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Ph. D. Dissertation in Engineering

Study on the Effect of Government R&D Policies and Defence Procurement on Private R&D Investment: A Computable General Equilibrium Approach

투자 유인 정책 및 국방 조달이
혁신 활동에 미치는 효과에 관한 연구
- 연산일반균형모형을 중심으로 -

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Graduate School of Seoul National University

Technology Management, Economics, and Policy Program

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Study on the Effect of Government R&D Policies and Defence Procurement on Private R&D Investment: A Computable General Equilibrium Approach

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Abstract

Study on the Effect of Government R&D Policies and Defence Procurement on Private R&D Investment: A Computable General Equilibrium Approach

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Even though there are critical views suggested by some economists on whether there is a market failure, it legitimizes the intervention of the government into private investment activities. There are two kinds of primary work that must be implemented by the government in a where it is believed that the government has to make up for the market failure. Above all, the government leads the implementation of R&D projects, which may be transferred to the private sector. In this case, the research institute established by the government may raise social welfare by carrying out the R&D tasks, of which the social rate of return is high but the private rate of return is low. Secondly, the government may implement policies that activate private investment, so that the investment is induced up to the level that is considered to be desirable by the society.

Currently, the private R&D investment accounts for a great part of total R&D investment, and the private sector is regarded as the main factor that determines the

national R&D capacity. Accordingly, in order to attain the sustainable growth through technological changes, first and foremost, the government shall activate the investment activities in the private sector. In this context, the government has been implementing various policies to attract investments in the private sector.

The investment-attracting policies that are commonly implemented by most countries, including the South Korean government, include the tax incentive, subsidy, financial support, human resource support, public procurement, institutional infrastructure, technology transfer transaction, technical instruction and consultation, and so on. With the various policy instruments being used to pursue the unique purpose of policies, the discussion on how the government can allocate resources effectively, in order to activate the innovation-oriented activities of the private sector, has come to the fore.

From the viewpoint of supply-push, the state subsidy and tax incentive scheme are the most focused policy instruments. Though both the state subsidy and tax incentive scheme have similar functions in terms of supporting the innovative activities with financial resources, they have opposite characteristics from each other as the state subsidy is a direct means, in which the level of government intervention is high, but the tax incentive is an indirect means. Accordingly, it is required to establish the policies on the basis of comparative evaluation of the effects of both policy instruments in order to design the policies efficiently. However, most of existing empirical studies have analyzed each policy instrument individually, so that there is a limit to what we can suggest with regard to relatively excellent policy instruments.

On the other hand, the economists have recognized the importance of demand-pull policy through debates, however, most of governments have mainly implemented supply-push policies. However, recently, the issues regarding limitation of the supply-push policies have been raised, which are centered around the EU and member countries, calling for the introduction of demand-pull policies positively. Recognizing the importance of demand-pull policy, the South Korean government has been making efforts to supplement the institutional strategies that will be used to implement the demand-pull policies.

In this context, this study is designed to carry out a comparative evaluation of the effects of direct subsidy and tax incentive, which are regarded as the typical policy instrument to attract investments from the viewpoint of supply-push. Along with this, the effect of national defence procurement will be analyzed, which accounts for a greater part of government expenditure among the public procurement that is a typical means of the demand-pull policies.

In order to achieve the purpose of this study, the knowledge-based Computable General Equilibrium (CGE) model has been introduced. As for the model presented in this study, the knowledge is regarded as a capital, and the knowledge capital will be used as a factor of production, along with the labor and physical capital. In addition, the knowledge capital is the source of spillover effect on external economy. So, the knowledge has been capitalized according to the recommendation of System of National Accounts 2008 (SNA 2008) and OECD (2010), so that the knowledge-based social accounting matrix (SAM) could be built up by reflecting the knowledge capital formed through the capitalization in a new account.

According to the study results, both the state subsidy and tax incentive appeared to be effective in promotion of R&D investment of the private sector. However, the tax incentive appeared to be more efficient than the direct subsidy. This result suggests that an effective government intervention is the attraction of investment activities through the market-oriented decision-making. Along with this, it suggests that the government shall have a more comprehensive view of the production and investment environment of each industry in advance in order to apply the direct intervention method effectively. On the other hand, according to results of the analysis of the national defence procurement, which was divided into the general defence procurement and the special defence procurement limited to the weapon systems, both cases appeared to promote the private investment. Especially, the weapons procurement system appeared to have relatively larger effect, which was because the purchase of Defense Acquisition Program Administration (DAPA) accounted for the greatest part of the defence industry market.

This study has an academic significance as it is differentiated from the existing literature as follows. Firstly, the effects of state subsidy and tax incentive have been compared with each other and evaluated directly by using the same dataset and analysis

model. Secondly, the investment-inducing effects of national defence procurement have been presented at the industry level. Thirdly, in comparison with the existing studies, in which the partial effect of investment-inducing policies was analyzed, this study has been focused on the analysis of the full effect of policies, in which the effects of knowledge spillovers have been applied according to investment activities. Fourthly, the effects of each policy instrument on innovative activities and economic growth have been analyzed. Accordingly, the degree of achievement of the ultimate goals of innovative policies has been evaluated quantitatively, which was designed to promote the economic growth through technological changes. Fifthly, the knowledge-based SAM and the CGE model will provide the foundation on which various policies can be evaluated in the future.

Keywords: R&D policy, Defence procurement, Market failure, Knowledge capital, CGE

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Chapter 1. Introduction

1.1 Research background

Some economists believe that the market failure must be corrected by the intervention of the government. The primary reason of the market failure related to R&D investments is the positive knowledge externalities, namely the spillover effect (Arrow, 1962). Because the principal agent carrying out R&D cannot monopolize the fruit of innovative efforts, the motivation to carry out R&D projects decreases. As a result, the innovation effort is made at the level which is lower than the level regarded as optimal by the society.

Another major factor of market failure is the uncertainty of innovation activities (Tassey, 1996; Wu et al., 2007). The uncertainties include the technological uncertainty and market uncertainty, and they exist throughout the innovation process. When the uncertainty rises, the investment decreases in general. Besides, other economist argued that the government support shall be given because of incomplete capital market, high entry barrier to the market, and lack of technological infrastructure (Cerulli, 2010).

There are two kinds of primary work that must be implemented by the government in a where it is believed that the government has to make up for the market failure. Firstly, the government leads the implementation of R&D projects, which may be transferred to the private sector. In this case, the research institute established by the government may raise social welfare by carrying out the R&D tasks, of which the social rate of return is high but the private rate of return is low. Secondly, the government may implement policies that activate private investment, so that the investment is induced up to the level that is considered to be desirable by the society[1].

