Performance Analysis on Different Research and Development (R&D) Types: Proactive Support Program for International Environmental Regulation

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Abstract

This study analyzed and compared the performance of companies involved in R&D and R&D Infrastructure activities. This study used Proactive Infrastructure Program for International Environmental Regulation as a case study because it is a program that supports both R&D and R&D Infrastructure in Korea. It also evaluated the R&D performance by combining and isolating R&D and R&D Infrastructure.

The analysis result shows only a handful of companies are actively involved in both R&D and R&D Infrastructure in the program. Differences in technical, economic, and social performance showed no statistically significant. For Economic performance, companies participated in R&D alone showed higher numbers; while for technical performance, companies involved in both activities had higher numbers. From the results of the analysis, it is difficult to state that combining R&D with R&D Infrastructure will create higher performance than R&D alone; however, the study noted an important point in that it R&D activities and its performance measurement need to be analyzed by types.

Keywords: Research and Development (R&D) Activities, Korea, Performance Analysis, Logic Model, Support Program Evaluation

1. Introduction

The interest in the latest research and development (R&D) activities for nations, enterprises, and all economic entities are on the rise. With the accelerated technological developments and higher uncertainties in competitions, innovation through R&D has become a vital source for the growth of nations and enterprises. For continuous innovation, it is important to focus on science-based strategies and on constant R&D; the effects of innovation are different depending on the situation and the strategies the nations and enterprises implement.

The purpose of this study is to analyze and breakdown the R&D driven technological innovation. According to OECD (2002), R&D is defined as acquiring new knowledge of all matters, including humans, cultures, and societies, or using already acquired knowledge in a systematic way to devise new applications. R&D activities, on the basis of the definition of R&D above, can be defined as 1) accumulating knowledge of science and technology, 2) acquiring new knowledge on objects, functions, and trends such as searching for new

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applications in an organized and creative way by taking advantage of knowledge accumulated, 3) taking advantage of existing knowledge to find out new ways for creative efforts and 4) supporting different R&D activities, such as financial affairs and R&D department operations.

Based on these comprehensive definitions, R&D activities can fall into three categories: R&D, R&D education and training, and R&D services (OECD, 2002). R&D, as defined above, refers to obtaining new knowledge through systematic and creative activities. R&D education and training refers to educational programs for human resources, and R&D service, which does not directly relate to R&D, refers to service programs that support science and technology activities.

Based on these definitions, R&D activities can be further classified as either R&D or R&D Infrastructure. R&D includes basic research[1], applied research[2], and development research activities[3]. R&D Infrastructure includes R&D education, human resources, R&D support services, facilities and equipment. While many studies have emphasized the importance of R&D, R&D Infrastructure has highlighted the importance of science and technology sector, but it has not been much discussed.

From the literature reviews, an increased attention to non-technological factors like R&D infrastructure related activities was observable; however, most of these studies focused on generalizing R&D activities and have used a unified performance measurement indicator. In reality, R&D activities can be classified by types, and each type needs a different performance measurement indicators and targets. Therefore, this study analyzed the different performance measurement results of R&D and R&D Infrastructure by using a case study of "Proactive Support Program for International Environmental Regulations." The study checked for comprehensive range of R&D activities, and evaluated the possibility of performance evaluation of R&D activities through practical engagement and disengagement of R&D and R&D Infrastructure.

2. Literature Review

2.1. Past Literatures on R&D Effectiveness and R&D Performance Measurement

It is undeniable that the interest of R&D performance measurement is on the rise. This topic had been under intense debate as there was no clear-cut definition of R&D performance measurement techniques. According to Brown (2005), measuring R&D performance was difficult because 1) the outcomes of R&D activities cannot be quantified and 2) outcomes of R&D activities lag the output of activities by several decades (ORAU, 2005). However, R&D performance measurement continued to be an important area of research as it raised interest to practitioners and R&D managers.

Earlier R&D performance researches were at the firm level. Chiesa, Frattini, Lazzarotti, Maznini & Troja (2008) looked at how to design a performance measurement system (PMS) that fitted the characteristics of R&D activities. There were lack of literatures in capturing the R&D performance measurement phenomenon and what performance measurement system was made up of (objectives, dimensions, and control objects). The paper used 48 Italian companies to provide logical steps a firm should follow through in designing a performance measurement system.

1 An experimental or theoretical study carried out to obtain new scientific knowledge based on natural phenomenon, and without targeting specific application

2 An original study carried out to acquire new scientific knowledge for practical purposes under specific goals

3 A systematic activity to improve materials, products, systems or services by utilizing knowledge obtained by studies

Continuing on their research, Chiesa et al (2009) looked at companies' objectives when measuring R&D activities' performance and what approaches of R&D performance measurement were to be used in different objectives. Through a case study of 15 Italian technology-intensive firms, the paper found that companies measured R&D performances with different purposes, such as to motivate researchers and engineers, to evaluate profitability of R&D projects, and stimulate organizational learning.

