Analysis and Plan for Improvement of Technology Transfer Efficiency for Public Institutes†

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Abstract

This paper uses data envelopment analysis (DEA) to analyze and evaluate the efficiency of technology transfers within public institutes. Research funding, research manpower, Technology Licensing (TLO) manpower and TLO operational costs are four input factors; the number of contracts for technology transfer and TLO operational costs are two output factors. The significant variables selected for evaluation of the efficiency of technology transfers are regional location, and type of research institute.

The analysis arrived at the following two conclusions: First, in the relocation of an institute the priority must be to create an environment that fosters research collaboration among industry, academia and research institutes by providing a well-organized infrastructure. Second, each research institute has to be able to conduct R&D according to their mandate.

Keywords: technology transfer, efficiency of technology transfer, DEA, public research institute

1. Introduction

In a knowledge-based society, knowledge contributes more to economic growth than traditional modes of production such as capital or labor. For this reason, there is growing attention being paid to research and development (R&D), because it adds value by producing, acquiring, distributing, sharing, utilizing and accumulating knowledge. Consequently, many countries are recognizing the importance of R&D and continuously increasing their investments in R&D in order to become competitive in the global economy.

Despite national fiscal difficulties and the global financial crisis, Korea has constantly expanded its R&D investments. In 2013, Korea ranked sixth in the world for R&D investment at 54.2 billion dollars, behind only the US ($453.5bn), Japan ($199bn), China ($163.1bn), Germany ($102bn) and France ($59.8bn). But Korea's R&D investment as a percentage of GDP is the highest in the world at 4.15 percent, followed by Israel (3.93%), Finland (3.55%) and Japan (3.35%). The Korean government increased its R&D investment from 2011 to 2013 by 7.3 percent, which is higher than France (5.4%), the U.S. (3.8%), Germany (2.7%) and Japan (1.5%) (MOSF, 2014).

However, R&D expenditure does not always lead

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to economic returns unless the technology developed from research is successfully transferred to industry and delivers innovative products and improved productivity (Ergas, 1987). To this end, the Korean government has sought to invigorate the technology market and to establish a foundation for technology transfer and commercialization, first through the 'Technology Transfer Promotion Law' of 2000, then through the 'Enforcement Decree of the Industrial Education Enhancement and Industry-Academia-Research Cooperation Promotion Act' of 2003, then through the 'Special Act on the Promotion of Special Research and Development Zones' of 2005, and finally through a series of 'Technology Transfer and Commercialization Plans' that have been announced since 2000.

Thanks to these efforts, the efficiency of technology transfers of public institutes is continuously increasing. Revenue generated by public institutes from technology transfers has grown 3.4 times, from 49 billion won in 2003 to 165.2 billion won in 2012. And the number of transfers has multiplied 6.2 times, from 1,076 cases in 2004 to 6,676 cases in 2012.

The Korean government's expenditure on R&D ranks high among developed nations; however, the quality or economic value of its research outcomes remains weak. For instance, quantitatively Korea ranks the 4th and 10th in the world for patent and research papers, respectively, but knowledge application or commercialization remains rather weak.

As of 2012, research productivity (as determined by revenue from technology transfers divided by expenditures on R&D) for all public institutes in Korea, including universities, is 1.49%, which is a third of the US (3.9%). In the US, the running royalty, an additional revenue from sales when commercialized, is ten times higher than Korea's. The number of start-ups adopting and providing technologies developed by universities and public institutes also remains low.

As statistics show, increasing R&D investments does not guarantee higher productivity or economic returns (Ergas, 1987). For this reason, it is critical to improve qualitative efficiency, as well as to promote the quantitative expansion of R&D investments in order to enhance long term national competitiveness (Lim et al., 1999).

As a country with limited resources for R&D, Korea needs to systemize the flow from technology development to commercialization. This will improve the efficiency of the technology transfer and commercialization system and produce technical and economic results (Min, 2014).

Most of the research on technology transfers from public institutes in Korea propose a correlation analysis between influential factors and the efficiency of technology transfers. But this provides a limited understanding of typical situations. As individual institutes have different environmental conditions, procedures and policies regarding technology transfers, it is necessary to study institutes by category.

Further research is necessary in this area, including detailed analyses of the efficiency and relevant variables of technology transfers in the public institutes[1] that are the principal vehicles for government-funded R&D.

This study is based on recognition of the need to improve the efficiency of technology transfers when public institutes conduct R&D with resources such as research workforce and funds, and produce research outputs such as patents and technology transfers.

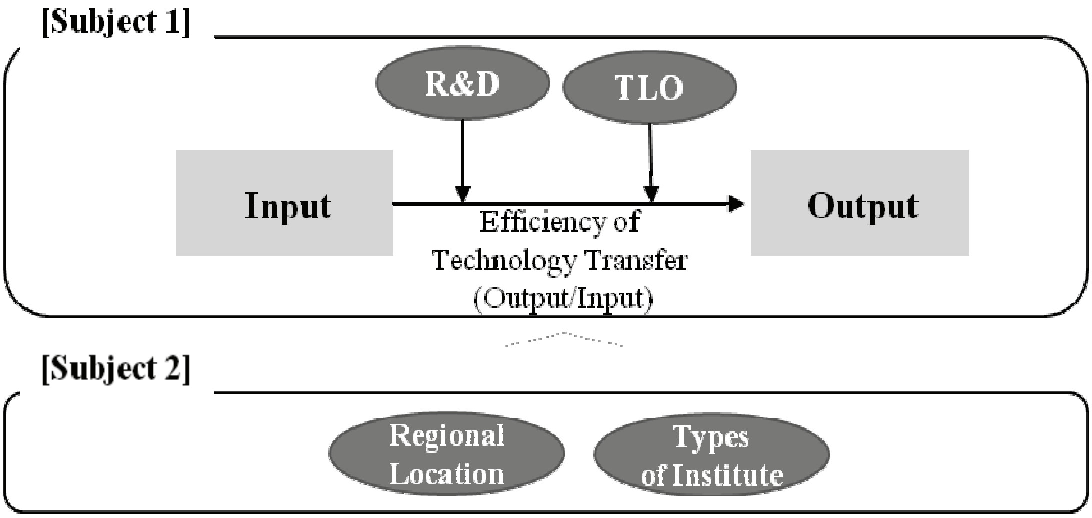
As Figure 1 illustrates, this paper aims to evaluate the efficiency of public institutes at conducting R&D