[1] In reality, the debate on whether there exists a market failure, or the governmental intervention is reasonable, is in progress. However, this study will be carried out on the premise that such a market failure exists.

1.2 Motivation and purpose

The government has been applying various investment-inducing policies in order to raise the investment level in the R&D of private sector. Each policy instrument has a peculiar object and institutional characteristic, and such policies may be divided into two types of confrontational relations, such as the supply-push vs. demand-pull, and influence vs. regulation (King et al., 1994).

In the situation where various policy instruments are being used simultaneously by the government, the effects of each policy instrument shall be scrutinized in order to prevent governmental failure and allow the government to intervene in the market effectively. Especially, when there exist a number of established policies with the same purposes, it is very necessary to choose relatively effective policy instruments in order to plan for and implement innovative policies.

Figure 1 shows the scale and share of direct and indirect government funding provided by OECD members in order to support the investment activities of enterprises. The weight of state subsidy and tax incentive, which are focused on the same policy objectives to support R&D activities with necessary financial resources, differs from country to country. The countries with a larger part of direct government funding include Russia and Slovenia, specially, the countries like Finland and Sweden do not provide indirect government support at all. On the other hand, the indirect government support accounts for a great part in Canada, Australia and France.

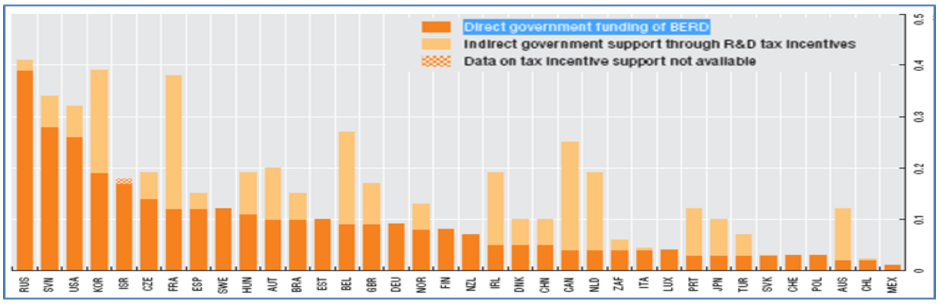

Figure 1. Direct and indirect government support for private R&D in OECD members

Source: OECD, OECD Science, Technology and Industry Scoreboard 2013

The reason why the preferable instruments of support differ from country to country is that the economic and social environment and the impact evaluations of policy means differ when each country chooses the optimal policy instrument. In this context, it is required to carry out a study focused on the analysis, evaluation, and comparison of the effects of each investment-inducing policy, in consideration of our own economic environment, in order to promote R&D investments in the private sector and maximize the effect of ongoing policies.

Accordingly, this study aims to analyze, evaluate and compare the effects of state subsidy and tax incentive, which are regarded as the typical policy means in terms of supply-push, and the public procurement, which is implemented from the viewpoint of demand-pull. It is expected that this study will provide some useful implications for the designing of effective investment-inducing policies.

1.3 Research outline

This thesis is composed as follows. In Chapter 2, the types of policy intervention and theoretical system will be examined. And after reviewing the effects and characteristics of the state subsidy, tax support and public procurement, the results of empirical analysis on each policy means will be examined as well. And in Chapter 3, the scheme for construction of knowledge-based Social Accounting Matrix (SAM) will be introduced, which is necessary for realization of CGE model. In Chapter 4, the effects of investment-inducing policies will be analyzed. Especially, the effects of state subsidy, which is a direct means of government support, and the tax incentive that is an indirect means, will be evaluated and compared from the viewpoint of supply-push. To achieve this, a literature research on investment models will be carried out first, in which the flow of technologies among industries and tax policy variable may be applied. And then, the simulation results will be presented after explaining the overall structure of knowledge-based CGE model. In Chapter 5, the effects of investment promotion caused by the national defence procurement are analyzed. In this study, the national defence procurement will be subdivided into the defence procurement, which includes the full expenditure of national defense, and the expenditure limited to weapons systems, so that both of them will be analyzed separately. For this reason, a literature research will be carried out first, which is aimed at examining the economic characteristics of the demand-pull policies focused on the national defence procurement and the defence industries. And then, the simulation results will be analyzed after building up the two types of SAM related to national defence procurement. Finally, in Chapter 6, the full contents of this thesis will be summarized and policy implications will be discussed. The thesis concludes with future directions of research.

Chapter 2. Theoretical background

2.1 Types of policy intervention and theoretical system[2]

Recognition of the background and viewpoint, in which each policy means is devised and used, is the preferential procedure in order to analyze and evaluate the effects of policies. That is because we need to consider the background and purpose of the establishment of each policy in order to evaluate individual policies. And also, through such examinations, we may judge whether the policy is biased or not.

King et al. (1994) put emphasis on the institutional factors regarding promoting the IT innovation, suggesting a theoretical system that helps classify and understand the policy instruments applied by the government in order to promote the technological innovation in the IT domain.

King et al. (1994) suggested that the government intervention aimed at promoting such innovative activities could be considered from the viewpoints of influence vs. regulation, and supply-push vs. demand-pull. The influence of an institution is the exerting of persuasive control over the practices, rules and belief systems of those under the institution's sway (Kimberly, 1979), and the regulation by institutions is the direct or indirect intervention in behavior of those under the institution's influence, with the specific objective of modifying that behavior through sanction or other affirmative means (King et al., 1994). The supply-push policies are related to the direct and indirect provision of many factors required for the creation of innovation, and the demand-pull policies are connected with the creation and articulation of demand for the innovation.

King et al. (1994) argued that the policy means seen from each viewpoint are not a substitutive relationship, but a complementary relationship, so that the government would choose a specific policy means according to the decision it made regarding which power is dominant in an innovation process.

Table 1 shows the classification of typical innovative policy means currently used by

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[2] The contents of this clause is based on the study carried out by King et al. (1994).

the government according to the analysis framework suggested by King et al. (1994).

Table 1. Major R&D policies of the Korean government

	Supply-Push	Demand-Pull
Influence	Direct subsidy Tax incentive Support with investment・loan security Provision of human resources Operation of government-funded research center	NEP compulsory purchase system Selection system for excellent products at the procurement agency Preferential purchase system for the products developed by small and medium businesses
Regulation	Human resource development project Support center for globalized professional manpower	Technology commercialization Ttechnology transfer projects Defence industry appointment system Various certification system

Taking a look into the R&D policies that are being implemented by the government, we may know that the government is making use of the policies with the aspect of influence-regulation-supply-demand simultaneously. However, though regulation-based systems, which aim to guarantee the self-regulating innovation activities of the private sector by creating a general environment for innovation activities, are being operated actively, the influence-oriented policy instruments have been applied with more attention than the regulation-based policy instruments. Meanwhile, the supply-push policies have been adopted more aggressively than the demand-pull policies. The supply-push policy is a comparatively direct method as it is used to provide essential elements and resources to the innovation activities of the private sector. And also, such policies have been used as a major means of government intervention in the market since 70~80s, when the government was leading the industrialization.