Similarly, there were many literatures on R&D performance measurement in the business-level. Many of the literatures have been using the relationship between R&D expenditures and investment with GDP or even patent number variables to see the effectiveness of R&D activities at the company level (Ojanen & Vuola, 2003). However, not many studies have conducted research and analysis R&D performance at the national level.

2.2. Importance of Linking R&D and R&D Infrastructure

Szakonyi (1994a, 1994b) developed an approach to compare performance of R&D departments and have identified ten R&D activities: Selecting R&D; Planning and managing projects; Generating new product ideas; Maintaining the quality of R&D process and methods; Motivating technical people; Establishing cross-disciplinary teams; Coordinating R&D and marketing; Transferring technology to manufacturing; Fostering collaboration between R&D and finance; Linking R&D to business planning.

R&D activities such as establishing cross-disciplinary teams, motivating technical people, and coordinating R&D and marketing, are examples of "non-technological factors" of R&D and innovation. According to Mothe & Nguyen Thi (2010), technological innovation refers to product and process innovation. It includes significant improvement to technical specifications and usages, components, materials, software and even user friendliness. Non-technological innovation, on the other hand, is related to organizational innovation, which is defined as "the implementation of a new organizational method in the firm's business practices", and marketing innovation, such as product strategy, price strategy, and promotion strategy (Mothe & Nguyen Thi, 2010).

There have been increases in the number of studies that have stressed the importance of non-technological innovations like R&D Infrastructure. Schmidt and Rammer (2007) mentioned that there were aspects of business, such as cooperate reorganization and marketing that cannot be demonstrated by innovative activities. Therefore, Schmidt and Rammer claimed that by combining non-technological innovations, such as marketing, organizational innovation, human resources development, and R&D Infrastructure, with product and process innovation will bring an improvement in sales.

With the recent proliferation of open innovation paradigm, innovation have encompassed both the term R&D and Infrastructure. OECD published Oslo Manual in 2005 that included organization, marketing and Infrastructure innovation along with product and process innovation. Schmidt and Rammer (2007) analyzed the effects and determinants of technological innovation and non-technological innovation by using Germany's CIS 4 (Community Innovation Survey) data.

Frenz and Lambert (2009) evaluated OECD innovation microdata projects in a firm-level in 20 countries to seek information on innovation. It used factor analysis on innovation survey data to see the different modes of innovation practices and acknowledge the importance of non-technological factors such as organizational and marketing innovation. Technological and non-technological innovations were activities that complement each other, not substitutes. Frenz and Lambert analyzed that there were no consistent patterns in the effects of innovation practices and the productivity. It was evident that similar policy instruments can lead to different responses in countries. Frenz and Lambert also suggested that other non-technological factors like value added or financial performance research should be pursued in the future.

OECD (2011) conducted a study on the different firms' sizes of the types of innovation (technological innovation only, non-technological innovation only, or a mix of the two). It was clear that the mix of technological and non-technological firms is growing as the number of firms with mix of innovation types is far more than the firms focusing on one type. It is important to consider the different impact of the two types of innovation when formulating innovation policies or setting up government support programs. Policies tend to favor the technological innovation more, but evidences showed that success often depends on the non-technological innovation (OECD, 2011).

A recent flow of studies shows that instead of focusing on just product or process innovation activities, non-technological innovation, such as administrative changes, organization structure, infrastructure and human resources, should be considered in order to generate more innovation. Therefore, rather than approaching innovation as a concept of R&D, it is necessary to understand R&D activity as an integrated perspective of Infrastructure and non-technological innovation.

Seeing it more logically, there needs to be properly supported R&D activities that not only support R&D programs, but also R&D Infrastructure programs along with effective policies to evaluate and analyze the influence of these programs.

2.3. R&D Programs for Different Types of R&D Activities in Korea

R&D performance measurement researches can be categorized and divided by functions and stages. Research evaluation techniques should vary by different types of R&D (Ojanen & Vuola, 2003). According to Pappas & Remer (as cited by Ojanen & Vuola, 2003), research functions vary from basic research, exploratory research, applied research, development research and product improvement research, while evaluation techniques need to vary from qualitative[4], semi-quantitative[5], and quantitative methods[6].

Depending on the type of R&D, it can be classified as either R&D or R&D Infrastructure program. According to the Ministry of Science, ICT, and Future planning (2013), R&D programs covers basic research, short and long-term industrial technology development, public technology development, defense technology development, and regional R&D. Infrastructure programs covers human resources, facilities & equipment, diffusion, and international cooperation. Table 1 shows the different R&D program taxonomy defined by the Korean government.