1 In 2013, the total expenditure on R&D by the Korean government was 16.9 trillion won. This total expenditure can be broken down as follows, from highest portion to lowest: government-funded research institutes (₩7tr, 41.3%), universities (₩4tr, 23.5%), SMEs (₩2.2tr, 13.0%), large corporations (₩0.9tr, 5.1%), national and public research institutes (₩0.8tr, 4.8%) and medium-sized enterprises (₩0.7tr, 3.9%).

and technology transfers with input factors that produce outputs. This study also considers external factors that can affect efficiency.

This study evaluates the efficiency of public institutes with the abovementioned input and output factors, and analyzes the factors that create differences among individual institutes. Based on the results and practical conditions, this paper suggests alternative policies to enhance the efficiency of technology transfers in public institutes.

Figure 1. Structure of research subject



2. Theoretical Background

2.1 Conceptual Understanding on Technology Transfer Efficiency

2.1.1 Efficiency

Efficiency refers to an organization's ability to generate maximum outputs with limited resource inputs. In general, the term technical efficiency is used to indicate 'the ratio between outputs and inputs.' By definition, "technical efficiency" is used as a metric for evaluating an organization's operational effectiveness by calculating maximum outputs with various combinations of inputs such as variability or substitutability of production agent. Therefore, an efficient organization is defined as an organization which achieves the maximum technical efficiency when carrying out a task. A technically efficient organization uses the minimum resource inputs to reach its goal (Park, 2008).

Creating an efficiency evaluation as a ratio between outputs and inputs is easy for organizations producing a single output with a single input. However, most producers use multiple inputs for multiple outputs. To calculate efficiency in those cases, it is necessary to consider total input, which puts weight on major inputs, and total output, which puts weight on major outputs (Kim, 2013).

$$\text{Efficiency} = \frac{Total\ Input\ Weights}{Total\ Output\ Weights}$$

$$= \frac{\sum_{m=1}^{M} (Output\ Weights(u) \times Output(m))}{\sum_{i=1}^{I} (Input\ Weights\ (v) \times Input\ (i))} \leq 1$$

To understand the definition of efficiency, it is necessary to differentiate the concepts of absolute efficiency and relative efficiency. Absolute efficiency is the ratio between outputs and inputs within a certain economic agent, and this can be represented by physical units or by ratios such as dollar amount per person. Therefore, absolute efficiency has no limitation in terms of its range of possible results. On the other hand, relative efficiency compares the ratio with the highest result value among all economic agents involved in production. The relative efficiency value is represented, for example, as 73% or 0.73 when the highest efficiency value is set as 100% or 1 as a standard. Since relative competitiveness is a major concern in most production activities, the concept of relative efficiency is used more often (Lee & Oh, 2010).

2.1.2 Technology Transfer Efficiency

The efficiency of technology transfers can also be represented as the ratio between outputs and inputs, which is identical to the general efficiency concept. Since a technology transfer is one of the procedures of R&D, for quantitative analysis it is helpful to understand the concepts of input, output and outcome in the broader sense of an R&D performance evaluation.

'Input' variables are the elements used for research and development activities, and include research funding, workforce, equipment, facilities, time and knowledge. 'Output' variables indicate the direct achievements of research and development activities, such as intellectual property rights including research papers or patents. 'Outcome' means an achievement in terms of the results of research and development activities, particularly its economic outcomes. This is measured by focusing on the commercialization of the research, such as income generated by patent royalties, value-added inducements, and sales increases. In short, an 'output' is the direct achievement of research and development, while an 'outcome' is its economic effect (Hwang, 2009).

This paper analyzes the efficiency of technology transfers using an 'output' ratio, which is based on R&D and technology transfer achievements as well as 'input' variables.

2.2 The Concept of DEA

Any attempt at measuring efficiency in the public sector will face several challenges. First, in contrast to the private sector, there is no distinct unit with which to measure output in the public sector. Second, there is no objective criteria with which to set the weights on selected and adversarial variables, because the public sector aims to achieve multiple purposes and intangible results. Third, it is useless to evaluate the efficiency of an organization itself, because the role of an organization in the public sector is interconnected with those of other organizations (Moon, 1998).

Nevertheless, there is a growing necessity to measure efficiency in the public sector by using multiple inputs and outputs whose values are hardly measurable. Since its introduction by Farrell (1957), DEA has been developed as a method to evaluate relative efficiency among subjects by comparing multiple inputs and outputs (Charnes & Rhodes, 1978).