On the other hand, the government implemented demand-pull policies for the defence industry from the earlier years as it was directly connected to the national security. The government restricted the competitive market entry, allowing the specific enterprises to produce military supplies and sell the products to the government, which was aimed at protecting and fostering the defence industry. However, despite the demand-pull policies for such defence industries, the innovative demand-pull policies as a whole have been of little importance among the innovation policies, and only recently the necessity of demand-pull policies has come to the fore.

2.2 Effects and characteristics of each policy instrument

2.2.1 State subsidy and tax incentive

2.2.1.1 Effects of state subsidy and tax incentive

The studies which were focused on the effects of existing investment-inducing policies have presented the results of econometric or qualitative analyses without concrete discussions about the mechanism in which each policy instrument had an impact on the R&D investment. On the other hand, David et al. (2000) suggested a clear framework of the mechanism in which the tax support, direct subsidy and government contracts had an impact on the R&D activities of the private sector.

The optimal level of investment in R&D project is determined at the point where the marginal rate of return (MRR) and marginal cost of capital (MCC) intersect.

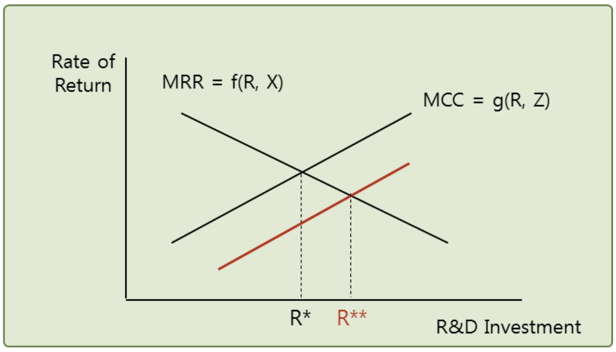


Figure 2. Optimal level of private R&D investment

Source: David et al. (2000)

In this figure, the MRR curve appears to have a left-downward incline. This is because an enterprise will carry out a project with high rate of return first, and then it will move on to another project with lower rate of return gradually. On the other hand, the MCC curve represents the opportunity cost of capital at the various R&D investment level, showing a right-upward incline. The reason why the curve shows a right-upward inclination is that the company uses the internal funds as the investment funds first, and then the company starts to rely on external funds (equity and debt) as the amount invested increases.

A policy instrument causes the changes in level of R&D investment by shifting the MRR and MCC curve.

$$MRR = f(R, X)$$
$$MCC = g(R, Z)$$

In this context, the exogenous variable X is a policy variable affecting the MRR, which includes the technological opportunities, the state of demand in its potential market area or line-of-business potential market, and the institutional and other conditions affecting the appropriability of innovation benefits. And the Z variable, which is an exogenous variable affecting the MCC, includes technology policy measures that affect the private cost of R&D projects, macroeconomic conditions and expectations affecting the internal cost of funds, bond market conditions affecting the external cost of funds, and the availability and terms of venture-capital finance (David et al., 2000). In short, the level of R&D investment can be determined by the exogenous policy variables.

$$R^{*}=h(X, Z)$$

Because the tax incentive directly causes the reduction of MCC of the R&D investment, it is expected that the tax support will not crowd out the private R&D investments, so that we may expect that the tax incentive would shift the curve to the right, increasing the R&D investments to the some extent. The direct subsidy may increase the R&D

investments, shifting the MCC curve to the right. It is because the fact that enterprises have received the state subsidy may facilitate financing by raising the awareness of enterprises in the financial market. On the other hand, the state subsidy may shift the MRR curve to the right through the indirect effects. In this case, the demand in the market increases sharply as the benefit of subsidy is recognized as a sign of creation of a new market.

However, some empirical studies have shown the results that are different from the policy means which may be expected on the basis of such conceptual analysis frameworks. In order to understand the background in which the results derived from theoretical analyses and empirical studies are not in accordance with each other, we need to review the characteristics of each policy means.

2.2.1.2 Characteristics of state subsidy and tax incentive

The state subsidy has effectiveness in activation of investment by raising the earning rate and reducing the private-sector R&D expense (Wu et al., 2007). Especially, the merit of subsidy is that the government can get the specification of R&D projects that will be carried out by enterprises in the concrete. In other words, the government can put restrictions on the types (product and process) and all purposes of R&D activities when providing the enterprises with a subsidy. And through the direct support to the area where the products have the nature of public goods, and the social rate of return is high but private rate of return is low, the government can create a strong ripple effect in the socioeconomic field (David et al., 2000). And also, the state subsidy granted to a start-up company, which lacks financial resources in the initial stage, though it wants to invest in R&D, may create a prompt effect in innovative activities (Avellar, 2011).

However, the subsidy system has some weak points as follows. Firstly, the government subsidy may crowd out the private R&D investment. For example, if the government provides subsidy to a project that is supposed to be implemented without subsidy, the private R&D investment itself may be crowded out. And an enterprise may hold off making a decision on other R&D projects in order to make progress in the project that has been provided with a subsidy (Howe & McFetridge, 1976). In this context, the fundamental problem of state subsidy is that the government is not able to investigate the investment environment of enterprises or industries accurately. For another example, we may consider the circumstances with inelastic supply of scientists and engineers in the technology market. When the state subsidy increases the demand for R&D, the prices for R&D may rise, which results in crowding out the R&D investment in the industry (Goolsbee, 1998).

Secondly, the enterprises with relatively less technical capacity may be excluded in the process of selection of an enterprise that will be provided with subsidy, so that an enterprise with excellent technology can be selected. In other words, the state subsidy may not be in accordance with the intrinsic function of government policy, which shall be focused on the weak in terms of marketplace. And also, there is a possibility that the winner is not picked by the function of a market, but by the government, as an unqualified enterprise is subsidized (Guellec & Van Pottelsberghe de la Potterie, 2003).

Thirdly, the government may force the enterprise to comply with the specific terms in return for the subsidy. The restrictions may play a negative role in R&D activities of enterprises. Finally, the subsidization process cause a lot of administration cost, which leads to the tax burden to the people.