For R&D, it can be defined as application research and development programs for new technologies for a short-term (within 3 years) commercialization. For Infrastructure programs, it is a performance based program, such as technical achievement, management/diffusion, and policy support. Similarly, recent national R&D programs in Korea are a mix of both R&D and R&D infrastructure support.

4 Algorithm or predefined ratio to generate numbers that can be compared with other projects and past experiences (Ojanen & Vuola, 2003)

5 Qualitative judgments that are converted to numbers (Ojanen & Vuola, 2003)

6 Intuitive judgements (Ojanen & Vuola, 2003)

Table 1. R&D programs taxonomy

Characteristics	Type	Concepts and Classification
R&D	1. Basic Research	➢ Create and acquire new knowledge through analyzing and researching new natural phenomena. (Pure Basic Type) ➢ Problem solving knowledge and creative fundamentals based research for a wide-range of applications for now and the future.
	2. Short-Term Industrial Technology Development	➢ Short-term (within 3 years) programs to commercialize new technologies and applications for developing new products and R&D.
	3. Long-term Industrial Technology Development	➢ Long-term (more than 3 years) programs to commercialize, promote R&D
	4. Public Technology Development	➢ Applied, Development and R&D programs that contribute to the quality of public life such as public health and disaster preventions
	5. Regional R&D	➢ Regional Infrastructure programs development such as university-industry cooperation, local clusters development
	6. Defense Technology Development	➢ Applied, Development and R&D programs that aims to strengthen the national defense and defense industry development
R&D Infrastructure & HR	7. Human Resources	➢ Supporting universities, colleges, professional training industry personnel and offering science and technology classes for primary and secondary education.
	8. Facilities & Equipment	➢ Construction of large research facilities and equipment ➢ It excludes purchasing simple equipment under the facility expansion with programs budget
	9. Diffusion	➢ Program purposes like technology commercialization, standardization, certification, outcome management/diffusion and policy support.
	10. International Cooperation	➢ Attracting overseas institutions, multilateral and bilateral cooperation agencies.

Source: Ministry of Science, ICT, and Future Planning (2013). National R&D Programs Standard Performance Indicators (Performance Goals & Indicators Guideline)

2.4. Past R&D Logic Model Researches

R&D performance research can also be separated by process phases. Numerous studies have also suggested that innovation and R&D should be managed as a process. According to Brown & Svenson (as cited by Ojanen & Vuola, 2003), R&D productivity should be evaluated as a processing system, which contains inputs, outputs, and outcomes. Cordero (1990) developed a model to measure innovation performance by looking at resources for technical, commercial, technical output, and marketable output units. Lee, Son & Lee (1996) used fifteen important criteria from input, throughput, output and outcomes to measure R&D effectiveness for twenty eight firms in Korea.

Instead of measuring the R&D performance by process phase, a logic model, one of the tools used to identify R&D program plans, is commonly used to analyze the logic flow of the programs by finding disconnections in the flow. Despite logic models' unpopularity among government R&D program planning process in Korea, number of researchers has focused on logic models. Kang (2013) improved a R&D program logic model and conducted a feasibility study on logic models. Park (2015) examined the relationship between R&D performance creation processes with R&D logic model for innovative R&D programs. Park created a logic model and identified ten variables; three input variables (R&D budget, R&D period and R&D workforce); five performance variables (SCI Publications, Patent Registration, Technology Transfer, Sales, and New Employment); and two external influence variables (Institution Type and R&D Collaboration Type). Park used a logistic regression on 929 R&D project data. The study found that 1) input variables were positively correlated; 2) R&D budget was positively correlated with all 5 performance variables; and 3) performance variables were statistically significant.

To the best of our knowledge, there were no prior studies that have applied a logic model to a government support program in Korea as a case study to evaluate and measure the R&D performance.

3. An Outline of the Case Study: Proactive Support Program for International Environmental Regulation

This study compared two R&D types by carrying out a case study in Proactive Support Program for International Environmental Regulation. It compared the performance of R&D and R&D Infrastructure companies with companies that focused only on R&D. Finally, this study analyzed the developing mechanisms by linking R&D with R&D Infrastructure.

According to Korea Institute of Industrial Technology (KITECH) (2014), the main objectives for Proactive Support Program for International Environmental Regulation are to 1) to be proactive, 2) to build an eco-industrial programs that can enhance competitiveness, and 3) to support "low-cost timely response" by providing international environmental regulation information, consulting, human resource support and certification support. It also needs to constantly monitor international regulation trends to provide "proactive response" reliably and build/operate automotive/chemistry /electronic industry-related international environmental regulatory tracking systems.