For instance, if 'number of employees' is on the horizontal axis and 'sales' is on the vertical axis, the slope of the line connecting each point to the origin corresponds to sales per employee. The steepest slope is the line passing closest to the vertical axis. This line is called the 'efficiency frontier.' This frontier touches at least one point and all points are on or below this line. The name Data Envelopment Analysis comes from this feature because in mathematical parlance, such a frontier is said to "envelop" these points (Cooper et al., 2006).

In DEA, the units subject to evaluation are called Decision Making Units (DMUs) and DMU can be applied to all agents using multiple inputs and outputs.

There are four reasons why DEA is an appropriate method for measuring the efficiency of research and development activities. First, research and development requires multiple inputs and outputs, which is suitable for DEA analysis. Through DEA analysis, the relative efficiency among DMUs is converted to a single unit by incorporating multiple inputs and outputs in the applicable manner. Second, as DEA was initially introduced to evaluate public organizations such as hospitals or schools, it is an optimal analysis tool for government-funded research institutes. Third, DEA uses objective criteria to assign 'weights' to each input and output. In contrast to the traditionally fixed proportion technologies where subjective judgement by experts are the major controller in assigning weights on units, DEA is not dependent on the subjective element. Fourth, the results of a DEA analysis can guide the improvements and goals of research and development activities. That is, DEA provides inefficiency measures as well as benchmark information on efficient reference sets (Hwang, 2009).

2.3 Preceding Studies

According to Seiford (2001), more than 800 studies on DEA models or efficiency evaluations using DEA models have been published. More studies have been introduced with diverse subjects, covering sectors such as medical services, education, financial services, national defense and manufacturing. Table 1 describes a summary of prior studies in Korea and other countries on R&D efficiency using DEA.

Table 1. Studies on technology transfer efficiency using DEA model

Researcher	Research Subject	Inputs	Outputs	Outcome
Kim & Park (2004)	National Research Centers	Research funding, Research workforce	Patent, Program, Research paper, Royalty	High efficiency in research centers in universities; High efficiency in material, physics and process studies
Park, et al. (2007)	R&D on Construction Projects	Research funding, Number of researchers	Knowledge accumulation (research paper, etc.), Knowledge transfer (patent, new technologies, etc.)	Low outcome and efficiency in knowledge accumulation
Nam et al. (2008)	Government-funded Research Institutes	Research workforce, R&D fund	SCI Research paper submission, Patent registration, Technology royalty	Efficient organizations: KIST, ETRI, KRICT
Hyun & Yoo (2008)	Public Research Institutes	R&D workforce and funds, Manpower for Technology Transfer, Number of technical skills	Newly developed technical skills, Patent application and registration, Technology transfer, Royalties from technology transfer	Efficiency negatively affected more by pure technology inefficiencies rather than by inefficiencies of scale Influenced more by an institute's type than by regional features
Kim et al. (2009)	R&D Projects on Nuclear Power	Research funding, Research workforce	SCI, Technology diffusion (Technology transfer, assessment and road-map)	Inefficiency in nuclear power development project, nuclear power infrastructure project, radiation technology development project

Kwak et al. (2010)	Government-funded Research Institutes	Research workforce, Number of contracts	International SCI Publication, Patent registration, Technology Royalty	Evaluation recommended every three years (medium length); No influence of time difference on efficiency
Kim (2010)	Projects on Technology Development in Local Industries	Technical development workforce, Government funding, Private funding, Project period	Technical advancement, Technical improvement, Cost reduction, Sales rate increase, Employment rate increase, Productivity enhancement	Average of 0.73 efficiency in technical development projects; Higher efficiency in core technology development group than common technology
Park (2010)	Projects on Technology Development in Local Industries	R&D expenditure, R&D period, Level of knowledge	Patent, Research paper, Sales, Job creation	Highest efficiency in: Jeju (region), Universities (type), Bio-health (strategic industry)
Baek & Jung (2011)	National Research Projects	Total R&D expenditure	Technical royalty, SCI publication, non-SCI publication, Patent registration in Korea and other countries	Leading TLO projects can improve the efficiency of R&D in funded institutes by 13.3% (Cost reduction by ₩13bn)
Jin & Yoon (2012)	Universities in Korea	Universities' capabilities, Characteristics of academia-industry cooperation and technology transfer department	Number of technology transfers and their royalties	Appx. 20% of universities in Korea efficiently transfer technologies
Lee (2012)	HR Training Projects	Government subsidy, Number of participant	No. of trainees, SCI publication, Patents, Commercialization and SW development, Technology transfer	Close relationship between patent and technology transfer, High efficiency in HR training
Kim (2013)	Government-funded Research Institutes in Economics, Arts & Social Studies	No. of full-time researchers and full-time administrators, No. of irregular employees, Labor costs, Research operation costs, general operation costs, Area occupied per person	Number of research papers published, Internal projects, Assigned and Irregular projects, Revenue from such projects, Contribution to the national policy, customer satisfaction	Input variables affecting efficiency: no. of irregular employees, research operation cost, area occupied per person Output variables affecting efficiency: No. of research papers published, internal research projects, assigned and irregular projects and revenue from such projects
Jeon (2013)	Government-funded Research Institutes in Economics, Arts & Social Studies	Fund (Budget) input, Labor (workforce) input	No. or research report production, Evaluation results of institutes	Lower efficiency for larger institutes Higher efficiency for institutions with more research reports and higher customer satisfaction