And the pros and cons of tax incentive are as follows. The tax incentive is a system that focuses on reducing the MCC of the R&D investment. Accordingly, unlike the state subsidy, the tax incentive is less likely to crowd out the firm’s own R&D investment (Wu et al., 2007). And the merit of tax incentive is that all the enterprises participating in R&D activities can qualify for tax cut without discrimination (Wu et al., 2007). Accordingly, it may be helpful for the enterprises that cannot qualify for the various government support policies, including the state subsidy (Guellec & Van Pottelsberghe de la Potterie, 2003). Above all, the most important characteristic of the tax incentive is that it is a market-oriented means. In a word, in the tax incentive, the type of R&D, implementation method and time are based on the decision made by the enterprise. Accordingly, unlike the direct subsidy system, there is slim chance of government failure, and the efficiency of the policy may be improved (Hall & Van Reenen, 2000).

Despite such merits of the tax incentive system, there are several weak points which are caused by the characteristics of the tax support, regarding the fact that it is an ex-post tool which supplement the R&D expenditure. Firstly, enterprises will prefer the project that may create bigger profits in short time in order to receive tax support. As a result, they will not consider the projects that ensure high-level social rate of return, or the projects such as research infrastructure, which requires a long-term implementation plan, as a priority factor of investment. Therefore, even though the enterprise investment is activated by the tax incentive, the ripple effect that can be enjoyed by the society may not be large (David et al., 2000; Hall & Van Reenen, 2000).

Secondly, the newly-established enterprises, which cannot afford R&D investments at the initial stage due to lack of liquidity, may be excluded from the selection of beneficiary (Hall & Van Reenen, 2000; Elschner et al., 2011). Accordingly, the tax incentive may act as a useful means only for the existing innovative enterprises (Avellar, 2011).

Thirdly, the tax incentive is reward for the efforts made in the past, so that the tax incentive may be recognized as an unexpected income from the viewpoint of enterprises. As a result, there is possibility that the tax incentive may not have no effect on the R&D strategies for enterprises (Guellec & Van Pottelsberghe de la Potterie, 2003).

Fourthly, the effects of various support policies and tax incentive may overlap with each other, and some enterprises in a specific situation may not feel an effect of the support due to the existence of upper bound of R&D tax credit and depreciation rate (Elschner et al., 2011).

Fifthly, in the case of incremental tax credit system, the current increase in R&D investment expands the foundation of future tax credits, so that there is a probability that the enterprises may put off or scale back investments (Eisner et al., 1983).

2.2.2 Public procurement

2.2.2.1 Definition of public procurement

The public procurement refers to the activities in which goods and services are acquired by the government or public agencies through a purchasing process (Hommen &

Rolfstam, 2009; Uyarra & Flanagan, 2010). Edquist et al. (2000) divided the procurement into the regular public procurement and public technology procurement in terms of the degree of innovation inducement. The regular public procurement refers to the case in which public agencies purchase the goods that do not need an additional R&D as such goods have already been launched into the market, or the decision on purchase and selection of the supplier is made on the basis of available information of price, quantity and performance (Edquist et al., 2000).

On the other hand, the public technology procurement refers to the purchase action in which a public institution buys goods, services or systems that can be developed within a reasonable period of time by an enterprise, which is willing to produce and sell the products through an additional R&D or new developmental work (Edquist et al., 2000). Similarly, we may use the 'innovative procurement' or 'procurement of innovation' in order to describe the procurement process which includes broader effort for innovation in R&D activities (Edquist et al., 2000).

2.2.2.2 Mechanism for the effect of procurement policy on innovation

In order to design a procurement policy that may promote an innovation activity effectively, we need to understand the mechanism in which procurement policies have an effect on innovation activities[3]. Cave and Frinking (2003) divided the effects of procurement policies on innovation efforts into the direct demand–pull impacts and indirect demand–pull impacts. The direct demand–pull impacts are elated to the efforts of procurement policies based on the intention to directly purchase the innovative products and services.

When an enterprise can capture the sales market at the initial stage and take the advantageous position first, the risk of innovation may be reduced (Dalpé, 1994). And public purchases of innovative products will deliver a positive signal to the market. The public procurement publicizes the function of relevant product widely in the private

[3] The influences on innovation may be understood by dividing them into the direction of technology change and the rate of technology change (Geroski, 1990; Dalpé, 1994; Edquist & Hommen, 2000; Hommen & Rolfstam, 2009). However, the concept has not been divided in this study.

market, raising the initial recognition of the product in the market. Such effects on the private market may be more important than the initial public procurement (Rothwell, 1984; Porter, 1993). In this manner, the procurement has a direct impact on innovation activities by purchasing innovative goods and services.

The indirect demand–pull impacts mean that innovation is a by-product of government procurement. According to Cave and Frinking (2003), the public procurement disseminates the R&D results, and reduce the cost and risk factors in innovation activities, or may have an indirect impact on innovation activities by supplementing the existing R&D results. Meanwhile, Cabral et al. (2006) identified three types of indirect effect of public procurement on innovation; by enlarging the market for new goods; by facilitating the adoption of new standards; and by changing the market structure.

In fact, many existing studies have analyzed the effects of government procurement from a static viewpoint. But it is required to understand the public procurement with dynamic views. As Cabral et al. (2006) mentioned, the effect of public procurement on a market structure may be a typical example of dynamic views. Especially, the dynamic effect of procurement can be derived from the studies which have been focused on the fact that the users have impact on innovation activities at the time when they demand products.

Since the beginning of studies carried out by Von Hippel (1976), a lot of studied focused on innovation policies have put emphasis on the interaction between users and manufacturers, along with the roles of users in the innovation process (Lundvall, 1993). For example, Von Hippel (1976, 1978) argued that in the case of a spreading network, it was more important to ensure the accessibility to the information and knowledge obtained from customers and suppliers in the relevant industry, where the products are manufactured on the basis of technical capacity, because new innovation results were created by using the existing technological knowledge through the internal mechanism or various spreading mechanisms.

Mowery and Rosenberg (1979) pointed out that the concepts of user needs and demand were not separated clearly from each other in the existing studies, which had analyzed the demand-pull impacts. They separated the effects of need-pull caused by users from the demand–pull effects mediated by the market. They thought that even though there were innumerable types of user needs, only a part of the needs could form a potential market of the products, yet only a small subset of these potential demands are fulfilled. Such recognition can be understood as an emphasis on the importance of lead users who convert the abstract needs to the demand for specific products.

Gardiner and Rothwell (1985) argued that the users who had clear requirements for design would play a role in making suppliers innovate or improve products. Von Hippel (1986) discovered the creation of user-led innovation in the science instrument industry. According to his study results, the strong and specific needs of lead users were realized in the later market.

Porter (1993) recognized that the role of users was important in the initial stage where development of products and industrialization was carried out, because the client needs for new equipment could change the form of existing products. And also, he argued that the initial users could predict the market demand of innovative product, and the enterprises could improve the product and the competitiveness continuously through prediction of demands.

Bresnahan and Greenstein (2001) observed the joint development process between the users and manufacturers in the IT industry, and they paid attention to the fact that general-purpose technologies were being adjusted in accordance with the specific problems and the various needs of users, who were participating in the joint development.

