransfer.ScienceandTechnologyPolicyInstitute,ResearchPolicy2013-16

Kim Yi-soo. (2009). , doctoral thesis at Seoul National University

Korea Institute of Startup & Entrepreneurship Development. (2017). Measures to Promote Strategic Tech-based Startups for the Development of Research Institutes

Kyungmook Lee. (1999). Institutional theory: Key issues and future study directions, Institute of Management Research at Seoul National University Business School, the Journal of Management, vol.33(4), 382-409.

Lee Chang-Kuk, Kim Yong-jin. (2015). Responding patterns of IT service providers according to participation restriction of large companies to public markets: Based on Institutional Theory, Korea Society of Management Information Systems Fall Conference, 149-161.

Lee Jang-jae, Lee Kang-chun. (2011). Exploratory approaches in responding to open innovation and government contribution, Korea Technology Innovation Society Academic Conference, 26-45.

Lee Jung-jae, Ko Yong-soo, Heo Dae-nyung, Shim Jeong-min, Kim Jin-yong, Kim Hyun-min, Do Kye-hun. (2008). A study on the future's strategy of human resources in S&T, Science and Technology Policy Institute

Lee Seung-keun, Ahn Sung-jo, Lee Kwan-Ryul. (2005). A Study on Technology Transfer Performances and Its Determinants of Technology Licensing Organization, Journal of the Korean Regional Development Association, 17(3), 31-50.

Ministry of Science and Technology. (2006). A study on planning for R&D human resource academy establishment, Ministry of Science and Technology

National Assembly Research Service. (2017). Status and implications of public tech-based startup indicators, issues identified from indicators

Rudolf Sinkovics & Byung Il Park. (2017). Institutional Theory and MNEs' Contributions to Social Safety Net in Local Markets: Subsidiary perspective, International Business Journal, Vol 28, Issue 1

Yang Seung-woo, Bae Ji-sun, Lee Myung-hwa, Kim Jae-kyung, Kwon Bo-kyung, Han Jeong-sun. (2013). Analysis and Legislative Measures for Improvement of Legal Framework Related S&T in Korea – FocusedonUtilizationandCommercializationofNationalR&DResults,ScienceandTechnologyPolicyInstitute

Anderson, M., Holm, U. and Holmstrom, C. (2001). “Relationship Configuration and Competence Development in MNC Subsidiaries,” In Hakansson, H. and Johanson, J. (Eds.), Business Network Learning, Amsterdam: Pergamon. 185-205.

Chun, Y. H., and Rainey, H. G. (2005). “Goal ambiguity and organizational performance in US federal agencies”. Journal of Public Administration Research and Theory, Vol.15(4), 529-557.

Cohen, W. and Levinthal, D. (1990). “Absorptive Capacity: A New Perspective on Learning and Innovation,” Administrative Science Quarterly, 35, 128-152.

Covin, J. G. & Slevin D. P. (1991). "A conceptual model of entrepreneurship as firm behavior", Entrepreneurship Theory and Practice, 16(3), 7-25.

DiMaggio, P. and Powell, W. W. (1983), "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields," American Sociological Review, 48(2), 147-160.

Dollinger. M. J. (1983). "Use of Budner's Intolerance of Ambiguity Measure for Entrepreneurial Research", Psychological reports, 53(3), 1019-1021.

Dorf R. C. and T. H. Byers. (2005). "Technology Ventures: From Idea to Enterprise", New York, McGraw-Hill

Dyer, J. and Singh, H. (1998). "The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage," Academy of Management Review, 23, 660-679.

Gilsing, Victor A. and Nooteboom, Bart. (2005). "Density and Strength of Ties in Innovation Networks: An Analysis of Multi-Media and Biotechnology , CentER Discussion Paper No. 2005-41.

Giselle Rampersad, Pascale Quester, Indrit Troshani. (2010). "Examining network factors: commitment, trust, coordination and harmony", Journal of Business & Industrial Marketing, Vol. 25 Issue: 7, 487-500.