Kang (2014)	Research Institutes in Science and Technology	No. of researchers, Direct cost of research	Patent registration, Technology transfer, Technology royalty	Efficiency affected by previous experience of institutes' heads, their leadership evaluation by external entities, proportion of PhD holders among researchers
Thursby & Kemp (2002)	AUTM, Universities in the US	No. of TTO experts supported by federal government, No. of faculty members that majored in biology, engineering and physics and their evaluation	No. of contracts for technology transfers, No. of contracts on research assigned by industry, New patent registrations, Invention reports, Revenue from technology transfers	Technology transfers and patents in universities are voluntarily improved through the efforts of faculty members for patent and technology transfer; outsourced R&D by corporations
Thursby & Thursby (2002)	AUTM, Universities in the US	Invention report, Patent, License	Total Factor Productivity (TFP)	Technology transfers and patents are improved according to the licensing purpose and corporate willingness to outsource R&D
Chapple et al. (2005)	Universities in the UK	Invention report, R&D funding, External legal costs, No. of TTO employees	Technology transfer contract, Technology royalty	Low efficiency and lacks economies of scale. It is necessary to organize technology transfer department on a small scale
Anderson et al. (2007)	AUTM, Universities in the US	R&D expenditure	US patent application and registration, Revenue from license, No. of licenses, No. of business start-ups	Low efficiency in medical schools. No difference found among state and private universities
Wang & Huang (2007)	R&D in OECD Countries	R&D stocks, workforce	Research paper, Patent	Less than half of countries conduct efficient R&D, more than 2/3 countries are under IRS
Hsu & Hsueh (2009)	R&D funded by government of Republic of China (Taiwan)	R&D workforce, Government subsidy, Corporate budget, Development period	Research paper publication, Patent stocks, Innovative commercialization, Revenue model	Efficiency affected by size of corporation, industry type and government subsidy for R&D
Kim (2011)	AUTM, Universities in the US	Invention disclosure, No. of TTO employees, Research expenditure	US patent registration, Technology transfer achievement, Technology royalty	Average productivity of technology transfer up 31% Result of universities' effort to improve commercial activities for revenue increase, and less efficient universities striving to learn from the leading universities.

3. Current Status of Public Institutes

3.1 Definition of Public Research Institutes

Generally speaking, public research is non-profit research conducted by organizations in the public sector in pursuit of the public interest (Larédo & Mustar, 2004). The term "public research" encompasses basic science research which broadly influences social affairs, as well as practical research in diverse fields ranging from public health, the environment, transportation, communication and national defense (Joly & Mangematin, 1996). Public research institutes conducting research in such fields have three properties in terms of R&D funds: organization ownership, research mission and field. First, public institutes are funded by governments, meaning they are supported by public funds. Second, public institutes are owned and controlled by government agencies. Third, public institutes aim to transfer and disseminate outcomes rather than own or accumulate them. The fields of research range from fundamental science, public technology to national defense (Senker et al., 1999).

The main research agent of national R&D projects can be categorized into industry-academia-research cooperatives and other organizations. Public research institutes can be identified as universities and research centers. Specifically, research centers include government-supported research institutes (GRIs), specialized manufacturing technology research institutes, and national or public research institutions.

The term "public research institute," as used throughout this paper, refers only to research institutes. Universities provide education and training that fosters researchers and focuses on fundamental science research (Cho et al., 2007). Faculty members of universities publish research in journals focused on specific academic areas of research (Kim et al., 2013).

In contrast, the national innovation system assigns research institutes a mission to perform R&D on a public level that cannot be performed by corporations or universities. Research institutes are the major agents in national R&D projects that mitigate possible market failure or institutional deficiencies. In particular, the subjects of research for such institutes are big science research or emerging and enabling technologies, which are simultaneously economically productive and extremely risky. Research institutes also bridge the gap between the pure science research of universities and the commercialization-focused research from corporations (Lee & Lee, 2011).

To this end, it is necessary to approach the efficiency evaluation for research institutes from a different perspective than that used to evaluate universities, as their goals and areas of research are distinct. This study recognizes these distinctive characteristics whenever it uses the term 'public research institute'.

Table 2. Types of institutes conducting research

Organization	Criteria
Industry	Large Corporations: corporations with a large amount of capital, employees or facilities
	SMEs: companies with little or an average amount of capital, employees or facilities
Academia	Universities: all 2-year colleges and 4-year universities throughout the nation
Research Institute	GRIs: all or part of the institutes' funds are provided by government
	Specialized Research Institutes: established to improve the competitiveness of specialized local industries and to support manufacturing technologies for SMEs
	National Institutes: operated by government agents for national research
Others	Non-profit corporation, Research association, Government-funded institution, multiple agents for research, etc.

Source: Excerpt from Performance Analysis Report of National R&D Program in Korea

3.2 Status of Technology Transfer in Public Research Institutes

Technology transfer is a phenomenon or process whereby an owner transmits technology or technology-related knowledge (explicit knowledge, tacit knowledge, know-how, etc.) (Lim et al., 2014). Public research institutes play significant roles in technology transfer, and continuously perform strongly.

The technology-related revenues of public institutes have increased from 89.3 billion won in 2007 to 117 billion won in 2012. The number of technology transfer cases is consistently rising.

The productivity of research funding in public institutes, which is evaluated based on the ratio of technology transfer revenue to funding input, has declined from 2.6% in 2007 to 1.8% in 2012. It is marginally higher than that of universities, whose ratio is 1.05%; however, overall productivity is far from the levels achieved by advanced countries. According to the AUTM US Licensing Survey in 2011, which surveys technology transfer revenue for universities and research institutes in the US, the average productivity in all research organizations is 3.93 percent, and US research institutes achieve 10%, five times higher than Korean institutes.