Malerba et al. (2007) put emphasis on the importance of the experimental users in the Internet, automobile and the aircraft industry. The term 'experimental users' connotes that users accept the fact that there is a risk involved in a new product or at the prototype stage of development, and the price and quality may not meet the requirements. New enterprises begin to sell their products to the experimental users, and continuously improve the products through their feedbacks.

Meanwhile, the studies on innovative policies have found out that the technical capacity of users was acting as an important factor in innovative activities, besides the user needs. Especially, in the case of capital goods, the customers may present specific requirements and provide technical support for innovation. And the role of users becomes more important as they can affect even the stage of prototype development (Dalpé, 1994). For example, Grandstand and Sigurdson (1985) found out that the government equipped with technical capacity was playing an important role in the strategic stage of technical specification and product development, when they analyzed the process of development in the Nordic countries. Through their studies, it was proved that the specialized knowledge of the government as a user in procurement had an indirect and dynamic impact on the innovation activities of producers.

When we consider the fact that specific needs and requirements of users, including their technical capacity, can have a significant impact on innovative activities in this way, we can make a guess on the effects of the government as a user on innovative activities in the industry. In a word, a public institution may be willing to become the first user of innovative products as a lead user and induce the improvement of such products, and create the demand of other users. And then, the suppliers, who participate in the public market through transactions with public clients equipped with high-level technical capacity, can be entitled to benefits such as the technology transfer (Dalpé, 1994).

2.2.2.3 Requirements for successful procurement policies

Though procurements are considered to have an effect on innovative activities in the industry to some extent regardless of the purpose, the policy makers shall review the relevant requirements in order to make such procurement policies be the more effective investment-inducing means.

Dalpé (1994) argued that the users from public sectors should clearly express the user needs regarding performance rather than presenting the requirements for standards or trademarks in order to create effective procurement policies. In this context, Dalpé (1994) argued that the innovation of enterprises or industries could be promoted when the direct requirements were established clearly by the institution using the products, rather than a central procurement agency which was not directly connected to the requirements of users.

Geroski (1990), who had observed the major results of innovation caused by public procurements in the computer, civil aircrafts and semiconductor industry, suggested the specific condition that could create innovation through procurement policies. According to him, the principal agent of procurement (namely, the institution using the products) shall apply the high standards for products and technologies in order to heighten the intensity of effect and obtain good results through procurements. And secondly, the public institutions shall define the definite needs at which innovation efforts are aimed. In addition, it is required to boost the relevant enterprises and industry by creating sustainable demand for the innovative products and services at the initial stage, and by providing common markets for those products and services. On the other hand, public institutions shall encourage competition among suppliers. And also, Geroski (1990) pointed out that the procurement policy could lead innovation in a wrong direction, particularly in relation to poor targeting, backward-looking protectionism and the support of national champions.

On the other hand, Edler and Georghiou (2007) put emphasis on the need for co-ordination across government. And also, they highlighted the combination of public demand with private demand through procurement policies, and the critical role of linkages between supply and demand in the process of innovation. The total demand may be increased by encouraging civilian needs at a new dimension, and a good environment for innovative activities may be created when suppliers have much contact with the lead users in the private sector, who have high technologies.

The requirements for a successful procurement policy include a significant scale of procurement. The purchaser's capability, which meets the requirements suggested by public institutions, may differ according to the market power. Dalpé (1994) argued that the government influence on suppliers increased when government purchases took up a considerable part of products in an industry. The enterprises will participate in a procurement of new complex goods, which consists of new and complicated technologies, only when the amount of order reaches the threshold and the revenue offsets the R&D costs, or when they judge that future contracts can be guaranteed. When the size of government procurement is bigger than a certain level, enterprises judge that it is profitable to meet the requirements of users in terms of profits by developing new products.

The content like this can be identified in the study of OFT (2004). According to OFT (2004), if a size of public demand reaches the considerable level, where the size of public procurement can exercise the purchasing power by integrating demand, the government can provide an actual opportunity for a product market in the public sector, and the private sector can get the critical mass that ensures profitability through R&D investments. This is in the same vein as the necessity of cooperation made by government agencies, which was mentioned by Edler and Georghiou (2007), and they also suggested that public procurements should be carried out through cooperation in the similar policy direction and range of purpose rather than individual purchases. Uyarra and Flanagan (2010) argued that the government could expand the market of specific goods through purchasing power of the public sector and the expanding market could act as incentives for innovation.

On the other hand, Porter (1993) argued that the scale of procurement played an especially important role in the high-tech industry, the industry characterized by substantial economies of scale in production, and the industry with high level of uncertainty.

2.2.2.4 Possibility of inefficient procurement policy

Because procurement policies in the public sector are set up after considering the political, institutional and economic factors in a complex manner, it is not guaranteed that such procurement policies will act as an effective means at all times. For example, if it is required to consider the regional distribution of orders, which affects elections, and the national security, the decision on procurement could be made in an economically inefficient manner (Dalpé, 1994).

Rothwell and Zegveld (1981) pointed out that, despite the fact that procurement policies can be effectively used to protect and boost the new-technology based enterprises, the several restrictions below could interfere with the use of such opportunities. Firstly, the absence of common recognition of the application strategy for procurement policies in public agencies may cause frequent shift in policy with enterprises left in uncertainty. As a result, it breaks the self-confidence of enterprises to succeed in the market. Secondly, if a procurement policy cannot be combined with various means supporting the innovation activities due to lack of market power of government in the total market, the procurement may not have an effect on the R&D investment. Thirdly, due to the lack of competition among suppliers in the public sector market, there are not many cases of market entry of newly established businesses into the public sector market. Fourthly, the government may lack the capability to deal with the area of technology, and it may be occasionally affected by interest groups, so that the government cannot make rational decisions at all times.

Williams and Smellie (1985) pointed out the purchasing tendency of government, which tried to maintain technical systems. They argued that the suppliers, who had provided the initial products, could easily participate in the follow-up maintenance and parts supply, and they were more likely to receive a further order, concluding that the government was apt to maintain the trade with the same supplier. This is because the government, as a purchaser, is also aware of the risks in the case where the government is purchasing products and services in which complicated technologies are embedded. In the cases of military supplies, which are subject to security and confidentiality requirements, it is difficult to replace the supplies with other goods, so that the government is more likely to maintain the same technical system. As a result, public agencies may form a close relationship with specific enterprises. In such a case, the enterprise will make effort to maintain the business relationship with public agencies by using political leverage rather than make effort to improve technology due to the awareness of the market that has been already formed. And also, such suppliers are apt to maintain the same technology in order to avoid the innovation risk and adjustment cost. And if there is no other option than to sell the product to public agencies, they will not carry out energetic innovation activities because the innovation results obtained from R&D activities cannot be applied to other fields (Dalpé, 1994).