There are five points to highlight about an infrastructure program. First, it is to provide up-to-date international environmental regulation information analysis and consulting support to companies. Second, it is to operate and manage chemical information in products and delivery system. Third, it is to diagnose domestic enterprises' environmental regulation cognitive level and to examine the impact of enactment/amendment of environmental regulations on industries. Fourth, it is to train experts in the field of international environmental regulations in the field of absorptive capacity of companies. Lastly, it is to support international environmental response R&D projects from 2006 to 2013. R&D was supported by type of technologies, such as product technologies, core industrial-environmental technologies, product services, and sustainable technologies.

Table 2 shows the different R&D performance of the program from 2006 to 2013. In a performance research conducted by yearly frequency analysis, the chart below shows that 2008 had the highest at 60, and decreased to 13 in 2013. This program

Table 2. R&D performance outcomes

	Frequency	Percent	Valid Percent
2006	11	5.0	5.2
2007	47	21.4	22.2
2008	60	27.3	28.3
2009	52	23.6	24.5
2010	9	4.1	4.2
2011	15	6.8	7.1
2012	5	2.3	2.4
2013	13	5.9	6.1
Total	212	96.4	100.0

is divided into infrastructure (which includes information, consulting, certification, and human resources) and R&D. 2014 Infrastructure project outcomes include a total of 897 cases of consulting and support services (177 cases of international environmental regulation counseling support, 683 cases of call center services, and 37 cases of on-site consulting). There were other outcomes, which include a total of 237 participants in the international environmental regulation proactive conference, 5 reports, enterprise database of 8,725 cases and personal database of 21,056 cases and more.

4. Research Methodology

4.1. Logic Model and its Usage for Program Evaluation

As described by Brown & Svenson (as cited by Ojanen & Vuola, 2003), innovation and R&D should be measured as a processing system, and therefore, this paper aims to measure the R&D performance of a Korean government support program through a logic model.

Logic model is a good tool to be used in managing, evaluating and measuring program performance. Logic model allows an in-depth, multi-perspective evaluation and dissemination of programs. According to Conrad, Randolph, Kirby & Bebout (2008), a logic model is a visual model that describes the essential components of a program, and shows the logical relationship between these components and their expected outcomes. There is no one way of representing a logic model, but it has four properties: 1) context; 2) theory and assumption of program's intervention; 3) the intervention; and 4) the outcomes. Logic model is a useful method for evaluating and measuring the R&D performance because not only the outcomes are visible, but also the probable relationship among components.

Through the course of program analysis, appropriate R&D performance measurement logic model is selected. Program logic model assists to better understand the work of stakeholders, performs program analysis to take advantages of performance targets and indicators, and analyzes the expected results of commitment of resources, program processes, and product specific time intervals (short, mid, and long-term). It also enhances the mutual understanding of different stakeholders like administrators, and evaluators by mapping out the program operations. Program associates can facilitate by linking performance targets and indicators through program analysis.

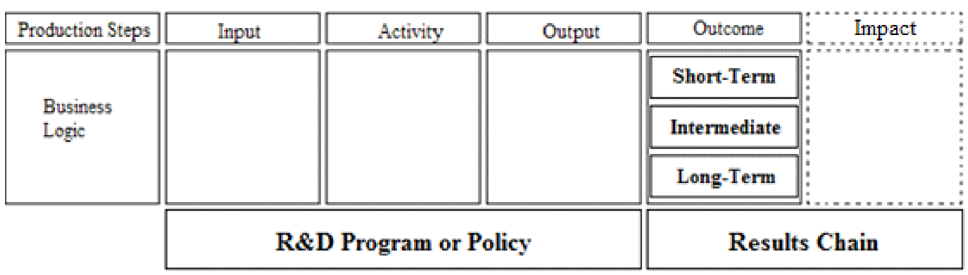
The performance measurement logic model is an instrument that observes the characteristics of a program utilizing components, such as ambient conditions and surroundings. Figure 1 displays a simple form of a logic model. There are a total of five components, which are inputs, activities, outputs, outcomes, and influences, such as important environmental features of the program such as social, cultural and political aspects. There are two sides to logic models: the R&D program/policy and the results chain. The R&D program/policy looks at the program or policy delivered by evaluating the inputs, activities and outputs. The results chain looks at the results from the program by separating the outcomes by time-periods (short-term, intermediate, and longer-term). It is expected that for short-term programs, the outcomes will occur within 3 years, 3 to 5 years for medium, and more than 6 years for long-term programs; however, it may vary depending on the program.