Table 3. Technology transfer revenue (2007-2012)

(Unit: million KRW)

Research Institutes		2007	2008	2009	2010	2011	2012
All		104,413	128,786	101,667	124,514	125,812	165,180
	Public Research Institutes	89,342	102.320	74,017	91,836	83,209	117,017
	Universities	15,071	26,466	27,650	32,678	42,603	48,162

Source: Technology Transfer & Commercialization White Paper 2007-2012

Table 4. Technology transfer contracts (2007-2012)

(Unit: million KRW)

Research Institutes	2007	2008	2009	2010	2011	2012
All	2,593	2,641	2,918	2,940	3,420	4,312

Source: Technology Transfer & Commercialization White Paper 2007-2012

Table 5. Productivity of research funding

Research Institues		2007	2008	2009	2010	2011	2012
All		1.70	1.30	1.35	1.48	1.32	1.49
	Public Research Institutes	2.60	1.90	1.91	2.02	1.69	1.80
	Universities	0.60	0.60	0.76	0.85	0.92	1.05

Source: Technology Transfer & Commercialization White Paper 2007-2012

4. Study Design

4.1 Data Collection

This study on technology transfer and commercialization for public research institutes (research institutes and universities) aims to provide evaluation criteria for technology transfers and commercialization projects, and to improve R&D productivity by promoting actions which efficiently disseminate the outcome and its application. The data in this paper is taken from the 'Technology Transfer and Commercialization White Paper,' a study conducted by the Ministry of Trade, Industry and Energy (MOTIE) and by the Korea Institute for Advancement of Technology (KIAT).

The data in the white paper is from an official survey of public research institutes[2] prescribed by the Technology Transfer and Commercialization Promotion Act. As an official survey authorized by Statistics Korea (authorization no. 11522), the data has much higher credibility than surveys conducted by individual researchers. This is especially true of the survey conducted in 2012, for which data was received from 262 public institutes out of a possible 275 (125 public institutes and 150 universities), and the response rate reached 95.3%.

This paper analyzes the data from research institutes, including GRIs, national or public research institutes and specialized research institutes, but excluding specialized universities. The period of analysis spans three years' data provided by the Technology Transfer and Commercialization Survey from 2009 to 2011, as these surveys have less missing data and high credibility.

4.2 Research Model and Hypothesis

4.2.1 Research Model

As its research method, this paper uses DEA Window, a dynamic efficiency analysis, to evaluate the efficiency of technology transfers in public research institutes.

The output-oriented BCC model with the Variables Return to Scale (VRS) assumption is used to evaluate the relative efficiency for the most efficient public institute, which is located on the best practice frontier. The software for efficiency evaluation is R programming, which allows flexible applications and modifications of the model. This paper uses the output-oriented model in an empirical analysis based on the assumption that (i) equiproportionate modification is adequate as there are more input variables (4) than output variables (2); (ii) it is appropriate to expand the scale of technology transfers in public research institutes at this moment.

The following three criteria are applied for data analysis: first, public institutes that have not produced any outcome are dismissed. As efficiency in DEA is the ratio of aggregated outputs to inputs, the efficiency of DMUs becomes zero (0) when there is no outcome. Theoretically, such DMUs do not have any impact on the composition of the frontier. Consequently, public institutes without any outcome are exempted from DEA. Second, the data excludes TLO with less than 10 million won in operational costs. An operational cost of 10 million won is seemingly insufficient to cover the costs of labor, patent management, technology transfer and other operations. Third, this paper eliminates institutions

2 Colleges of Theology and Education, government agencies for R&D operation and management are excluded from the survey.

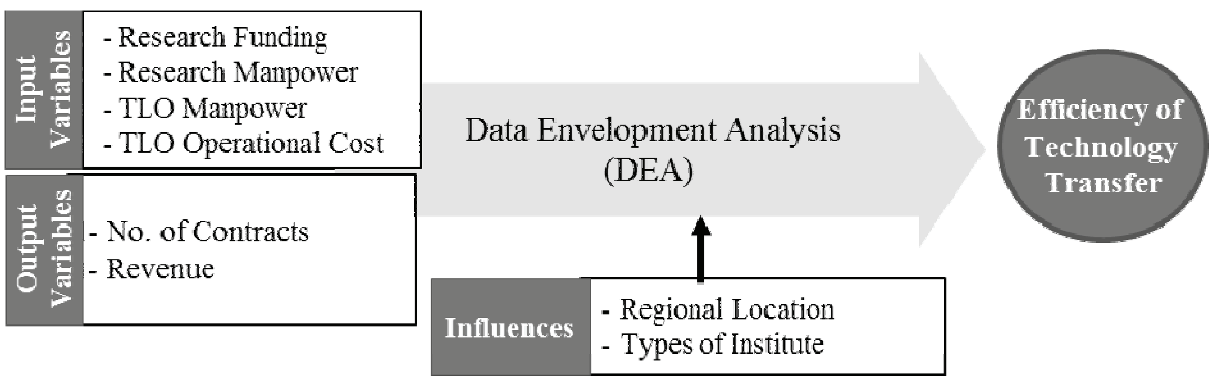
with less than ten signed technology transfer contracts. Many of those are considered as passively engaging in minor tasks and less committed to TLO operations.

Categorizing DMUs can be questionable due to their inadequate number. If the number of DMUs is small compared to the selection of input or output factors, the efficiency of all DMUs is calculated as 1, which indicates that they are completely efficient. Golany et al. (1989) claimed that the number of DMUs should be twice as many as that of input and output items, and Banker et al. (1984) asserted that the number should be more than triple if the DMUs are to be distinguished and placed in categories. Boussofiane et al. (1991) argued that to create categories the number should be twice the number of inputs multiplied by outputs. To comply with the aforementioned criteria proposed in other studies, this paper used 21 DMUs.