In this manner, when the decision on procurement is made on the basis of consideration of other things rather than the quality and technical factors, the tendency to produce innovative products may be reduced and the influence of procurement policies on innovative activities may be reduced as well.

2.3 Literature review

2.3.1 Empirical evaluation of subsidy policy

In general, economists have reached a consensus that the effects of subsidy on R&D investment of enterprises have both positive and negative results. Howe and McFetridge (1976) carried out a econometric analysis on the determinants for the R&D investment carried out by 81 Canadian enterprises in the electric, chemical, and machinery industry during the period between 1967 and 1971. According to the analysis results, it was confirmed that the reception of subsidy had not caused a change in the total R&D expenditure of the enterprises in the chemical and machinery industries, however, the reception of subsidy had caused a small increase in the total R&D expenditure of the enterprises in the electric industry. On the basis of the results, they concluded that the subsidization could not replace the private R&D investment. And they also argued that the subsidy policy had increased the total R&D expenditure of the society as much as the amount of subsidy (not more than the amount).

Czarnitzki and Hussinger (2004) analyzed the direct impact of R&D subsidy granted by the German government on the promotion of private R&D investment and the indirect impact of R&D subsidy on the technical performance (or innovation achievement, measured by the number of patents). They collected the annual data from 3,779 enterprise in the manufacturing industry during the period between 1992 and 2000, and then the Propensity Scoring Method (PSM) was applied to data analysis, so that they could conclude that the hypothesis that government subsidy accelerated the private R&D investment could not be rejected. After all, they argued, the enterprises that had received the subsidy used it in R&D activities, and the scale of R&D investment increased by 30.4%. Lerner (2000) pointed out that the subsidy granted by the US SBIR program could function as a quality certificate for small and medium businesses, so that it could help them qualify for a loan from banks. On the basis of such interpretation, Czarnitzki and Hussinger (2004) assumed that German businesses could increase the R&D investment through such effects.

Guellec and Van Pottelsberghe de la Potterie (1997) analyzed the effects of the subsidy on private R&D investment by using a total of 216 observations, which were collected from 17 OECD countries during the period between 1981 and 1996. They assumed that the elasticity of private R&D with respect to direct subsidies was 0.06 in the short run, but it was 0.22 in the long run, so that they could confirm that the state subsidy had a positive effect on the promotion of private R&D investment. However, they found out that the effect of subsidy on the promotion of private R&D investment rose in proportion to the subsidization rate, but it began to decrease after reaching the threshold (inverted U-curve in accordance with subsidization rate). In a word, they argued that the government subsidy had the greatest promotional effect when the subsidization rate was 15%, and then it began to reduce, showing rather negative effects when the rate exceeded 30%. Accordingly, what they suggest is that the country which granted a moderate amount of subsidy achieved better results than the country which subsidized too much or too little.

Klette et al. (2000) carried out a survey study on the five micro-econometric researches (Irwin & Klenow, 1996; Lerner, 1998; Branstetter & Sakakibara, 1998; Griliches & Regev, 1998; Klette & Møen, 1999), in which the effects of government-granted R&D subsidy on commercial R&D were analyzed. It was identified that the subsidy had a positive effect on the promotion of private R&D on the basis of the results of the four out of five studies. However, they pointed out that if enterprises which did not receive government subsidy were selected as a control group in such studies, it was based on the tacit premise of random sampling. In other words, they pointed out that though the difference-in-difference (DID) or the methodology of Heckman et al. (1998) were applied to the existing studies they reviewed, the effects of subsidy might have been overestimated as the selection bias was not dealt with correctly.

The study result in which the selection bias was considered is as follows. Firstly, Busom (2000) analyzed the effects of subsidy by applying the Heckman–type selection model on the basis of the cross-section data of the 145 Spanish enterprises, which had received a subsidy from the Center for Industrial Technological Development (CDTI). On the whole, the complementarity effect appeared to be dominant in her study. However, 30% of the enterprises appeared to have a substitution effect. Lach (2002) applied the difference-in-difference method to a study focused on the analysis of panel data of the enterprises that had carried out R&D in Israel during the period between 1990 and 1995.

In this research, it was identified that the complementary effect existed between the subsidy and R&D investment only in the cases of small-sized companies, but the subsidy appeared to have no significant effect on large firms in the results of analysis. Wallsten (2000) analyzed the effects of SBIR, which was a program designed to support small and mid-sized technology-intensive enterprise in the USA, by using the 3SLS estimator. According to the result, Wallsten found out that the complete substitution effect was occurring between the government subsidy and R&D investment of enterprise.

David et al. (2000) carried out a survey research regarding the 33 studies reported in the period between 1966, when Hamberg's study was published, and 2000. On condition that the existence or non-existence of significance of estimated coefficients is ignored, 11 papers (33.3%) out of the 33 papers reported the net substitution relationship between the government subsidy and private investment, while the rest of 22 papers (66.6%) reported the net complementary relationship. Classifying the results according to the level of subjects of analysis, they found out that almost the half of studies (9/19) on business and firm unit showed the substitution relationship, while the 2 out 14 studies on industrial and national level showed the substitution relationship. It implied that the substitution effect reduced as the integration level of the subjects of analysis rose due to the spillover effect of R&D occurring among the industries. According to the examination of differences among countries, the 5 studies out of 6 studies, which targeted the countries other than the USA, appeared to have complementary relationship, while the 12 studies out of 21 studies, which targeted the the USA, appeared to have a relatively mild complementary relationship. Especially, according to the study results focused on the units lower than an enterprises, the 7 studies out of 12 studies on the USA appeared to have a substitution relationship, but only 2 studies out of 7 studies on the countries other than USA appeared to have a substitution relationship, so that the existence of regional contrast was identified. David et al. (2000) have not suggested a general conclusion regarding the effect of subsidy due to the difference in the methodologies in the literature and the purposes of government subsidies, including the detailed level of materials used in the research.

2.3.2 Empirical evaluation of tax incentive

Since the enforcement of the R&D tax credit system in the USA in 1981, a lot of studies analyzed the effects of this system. Using the time-series analysis, Baily and Lawrence (1985) compared the actual investment level and the investment level that may be predicted on the basis of historical R&D investment. They proved the effects of the R&D tax credit by confirming that the actual investment level of the 12 R&D-intensive manufacturing industries had risen an average of 7.3% from the existing investment level during the period between 1982 and 1983.

And also, Brown (1985) confirmed that the amount of R&D investment during the period between 1981 and 1984, after the enforcement of R&D tax credit system, was much more than the predictive value based on the time-series model. According to his study, the actual R&D investment increased by 25% in 1984 due to the tax credit system, which was introduced in 1981.