In detail, the "Input", also known as resources, for the logic model is related to funding, accumulated technical knowledge, facilities, equipment and other input required to support programs such as developing and promoting technologies. For "Activity", it is to induce a series of actions or outputs and results taken to achieve the technical development. "Outputs" is related to direct and immediate results in goods, services or products that can be reflected in numbers. The "Outcome" is presented as a program performance in the short-term (changes and benefits that are caused by program's outputs), intermediate (results from short-term outcomes), and long-term (impacts followed by intermediate outcomes). It is expected that short-term outcomes will occur within 3 years of the program's initial phase, 3 to 5 years for intermediate outcomes, and more than 6 years for long-term outcomes; however, it may vary according to the program. Since there are many arenas of R&D and innovations, there are different kinds of intermediate and ultimate outcomes such as economic, social and mission benefits (Jordan, 2008). "Influence" is not a result of the program, but is a critical feature of the performance. Influences, which can be either positive or negative, are the intended or unintended changes in the society or in the economy due to the implementation of programs.

The logic model process requires five steps (Samsuri, 2011): first, collecting information, second, defining the problem and context of the program, third, defining elements for the logic model, fourth, constructing the logic model, and fifth is to verify the logic model. Many governments' agencies have used logic models to monitor and evaluate programs. For example, the US Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) have used the logic model to increase energy supplies and modernize the energy infrastructure (Jordan, 2008).

A logic model has several objectives for program evaluation (Conrad et al, 2008). First, it provides clarification of program goals. Most programs have more than one goal; a logic model helps to identify the more important goals for evaluation. Second, it identifies underlining theory. Logic model is a "valuable tool for elucidating the theory behind a program because it defines the assumptions and the line of reasoning among the assumptions, activities and outcomes" (Conrad et al, 2008). Third, logic model provides a framework in which a program can be evaluated from. A logic model describes a model in details and can assist what data should be collected during the evaluation process. Fourth, logic model is a good tool that can help program managers to prevent from deviating from the ideal situation, and stay consistent throughout the program period.

Figure 1. Basic form of logic model



There are numerous benefits of using a logic model. First, it is a model that highlights "plausible pathways through which resources translate into outcomes" and sense how programs will function under set conditions (Samsuri, 2011). The logic models help to examine various aspects of the program, such as the type of R&D, managements, evaluation, planning and structure of the program to understand and set appropriate performance goals and indicators. The logic model can be created any time during the program life cycle, and can be revised as more information and data are collected.

4.2. Setting Performance Indicators for a Logic Model

Performance indicators are set according to the type of R&D when the logic model is established. R&D performance indicators can be examined using five performances (scientific, technical, economic, social and infrastructure). The Ministry of Science, ICT, and Future Planning (2013) recommends setting the performance indicators as presented in Figure 2 below for each type of R&D programs.

The program's length are determined by considering each program's characteristic, but in general as stated above, short-term programs last within 3 years, 3 to 5 years for mid, and more than 6 years for long-term programs. Performance targets and indicators must be configured by firm-type and by key performance achievements. For program types, other than basic research, program associates should avoid putting high weight on papers and journal articles, and should identify at least two performance indicators.

Scientific performance indicators are not associated with pure science, application or development. It refers to basic research, and applies to elementary principles of all areas, and represented by national R&D achievements like publications, and life resources.

Technical performance indicators are direct and indirect results of technological development aiming at industrial applications, contents, software, and services. It is difficult to distinct the initial and the applied phase, since it is closely related to the industrial nature. The results of technical development can be tangible such as IP (intellectual property), products, but also intangibles like services.

Economic performance indicators can be divided into either direct or indirect results. Direct results refer to economic values that were generated through market transaction. Indirect results refer to contents created by companies supported by R&D organizations. Examples of economic performance indicator are sales rise and market value of a company receiving support.

Social performance indicators refer to training, job creation and other human resources related areas, and are divided by sectors. It also represents promoting international cooperation, and creating a culture for technology and science. Some typical examples are employment related numbers (number of college graduates in the field, employment rate, etc.), and marketing performance.