To select input and output variables, this paper employs the four selection criteria recommended by Sun (1988). First, inputs and outputs are controlled, adjusted and quantified, and they are critical to achieving official goals. Second, more inputs do not result in output increases or decreases, and these at least must remain unchanged. Third, inputs and outputs are the net value produced or consumed during the same period of evaluation, not the value accumulated. Fourth, inputs and outputs have a positive (+) quantity, or should be convertible to a positive quantity. Based on the four selection criteria, this paper sets the following input and output items: for input factors, research funding, research workforce, TLO workforce and TLO operation cost; for output factors, the number of contracts made for technology transfers and technology transfer revenue.

The relevant variables of this study are regional location and type of institute. However, the final number of data for analysis after data refinement is approximately a mere 21 per year. As regression analysis assumes that variables have normal distributions, this paper fails to satisfy the data requirements of a minimum of 30 samples. Therefore, the properties of the two relevant variables and their relationships to the technology transfer efficiency are evaluated in accordance with the group's average value.

Figure 2. Research model



4.2.2 Research Hypothesis

- Regional Location

Regional Innovation System (RIS) is defined as a system where companies or organizations interact within an established institutional environment within a region (Cooke, 2001). Within an RIS, the participants interact within a network so they can achieve faster technological innovations by generating synergies in areas such as workforce, finance, information, consultation and decision making procedures (Koschatzky, 1993).

An RIS emphasizes cooperative relationships among industry, university and research institutes and encourages networking among organizations leading regional innovation. RIS are the leading organization for innovation and are led by local universities, research institutes, corporations, government and local government. The best example of an RIS led by universities is Silicon Valley in the US, as the research activities of Stanford University are closely connected with industries, which generates the world's greatest innovations. Daedeok Innopolis in Daejeon, Korea, is an exemplary RIS led by research institutes. RIS led by corporations are found in Cambridge in the U.K., Baden-Württemberg in Germany and Otaku in Tokyo, Japan. Lastly, cities with a successful RIS led by the central or local government are Kista in Sweden, Sheffield in the UK, Milan in Italy and Zhongguancun in China (Yoon et al., 2003).

In Korea, some studies show that the Seoul metropolitan area and Chungcheong province have advantages in creating and transferring knowledge, because relatively more research institutes are centered around the area, which makes the region grow faster than others (as cited in Hong, 2009). On the other hand, Hyun (2008) demonstrated through empirical research that the inefficiency of technology transfers can be attributed to institutional properties rather than regional characteristics.

This paper attempts to verify whether technology transfer efficiency is higher in the metropolitan area than in other regions in Korea.

(Hypothesis 1) Technology transfer efficiency is affected by the regional location of research institutes.

- Types of Research Institutes

The assumption that the type of research institutes may contribute to efficiency is based on the following factors.

The first factor is the budget structure of research institutes. The research of GRIs' is exclusively funded by government or open competition to the public, while specialized institutes carry out research funded entirely by open competition, and national or public institutes are funded by national subsidies.

Whereas national or public institutes are completely funded by government budgets for domestic projects, specialized research institutes are funded by open competition through the Project Based System (PBS) for research expenditures, labor costs and other indirect costs. GRIs introduced PBS in 1995; however, the system has not yet fully been established, as approximately 60 percent of the budget is covered by the government budget for domestic projects. Due to this funding structure, national or public research institutes and GRIs may lag in their efforts to conduct technology transfers. In contrast, specialized research institutes vigorously perform technology transfer activities in order to generate funds (investments) from various sources, and this leads to high efficiency.

The second factor is research scope of the research institute. The three phases of national R&D projects are described in Table 6.

National or public institutes are involved in the basic research phase, GRIs in the basic, applied and development research phase, and specialized institutes in the development research phase. Specialized institutes are expected to have a high technology transfer efficiency, as their research is focused on commercialization in collaboration with corporations in which researchers are highly knowledgeable.

(Hypothesis 2) Technology transfer efficiency is affected by the types of research institutes.

Table 6. Types of national research development projects

	Description
Basic Research Phase	The theoretical or experimental research phase carried out in order to obtain new knowledge on phenomena and observable facts where specific applications or business tasks are not direct objectives.
Applied Research Phase	The independent research phase is carried out in order to obtain new scientific knowledge with mainly practical purposes by using knowledge obtained in the basic research phase.
Development Research Phase	The systematic research phase, in which knowledge obtained from the basic research phase, application research phase, and actual experience is used to produce new products, devices, and services or to make practical improvements to items that have already been produced or installed.

Source: Regulations on the Management, etc. of National Research and Development Projects, Article 2 (Phase of Research Development Projects)

4.3 Research Variables

4.3.1 Input Variables

Research funding and workforce are the variables that are commonly used to evaluate R&D efficiency (Serrano-Cinca et al., 2005). This paper adds two more variables, TLO workforce and operational costs, in order to measure technology transfer efficiency.

Research funding is the cost of research and development activities needed to create new technologies or products, or to discover new processes by utilizing conventional knowledge. Research funding is the sum invested by the government and the private sector.

Research workforce is a significant factor in R&D activities as it conducts the research and produces the outcome. Research workforce includes anyone with a bachelor's degree or with equivalent expertise. Research workforce is involved in research and development activities in such fields as science and technology or industrial technology.