Hallėn, L., Johanson, J. and Seyed-Mohamed, N. (1991). "Interfirm Adaptation in Business Relationships," Journal of Marketing, 55, 29-37.

Hakansson, H. and Snehota, I. (1997). "Developing Relationships in Business Networks". London: Routledge.

Jackson, M. O., & Rogers, B. W. (2007). "Meeting strangers and friends of friends: How random are social networks?". American Economic Review, 97(3), 890-915.

Kogut, B. and Zander, U. (1992). "Knowledge of the Firm, Combinative Capabilities, and The Replication of Technology," Organization Science, 3, 383-397.

Lane, P. J. and Lubakin, M. A. (1998). "Relative Absorptive Capacity and Interorganizational Learing," Strategic Management Journal, 19, 461-477.

Laird, L. and Sjoblom, L. (2004). "Commercializing Technology: Why is it so Difficult to be Disciplined?", Business Horizons, Vol.47(1),.65-71.

Lassen, A. H., F, Gertsen and J. O. Riis. (2006). "The Nexus of corporate entrepreneurship and radical innovation:, Creativity and Innovation Management, 15(4), 359-372.

Lumpkin, G.T. and Dess, G.G. (1996). "Clarifying the Entrepreneurial Orientation Construct and Linking It to Performance", Academy of Management Review, 21, 135-172.

McGrath, J. E. (1964). "Toward a "Theory of Method" for Research on Organizations". In W. W. Cooper, New Perspectives in Organization Research. 533-556.

Meyer. J. W., and Rowan, B. (1977). "Institutionalized organizations : Formal structure as myth and ceremony", American Journal of Sociology, Vol.83, 340-363.

Miller, D. (1983) "The Correlates of Entrepreneurship in Three Types of Firms". Management Science, 29, 770-791.

Mizruchi, M. S. (1994). "Social network analysis: Recent achievements and current controversies". Acta Sociologica, 37(4), 329-343.

Moray N, Clarysse B. (2005). "Institutional change and resource endowments to science-based entrepreneurial firms", RESEARCH POLICY, Vol: 34, Pages: 1010-1027.

Rothwell, Roy and Zegveld, Walter. (1982). "Innovation and the Small and Medium Sized Firm". University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship

Phan, Philip H. and Siegel, Donald S. (2006). "The Effectiveness of University Technology Transfer: Lessons Learned from Quantitative and Qualitative Research in the U.S. and the U.K", Rensselaer.

Santoro, M. D. and Chakrabarti, A. K. (2002). "Firm Size and Technology Centrality in Industry-University Interactions", Research Policy, Vol.31(7), 1163-1180.

Schumpeter, J. (1934). "The theory of economic development". Cambridge, MA: Harvard University Press

Shane, S. and and S. Venkataraman. (2003). "'Guest editors' introduction to the special issue on technology entrepreneurship'", Research Policy, 32(1), 27-48.

Siegel. (2007). "Quantitative and qualitative studies of university technology transfer: synthsis and policy recommendations", in Audretsch, D.B., Grilo, I. and Thurik, A. R. (eds.), Handbook of Research on Entrepreneurship Policy, pp. 186-199, Edward Elgar.

Simonin, B. L. (1999). "Ambiguity and the process of knowledge transfer in strategic alliances". Strategic Management Journal, 20(7), 595–623.

Suchman, M. C. (1995). "Managing Legitimacy: Strategy and Institutional Approaches", Academy of Management Review, 20, 571-610.

Teece, J. Pisano, G. and Shuen, A. (1997). "Dynamic capabilities and strategic managemen"t, Strategic Management Journal , Vol. 18, 509-534.

The Canadian Academy of Engineering. (1998). "Wealth through Technological Entrepreneurship", Ottawa

Wernerfelt, B. (1984). "A Resource-based View of the Firm, Strategic Management Journal. (1984), Vol.5(2), 171-180.

Yu, B., Hao, S., Ahlstrom, D. et al. Asia Pac J Manag. (2014). "Entrepreneurial firms' network competence, technological capability, and new product development performance", Asia Pacific Journal of Management, Volume 31, Issue 3, 687–704.