By applying the similar method, Cordes (1989) concluded that the R&D tax credit introduced in 1981 had promoted the investment in the USA. His study proved that the enforcement of R&D tax credit helped the actual amount of R&D investment increase by 8.7% in 1981, 17.4% in 1982, 25.5% in 1983, and 26.8% in 1984.

Eisner et al. (1984) found out that there was no difference in increase of R&D expenditure between the enterprises to which the tax credit system for R&D investment was applied and other enterprise to which the system was not applied after the enforcement of tax credit system. They argued that the effects of tax credit system was offset in the long run because the enterprises increased the expenditure through which they could qualify for the benefit of tax deduction, while they reduced the R&D expenditure through they could not become a beneficiary of tax credit.

Tillinger (1991) confirmed that in the case of an enterprise of which the Tobin's Q value was close to '1', the R&D tax credit was effective, however, if the Tobin's Q value was bigger or smaller than '1', the effect of tax credit on R&D expenditure was very small.

Bernstein and Nadiri (1988) analyzed the determinant of labor, physical capital investment and R&D investment, including the interaction among them. They collected the data of enterprises recoded during the period between 1959 and 1966, and analyzed the data after dividing them into four types of industry. According to the analysis result, the R&D investment demand decreased by 0.5% when the rental price of the R&D capital increased by 1% in each of the four industries.

Falk (2006) found out that the tax incentive system measured by B-index had a significant effect on the demand of private R&D investment after applying the dynamic panel analysis to the OECD country level data built up during the period between 1980 and 2002. According to his study, the short-run elasticity of R&D investment with respect to the price of R&D was about –0.22, and the long-run elasticity of R&D investment was 0.84. In short, the amount of short-term R&D investment appeared to have increased by 0.22% when the B-index decreased by 1%. Such results accord closely with the existing study results. In their reports confirming that the price elasticity of R&D expenditure was about 1.0 at the industrial level, Bloom et al. (2002) argued that R&D investments were sensitive to capital costs. And the European Commission (2003) and Guellec and Van Pottelsberghe de la Potterie (2003) reported that the price elasticity of R&D expenditure was -0.81 and 0.31 respectively.

Kim (2007) analyzed the effects of tax incentive by using the enterprises panel data collected during the period between 2002 and 2004. He argued that when the user cost of capital after taxation decreased by 1% through the expansion of the tax incentive system, the R&D investment based on the internal financial resources of small and medium businesses and the major companies would increase by 1.4% and 0.8% respectively.

2.3.3 Comparison between the effects of direct and indirect means

When deciding which means is more effective, the direct or indirect means, we may directly refer to studies which are focused on the comparisons between direct and indirect means. And also, we may indirectly refer to the studies in which the two types of policy variables have been included in the analysis model in order to analyze the effects of each policy variable.

The studies carried out to compare the effects of direct and indirect means are as follows. Kwack (1984) compared the results of indirect tax support and export subsidy, which had been granted to the enterprises of overall industries, with the results of R&D tax credit provided to specific industry. According to the results, the effects of investment tax credit appeared to be excellent in terms of production activities, while the effects of indirect tax and export subsidy appeared to be excellent in terms of social welfare.

Kwon and Paik (1995) analyzed the effects of capital market distortions on capital formation in the economy by using the CGE model. Their model assumes that the producers decided the level of fixed capital investment on the basis of the expected sales during the given period, factor prices and the current inflation rate. According to their study, which was aimed at manufacturing businesses after establishing the year 1978 as the base year, the tax incentive and financial support appeared to have an effect on the increase in fixed capital investment. Especially, the tax incentive appeared to be more effective in the investment promotion as the financial support caused the increase in fixed capital investment by 6.8%, while the tax incentive caused the increase in investment by 11.6%.

Zhu et al. (2006) argued that the state subsidy was more effective than tax incentive in promoting the R&D investment, according to their study carried out by using the industry-level panel data regarding the Shanghai area. The data was limited to the period between 1993 and 2002. Especially, they suggested that the state subsidy promoted the private R&D investment, while the tax support had effect on reduction of R&D investment in the private sector.

Kim et al. (2011) compared the effects of policy means by applying the Ordered Probit Model which was based on the Technology Innovation Survey (2005). According to the result of analysis on overall enterprises, it was found out that the benefit regarding tax expenditure appeared to raise the probability in attempt to innovate by 15.6%, while the benefit regarding government subsidy appeared to raise the probability in attempt to innovate by 18.3%, so it was concluded that the effect of subsidy system was better. However, when the subjects of analysis was limited to small and medium businesses, the probability of innovation attempt affected by the benefit regarding tax cut increased by

22.0%, while the probability of innovation attempt affected by the benefit regarding government subsidies increased by 16.6%, so it was concluded that the effect of tax support was better than that of subsidy.

Avellar (2011) compared the effects of direct and indirect means by using the PSM methodology on the basis of firm-level data collected during the period between 2006 and 2008. According to him, the difference in the average scale of investment between the enterprises, which received a tax incentive, and the enterprises, which did not receive tax credits, appeared to be two times as big as the cases in which the government subsidy was given to such enterprises. As a result, he concluded that the tax incentive is more effective than the government subsidy.

On the other hand, the effects of direct and indirect means can be indirectly compared on the basis of the following studies. The study of Guellec and Van Pottelsberghe de la Potterie (1997) suggested that both the direct subsidy and tax incentive had a short-term effect of private R&D investment promotion. According to their study, the short-run elasticity of private R&D investment with respect to the government subsidy was 0.06, and its elasticity with respect to tax incentive (when the B-index was a proxy variable) was -0.18. However, the long-run elasticity of private R&D investment with respect to government subsidy was 0.22, so that they could conclude that the direct subsidy was more effective than the tax incentive in the long term, deriving the elasticity of the value of '0' regarding the tax incentive. Regarding such differences, they concluded that it was because the subsidy encouraged the enterprises to begin a new investment project, but the tax incentive mainly induced them to gradually increase investments in the project in progress.

Hall and Van Reenen (2000) made an indirect comparison between the subsidy and tax incentive from the view point of benefit-cost ratio. The benefit implies the amount of R&D induced by the tax credit. And the cost means the amount of tax revenue lost due to the presence of the credit. The ratio of these two quantities is the benefit-cost ratio; when the size of investment-inducing effect is bigger than the cost, the tax incentive is more effective in terms of comparison between costs and effects than the subsidy; if the size of investment-inducing effect is smaller than the size of tax support, the subsidy is more effective in terms of comparison between costs and effects than the tax incentive. Their survey on the existing studies on effects of the tax incentives confirmed that when the enterprises received one dollar's worth of tax support, the enterprises created a dollar's worth of additional investment in average. In a word, they concluded that both the tax incentive and subsidy had an equal level of effect.