TLO workforce is defined as persons exclusively responsible for TLO activities including the application, registration and management of industrial property rights, technology transfer consultations and contracts, assistance for start-ups and technology marketing.

The TLO operational cost is the sum spent on workforce, technology marketing and other activities needed to operate TLOs.

4.3.2 Output Variables

Among the 21 prior studies, more than five researchers adopted patents, research papers, number of technology transfers and technology transfer revenue as output variables.

Although papers and patents have been used as output variables in prior studies, research papers hardly influence technology transfers, and patents are mostly registered to accomplish the objectives of government-supported R&D[3].

As this paper aims to study the efficiency of

3 As of 2013, the patents registered by 25 government-supported research institutes are as many as 34,888. However, only 11,706 patents, which is 33.5 percent, have been practically applied. The number of dormant patents rose 24 percent, from 4,533 cases in 2011 to 5,622 in 2013. This is because the success of R&D projects are only evaluated by quantitative index, such as the number of published paper or patents. (The Korea Economic Daily, Nov 09, 2014)

technology transfers in public research institutes, it is reasonable to set as output variables the number of technology transfers and their revenue.

The number of technology transfer contracts represents how much knowledge (technology) has been transferred to the private sector (industry, etc.) and practically applied. This measures whether an institute is fulfilling its role of 'disseminating public technology.'

The revenue generated from technology transfers means the 'profit generated for the institutes' through technology transfers.

Table 7. Variables for efficiency evaluation: Inputs

	Variables	Operational Definition	Measurement Indicators
R&D Variables	Research funding	Expenditure on R&D (including funds from government and private sector)	Research funding (million won)
	Research workforce	Technology development workforce on R&D (full-time)	Research workforce (person)
TLO Variables	TLO workforce	workforce for technology transfer only in TLO	TLO workforce (person)
	TLO operational costs	Operational costs for TLO	TLO operational costs (million won)

Table 8. Variables for efficiency evaluation: Outputs

	Variables	Operational Definition	Measurement Indicators
Variables for Dissemination	No. of contracts for technology transfers	Number of contracts for technology transfers	No. of contracts for technology transfers
Variables for Revenue	Technology Transfer Revenue	Fixed & running royalty from technology transfers	Amount of revenue from technology transfers

Table 9. Relevant variables for efficiency

	Variables	Operational Definition	Measurement Indicators
Environmental Variables	Regional Location	Categorized into: Metropolitan area, Chungchung, Gyeongsang, and Jeolla Provinces	Metropolitan area, Chungchung, Gyeongsang, Jeolla Provinces
	Types of Research Institutes	Categorized into: Government-supported Research Institutes, Specialized Manufacturing Technology Research Institutes and National or Public Institutes	GRIs, Specialized Research Institutes, National Institutes

4.3.3 Environmental Variables

There are many factors affecting the input and output variables in measuring technology transfer efficiency of public institutes. After a thorough examination of prior studies as well as of government policies on technology transfer projects and of the status of public research institutes, this paper takes into account regional location and types of research institutes as environmental variables which can affect the efficiency of technology transfers in public research institutes.

The institutes discussed in this paper are spread throughout the country. To test the statistical significance of location, this paper classifies institutes in accordance with three geographical regions: Seoul & Gyeonggi, Daejeon & Chungnam, and others. Moreover, the types of research institutes are categorized as government-supported, specialized and national or public institutes.

5. Analysis on Technology Transfer Efficiency of Public Institutes

5.1 Efficiency Analysis by Year

To track the changes in efficiency over a three-year period, this paper selects the DMUs that have data for each year. The data analyzed in this paper is based on a minimum number of DMUs in 2009, and institutes which do not have data for 2010 and 2011 are eliminated.

Institutes B, D, F and H achieved a grade of 1.00 for efficiency for the three consecutive years. On the other hand, institutes E, I and G showed gradual declines in efficiency. The yearly data demonstrates drops in efficiency in overall research institutes: 0.84 in 2009, 0.76 in 2010 and 0.72 in 2011.

The analysis by type of institute revealed grades of 0.76 for GRIs and 0.87 for specialized institutes; the analysis by regional location produced grades of 0.80 for the Seoul metropolitan area, 0.73 for Chungcheong province, 0.99 for Gyeongsang province and 1.00 for Jeolla province.

Table 10. Change of efficiency analysis (2009-2011)

Research Institutes	Efficiency				Type of Institute	Region
	2009	2010	2011	Average		
A	1.00	0.58	1.00	0.86	Government	Gyeonggi
B	1.00	1.00	1.00	1.00	Specialized	Gwangju
C	1.00	0.56	0.66	0.74	Government	Daejeon
D	1.00	1.00	1.00	1.00	Government	Daejeon
E	1.00	0.34	0.34	0.56	Government	Seoul
F	1.00	1.00	1.00	1.00	Government	Daejeon
G	1.00	0.61	0.48	0.70	Government	Daejeon
H	1.00	1.00	1.00	1.00	Government	Gyeonggi
I	0.98	0.32	0.30	0.54	Government	Daejeon
J	0.96	1.00	1.00	0.99	Government	Gyeongnam
K	0.92	0.94	0.66	0.84	Specialized	Chungnam
L	0.81	0.64	1.00	0.82	Government	Chungnam
M	0.78	1.00	0.45	0.74	Government	Daejeon
N	0.70	0.93	0.68	0.77	Specialized	Gyeonggi
O	0.64	0.83	0.82	0.76	Government	Gyeonggi
P	0.55	0.59	0.68	0.61	Government	Daejeon
Q	0.48	0.85	0.71	0.68	Government	Daejeon
R	0.28	0.52	0.23	0.34	Government	Daejeon
Average	0.84	0.76	0.72	0.77		

5.2 Analysis of Hypotheses

5.2.1 Regional Location

The geographical distribution of research institutes is as follows: 5 in Gyeonggi-do (0.686), 2 in Gyeongsang-do (0.800), 1 in Gwangju (1.000), 9 in Daejeon (0.571), 2 in Seoul (0.725) and 2 in Chungcheong-do (0.707). As this proves, most institutes are located in Gyeonggi-do and Daejeon. If too many areas are recognized as DMUs, it becomes too difficult to make relative comparisons because variation occurs among the efficiency value. For this reason, this paper categorized the data as follows: 7 in Seoul and Gyeonggi-do (0.697), 11 in Daejeon and Chungnam province (0.595) and 3 in other regions (0.867).