Business Type/Period	Output	Short-Term Outcome	Long-Term Outcome
1. Basic Research	Scientific Performance Technical Performance	Scientific Performance Technical Performance	Scientific Performance Technical Performance Economic Performance Social Performance
2. Short-Term Industrial Technology Development	Technical Performance Financial Performance	Technical Performance Financial Performance	Technical Performance Financial Performance
3. Long-term Industrial Technology Development	Scientific Performance Technical Performance	Scientific Performance Technical Performance Economic Performance	Economic Performance
4. Public Technology Development	Scientific Performance Technical Performance	Scientific Performance Technical Performance Economic Performance	Economic Performance Social Performance
5. Regional R&D	Scientific Performance Technical Performance Economic Performance	Technical Performance Economic Performance Social Performance	Economic Performance Social Performance
6. Defense Technology Development	Technical Performance Economic Performance Infrastructure Performance	Technical Performance Economic Performance Infrastructure Performance	Technical Performance Economic Performance Infrastructure Performance
7. Human Resources	Scientific Performance Technical Performance	Scientific Performance Technical Performance	Economic Performance Social Performance
8. Facilities & Equipment	Infrastructure Performance	Infrastructure Performance	Economic Performance Social Performance Infrastructure Performance
9. Diffusion	Technical Performance Economic Performance Infrastructure Performance	Technical Performance Economic Performance Infrastructure Performance	Technical Performance Economic Performance Infrastructure Performance
10. International Cooperation	Scientific Performance Technical Performance	Scientific Performance Technical Performance	Economic Performance Social Performance

Figure 2. Programs' key performance by type (example)

Infrastructure performance indicators refer to research facilities, equipment, IT systems and military purpose technologies (weapon systems). Some typical examples are research facility equipment, information systems, and weapon systems.

5. Using the Logic Model in the Case Study Evaluation

For measuring the performance of the program, the study conducted a review of the performance measurement logic model and set the overall framework. In order to set the program evaluation logic model, it is necessary to look at the nature of the program systematically. In the case of this program, it is a key to distinguish the type of R&D (R&D or the R&D and R&D Infrastructure) and understand that logic models may vary accordingly. Proactive Support Program for International Environmental Regulation is a long-term industrial-technology development program; therefore, according to previous studies and Figure 2, the indicators would be the technical, economic and social performances.

Table 3. Examples of logic models for Proactive Support Program for international environmental regulation

Logic Models		Input	Activity	Output	Outcomes		
					Short-Term	Intermediate-Term	Longer-Term
Business Logic		Support International environmental regulation information analysis and consultation	Operate delivery system, manage chemical information, and measure impact factors	International environmental regulation policy satisfaction Utilizing international environmental regulation trend analysis	Additional investments in environment response industry Cutting down production costs Improving technical performance such as technology transfer success and patents	Increase sales Growth in exports Job creations Environmental compliance Creating university-industry partnership	Establishing international environmental regulation platform
Branch table by Business Types	R&D			Business performance satisfaction	Number of cases of creating IP Number of cases of technology transfer Total reduction of production costs Additional R&D proactive investments	Sales/Exports increase Total employment headcount Enhancing cooperative relations	Establishing international environmental regulation platform
	Infrastructure			Business performance satisfaction	Revenue generating contribution Creating new businesses Whether to invest in additional companies Resolving technical difficulties	Number of new technologies Promote university-industry cooperation Employ field personnel	Degree of vitalization of international environment regulation response

Table 3 shows the selected performance measurement logic model for the Proactive Support Program for International Environment Regulation. R&D part of the program can be divided into short-term industrial development and diffusion sector; it is difficult to output results for scientific and infrastructure achievements due to lack of support. The Ministry of Science, ICT, and Future Planning (2013) has created a set of performance indicators for different activities. The study selected the most appropriate indicators for Input, Process, Output, Outcomes (Short, Intermediate and Long-terms) of the performance measurement logic model.

In order to design and measure the performance measurement logic models, surveys and quantitative assessment were conducted. In order to analyze the logic models, the type of participation was separated into three groups: R&D only companies, R&D and Infrastructure companies, and Infrastructure only companies. Due to the different ways of supporting (logic models and the character of business), it is not easy to compare the performance of R&D only and Infrastructure only companies. Therefore, this study focused on comparing companies participating in R&D only with companies involved in R&D and Infrastructure.

Table 4. Forms of participation for Proactive Support Program for International Environmental Regulation (multiple responses)

<table>
<tr><th colspan="2">Headings</th><th>Number of Cases</th><th>%</th></tr>
<tr><td colspan="2">Companies involved in R&D</td><td rowspan="5">202</td><td>17.8</td></tr>
<tr><td rowspan="4">Companies involved in Infrastructure Program</td><td>Support in accordance to consultation</td><td>16.3</td></tr>
<tr><td>Involved in environmental regulation proactive training</td><td>81.3</td></tr>
<tr><td>Participation in international environmental regulation related events</td><td>40.1</td></tr>
<tr><td>Obtain governmental proactive information on international environmental regulations</td><td>51.0</td></tr>
</table>

Table 5. International Environment-Government Support Program by company types

	Company Type	Frequency (Number)	Percent (%)
Participating in R&D	Conglomerates	1	6.7
	SMEs	8	53.3
	Venture Company	2	13.3
	Others	4	26.7
	Total	15	100.0
Participating in Both the R&D and Infrastructure	Conglomerates	8	38.1
	SMEs	6	28.6
	Venture Company	1	4.8
	Others	6	28.6
	Total	21	100.0
Participating in Infrastructure	Conglomerates	55	33.1
	SMEs	86	51.8
	Venture Company	5	3.0
	Others	20	12.0
	Total	166	100.0

5.1. Analysis and Common Achievements for Proactive Support Program for International Environmental Regulation

5.1.1. Subject of Analysis

This study conducted an analysis on 202 companies participating in the international environmental government support programs. Table 4 shows the different R&D types of firms that participated in the program. Research shows that only 18% companies, involved in the governmental support program, participate in R&D. Meanwhile, portion of environmental regulations training companies has increased to 81%. The range of companies involved in activities such as education and acquisition of information has increased.

Table 5 shows the companies participating in the program by types. The number of companies involved in only R&D was 15; whereas the number of companies involved in only Infrastructure was 166. In addition, 21 companies were associated with both the R&D and the Infrastructure. SMEs accounted for 53.3% and 51.8% of the R&D only and Infrastructure only companies, while a relatively large 38.1% of companies participating in both the R&D and Infrastructure were conglomerates.

Table 6 shows the satisfaction level and the opinion of the 202 companies that participated in the international environment government support program. The overall satisfaction level of this program is 3.31; partnership had the highest rating of 3.39, and followed by project system (3.29), and research outcomes (3.24).

Table 6. Satisfaction of the Proactive Support Program for International Environmental Regulation

Headings	Cases	Average Rating
Program Execution Systems	202	3.29
Partnerships		3.39
Research Outcomes		3.24
Subtotal		3.31

5-point scale (Very Unsatisfied: 1, Unsatisfied: 2, Average: 3, Satisfied: 4, Very Satisfied: 5)

Table 7. Satisfaction of the Proactive Support Program for International Environmental Regulation by company participation types

Headings	Type of Participation	Average Rating
Program Execution System	Participating in R&D	3.60
	Participating in both the R&D and Infrastructure	3.48
	Participating in Infrastructure & HR	3.24
Partnerships	Participating in R&D	3.87
	Participating in both the R&D and Infrastructure	4.00
	Participating in Infrastructure	3.27
Research Outcomes	Participating in R&D	3.73
	Participating in both the R&D and Infrastructure	3.67
	Participating in Infrastructure	3.14

Table 7 shows the overall satisfaction of the international environment government support programs by participating form. For project execution systems and research outcomes for companies involved in R&D showed a satisfactory level of 3.60 and 3.73, respectively. The satisfaction level with partners for companies involved in both the R&D and R&D infrastructure has been identified as high as 4.00. The satisfaction based on partnership for companies involved in R&D infrastructure is considered to be relatively low.

Table 8 indicates the different levels of satisfaction for the International Environment Government Support Programs' outcomes. Two highest ratings were policy settings (3.59) and support/information exchange (3.58). Satisfaction level for technical achievements like technology commercialization and new technology development was relatively low.

Table 8. Satisfaction for research outcomes of the Proactive Support Program for International Environmental Regulation

Headings	Number of Cases	Average Rating
International Environmental Policy Settings Satisfaction	202	3.59
Enhancement of R&D capabilities of the Company		3.24
New Technology/Product Development		3.16
Increased revenue through technology commercialization		3.05
International environmental response support and information exchange		3.58
Subtotal		3.32

Table 9. Satisfaction for research outcome of the Proactive Support Program for International Environmental Regulation by company participation types

Headings	Type of Participation	Average Rating
International Environmental Policy Settings Satisfaction	Participating in R&D	3.67
	Participating in both the R&D and Infrastructure	3.86
	Participating in Infrastructure	3.55
Enhancement of R&D capabilities of the Company	Participating in R&D	3.67
	Participating in both the R&D and Infrastructure	3.43
	Participating in Infrastructure	3.18
New Technology/Product Development	Participating in R&D	3.60
	Participating in both the R&D and Infrastructure	3.19
	Participating in Infrastructure	3.11
Increased revenue through technology commercialization	Participating in R&D	3.47
	Participating in both the R&D and Infrastructure	3.14
	Participating in Infrastructure	3.00
International environmental response support and information exchange	Participating in R&D	3.53
	Participating in both the R&D and Infrastructure	3.95
	Participating in Infrastructure	3.54

Table 9 shows the satisfaction for research outcomes of the international environment government support program by business participation types. For "international environmental policy settings satisfaction" and "international environmental response support and information exchange", companies participating in both the R&D and R&D infrastructure show relatively high satisfaction level of 3.86 and 3.95 respectively. For companies involved in R&D, satisfactions in "enhancement of R&D capabilities of the company", "new technology/product development" and "increase revenue through technology commercialization" are identified as 3.67, 3.60 and 3.47 respectively. Meanwhile, companies involved in R&D infrastructure show relatively low satisfaction level in research outcomes.