The analysis reveals that, except for institutes in other regions, the institutes in Seoul and Gyeonggi-do are 10.2% more efficient than those in Daejeon and Chungnam province. Thus it can be inferred that institutes in the metropolitan area have higher efficiency of technology transfer than those in provincial areas, as the metropolitan area has well-established RIS and more corporations for technology transfers.

5.2.2 Types of Institutes

The 21 research institutes in this paper are classified as 18 GRIs (0.655) and 3 specialized institutes (0.747). The efficiency of specialized institutes is 9.2% higher.

However, the efficiency of specialized institutes is not necessarily higher, because generally speaking, more DMUs may lower the average value of an institute's efficiency. And yet, to some extent this analysis correctly explains the relationship between the nature of a research institute and its technology transfer efficiency by using the calculated average value and researchers' estimates. As the result displays, specialized institutes have a higher efficiency due to the fact that they exist to conduct research and development near corporations striving to commercialize new technologies.

Table 11. Summary of hypotheses

	Hypothesis	Results
H1	The technology transfer efficiency is affected by the regional location of research institutes.	Normal Relation
H2	The technology transfer efficiency is affected by the type of research institutes.	Normal Relation

6. Conclusion

6.1 Summary of Research

With rapid technological changes, there is growing competition for advanced technology around the world. The interdisciplinary approach between different industries amplifies the social and economic importance and influence of science and technology. Therefore, to efficiently manage government-supported R&D, it is necessary to maximize the efficiency of public research institutes including GRIs, which account for a large portion of the government budget.

To help enhance the technology transfer efficiency in public research institutes, this paper analyzes 3 years of data to determine the current situation and to establish policies accordingly.

This paper also suggests the following two hypotheses to identify certain trends within the three year period under examination, even though a statistical analysis is lacking due to insufficient data.

First, this paper recognizes that a meaningful relationship exists between regional location and efficiency rankings. However, Gyeongsang and

Jeolla provinces are excluded, as they each have only one DMU. The Seoul metropolitan area, where most corporations are located, shows a higher efficiency than Chungcheong province. Compared to the SMEs and venture businesses conducting technology transfers, public institutes in the metropolitan area are more efficient.

Second, this paper recognizes that a meaningful relationship exists between institute types and efficiency rankings. Except for national or public research institutes with zero DMU for analysis, specialized research institutes show efficiency numbers above 0.1 for all years. This is due to the fact that the specialized institutes are founded for the purpose of conducting research and development activities highly related to technology commercialization.

After proving the hypotheses on technology transfer efficiency in public research institutes, this paper arrives at the following policy implications:

It is necessary to consider that the relocation of public institutes may have negative impacts on the efficiency of technology transfer. In this regard, infrastructure and an environment for industry-academia-research institution collaboration needs to be provided prior to relocation.

Also, when evaluating the efficiency of government-supported projects operated by TLOs or public research institutes providing technology transfer services, it is necessary to apply diverse criteria rather than quantitative results such as technology transfer revenue or contract cases.

6.2 Limitations and Future Research Direction

This paper has certain limitations, and suggests the following three directions to help future researchers overcome such limitations and achieve desirable outcomes.

First, it is necessary to analyze the technology transfer efficiency for universities. This paper narrowed its subjects to GRIs, specialized institutes and national institutes, excluding universities with R&D purposes and specializations in technology. For this reason, it is difficult to determine technology transfer efficiency for the entire nation. In addition, there is insufficient valid data for national or public institutes, which makes the comparison incomplete. As universities have lately been investing a great deal of effort into the commercialization of technologies through university-based technology holding companies or industry-academia collaboration, it is meaningful to analyze the efficiency of universities with equivalent criteria.

Second, it is necessary to analyze efficiency for the mid-term and long-term. This paper originally attempted to evaluate data accrued over a five year period, from 2007 to 2012, which covers the entire period of the technology transfer and commercialization achievement survey. However, this period had to be shortened to three years, from 2009 to 2012, because the raw data are partly missing or have input errors. Future research must necessarily include data for the missing years and add data from recent years (2013-2014) in order to support a mid-term and long-term analysis of efficiency. If more than five years of data were obtained, this would allow easier access to the efficiency trend analysis by expanding the DEA Window.

Third, it is necessary to add a variety of variables. This paper provides relatively conservative input, output and outcome variables based on prior studies in Korea and abroad. In future research, new variables should be added to find relevant factors which this paper does not address. Also, it is noteworthy that the survey on technology transfer and commercialization achievements, which is adopted to secure credibility and public confidence, limits the flexibility and creativity of the research. Researchers should conduct surveys with their own ideas for data supplementation. In addition, it is advisable to perform analyses of relevant variables through Tobit models by enhancing the statistical significance of data.

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