6. Performance Comparison of companies by R&D Types

In order to compare the performance by companies participating in both R&D and Infrastructure with companies involved in only R&D, the study analyzed the results in three perspectives: economic, social and technical performance.

6.1. Economic Performance

When analyzing the economic performance using the sales and production cost reduction, companies involved in R&D showed relatively higher than companies participating in both the R&D and the Infrastructure. This difference, however, is insignificant. Table 10 shows the statistics results of the economic performance of the program.

6.2. Social Performance

This study investigated the changes in sales and in cost reduction. For social performance, full-time employment workforce for both types of companies showed a similar number of an average of 2.5 workers. In addition, temporary job creation was slightly higher in companies involved in both R&D and Infrastructure than companies in R&D alone; however the difference is not statistically significant. Table 11 shows the statistics results of the social performance of the program.

6.3. Technical Performance

Comparing the technical performance before and after technological independence, companies participating in both R&D and R&D infrastructure were somewhat higher than companies involved in R&D. In addition, companies involved in both R&D and R&D infrastructure had a higher number of patent applications/registration and papers published. Companies involved in R&D only showed a higher number of technology transfers and in imports; the mean difference between the two types was considered to be statistically significant under 0.1%. Table 12 shows the statistics results of the technical performance of the program.

Table 10. Economic Performance for program participating companies by research types

	Cumulative Research Performance (times)	
	Sales	Production Cost Reduction
R&D	3.53	2.26
R&D and Infrastructure	3.25	1.70
t-test	0.845	0.416

Table 11. Social Performance for program participating companies by research types

	Full-time Employment (Headcount)	Part-Time Employment (Headcount)
R&D	2.56	1.11
R&D and Infrastructure	2.55	1.45
t-test	0.995	0.758

Table 12. Technical performance for program participating companies by research types

	Technology Independence		Technology Transfer (Number)	Technology Transfer Import (1 mil won)	Patents		Papers
	Before	After			Applied	Registered	
R&D	58.0	98.0	1.67	248.6	2.8	1.2	1.2
R&D and Infrastructure	62.5	107.5	0.85	138.5	6.0	1.3	4.5
t-test	0.833	0.774	0.069	0.453	0.430	0.975	0.125

* Figures for Patents and Papers are sum of both domestic and international

7. Conclusion

This study analyzed and compared the performance of companies involved in R&D and R&D Infrastructure activities utilizing the Proactive Support Program for International Environmental Regulation as a case study. It also evaluated the R&D performance by combining and isolating R&D and R&D infrastructure. In addition, Proactive Support program for International Environmental Regulation was a suitable case for this study because it is a program that supports both R&D and Infrastructure.

The analysis result shows only a handful of companies are actively involved in both R&D and R&D infrastructure in the program. Differences in technical, economic, and social performance showed no statistically significant. For economic performance, companies participated in R&D alone showed higher numbers, while for technical performance, companies involved in both R&D and R&D infrastructure had higher numbers. The consequence does not align with the previous studies' outcomes of combining technological and non-technological factors will improve innovation performance. Despite receiving additional government support through R&D and R&D infrastructure co-participation, existing companies rely on the government for support on investment areas that have to be self-financed. From the results of the analysis, it is difficult to state that combining R&D with R&D infrastructure will create higher performance than R&D alone; however, the study noted an important point in that it R&D activities, and its performance measurement need to be analyzed by types.

This study contains the following limitations. First, this government support program targeted a small number of companies in a limited area. This result cannot be predicted with limited analysis; therefore, a review of companies and more diverse programs are needed. Second limitation is measuring performance using government support program alone. Due to the high possibility of improving a company's performance through self-investment and support, reviewing company's innovation performance through indirect effect like government support shows limitation. Third limitation is in the logic model used in the research methodology. This research was conducted on the basis of the national R&D evaluation guidelines; therefore, the paper acknowledges that there is a limit in selecting a fragmentary policy methodology. However, this study was significant in applying an actual policy model and fixing the government's biased tendency to focus on R&D-oriented performance and exploring/comparing/reviewing the combined performance of R&D and R&D infrastructure.

Since the two R&D types of participation did not show statistically significant difference, it would be important to draw upon the policy implications. In the future research, a more diverse analysis and comparison of science and technology policy programs of R&D types would be needed. In addition, showed in the analysis section of this study, it is important to distinguish R&D only and R&D for Infrastructure types. Looking at the current study analysis, since there was not a big difference in the performance between the two types, this subject of non-technological factor with technological factors will increase innovation performance need to be taken into account in depth.

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