Wu et al. (2007) carried out a regression analysis by using the panel data from nine countries, which was collected during the period between 1985 and 1995. According to them, the elasticity of private R&D investment with respect to the user cost of R&D appeared to be about 0.6, while its elasticity with respect to government subsidy ranged from 0.24 to 0.41. In short, they suggested that the R&D investment at the national level reacted to the user cost of R&D more sensitively than the subsidy did. On the basis of the result, we may judge that the indirect means of tax incentive is more effective than the subsidy.

Kim (2007) found out that when the user cost was reduced by 1% due to the expansion of tax incentive, the increase of R&D investments of the private sector ranged from 0.5% to 1.1%, however, the firm’s own R&D investment decreased by 0.06%-0.07% when the direct government subsidy increased by 1%. In particular, on the premise that the R&D of small and medium businesses reacted sensitively to the user cost, and the government subsidy crowded out the firm’s own R&D, they argued that the tax incentive was more effective than the subsidy policy when the policy goal was aimed at increasing the firm’s own R&D investment.

2.3.4 Empirical evaluation of procurement policies

The results of many empirical studies have confirmed that demand-pull policies act as major variables in innovation activities. Since Schmookler (1966) put emphasis on the importance of market scale regarding motivation for changes in technology, a lot of economists have paid attention to the innovation-inducing effects of demand. Eisner (1978) emphasized the relative importance of the demands or sales, liquid assets, and capital costs, which could play a role as a determinant in making a decision on investment of an enterprise. According to the result of his study, the demands and sales were the major determinant of business investments, and the liquid assets occasionally acted as an important factor. When considering his opinion, we may conclude that Eisner (1978) supported the acceleration theory of investment[4].

On the basis of his own case studies, Utterback (1974) argued that 60-80% of major innovations were caused by the reaction between market demands and recognized needs. Rothwell and Zegveld (1981) carried out a comparative analysis on the innovation-inducing effects of the R&D subsidy and the procurement contract of the government. They argued that the long-term procurement policy of government was more effective in generating innovation than R&D subsidies in various fields.

Geroski (1990) analyzed the quantitative and qualitative significance of the government's demand for innovations. He argued that the government's demand could reduce the risk and uncertainty that enterprises would face in the future market environment. Especially, he suggested that the influence of government procurement in rapid innovation activities could become important, particularly when considering the contents of the study of Rothwell and Zegveld (1981), which argued that the more rapid the innovation was, the more important role the predictability played. And also, Geroski argued that procurement policies were more effective in inducing innovations than R&D subsidies, which had been used frequently as a means of innovation policies. On the other hand, Geroski and Walters (1995) confirmed the casualty, in which demands induced innovation activities, by carrying out a time-series analysis where the innovation and patent data in the UK were used.

Brouwer and Kleinknecht (1999) regarded the demand, firm size and characteristics of industry as the major variables that could have a significant impact on innovation activities. During the period between 1988 and 1992, they carried out regression analyses on the 441 enterprises selected from the manufacturing and service industry in Netherland. According to the results of their study, the scale of enterprise had no effect on innovation activities. On the other hand, they identified that the increase in demand was a significant

[4] The acceleration effects refers to the fact that the investment demand is closely connected to the importance of growth rate of sales, and this theory came to the fore as the study of Clark (1917) was published.

variable in innovation, so that the demand-pull effect suggested by Schmookler could be proved. And also, on the basis of such results, they concluded that the Keynesian theory could play an important role in explaining the determinants of investments.

Sung (2001) analyzed the determinants of investments of the private sector by using the panel data (1990-1997) collected from the enterprises in the Korean manufacturing industry He argued that the sales growth rate and cash flow had a positive effect on investments, presenting the result of his own research, in which the long-run elasticity of firm's investment with respect to sales and cash flow were 0.03 and 0.01 respectively.

In a survey of more than 1,000 enterprises and 125 economic federations, BDL (2003) argued that more than 50% of respondents recognized the new requests and demands as the major source of innovation activities. On the other hand, BDL (2003) argued that the market factor played the more important role than that of technology-push, presenting the results in which only 12% of total enterprises promoted R&D activities on the basis of new technology development inside the enterprise.

Palmberg (2004) and Saarinen (2005) carried out an analysis on the data regarding the innovation, which had been commercialized during the period between 1984 and 1988, so that they could confirm that 48% of the projects that had created the results of successful innovation were caused by the government procurement or regulations. Besides, the arguments that the market demand and procurement policies acted as an important factor for innovation activities were supported empirically by the studies carried out by Fazzari (1993), Chirinko et al. (1999).

2.3.5 Limitation of the existing studies

As shown in the previous clause, most of the studies cannot provide any clues to identify which policy means is relatively more effective, the direct or indirect means, by analyzing the effect of policy means limited to either the tax incentive or subsidy. It is possible to compare the effects of policy means indirectly by using the results of studies on each policy means carried out individually. However, such indirect comparisons may cause considerable distortion when interpreting the policy effect as the individual studies were carried out on the basis of different analytical frame, data system and targets.

Meanwhile, the subjects of most studies were the enterprises that belong to a specific industry, or specific industries. And in some studies, the data at the industrial level has been presented by pooling, or the results of effect analysis on policy means have been presented at the national level. In a word, such studies have failed to suggest any results regarding the difference in effects of the same policy means on individual industries. A policy means which had a positive effect on an industry cannot be a panacea for other industries. Even though a policy means is effective in a specific industry (country), we cannot expect that such results will occur in the other industry (country) with equal effect. Complicated circumstances such as operational, technological and environmental factors, have impacts on innovation, so that we need to understand the characteristics of each industry in order to carry out innovative policies effectively (Anex, 2000).

The methods used to measure the effects of R&D policies in the existing studies can be divided into two types. The first one is focused on the analyzing the degree to which support policies promote the private R&D investments, and the other is focused on the comparison between the cost of policy support and the results of investment promotion. However, the results of analysis in this way only show the partial effect, and the full effect of policies has not been considered (Hall & Van Reenen, 2000). For example, Hall and Van Reenen (2000) argued that the full effect of policies could be identified through the analysis, in which the changes in output were included, because the reduction of capital costs, which was caused by tax incentive policy, led to an increase in output, and the increase in output could result in an increase in investment. In addition, such aspects may be highlighted more when considering the spillover effects of knowledge.

The existing studies have failed to provide implications regarding the ultimate effects (economic growth) of technology policies. Though the goal of R&D policy means is to increase the private R&D investment, the ultimate goal of technology policies embracing the innovation-inducing policy means is to promote the economic growth through technological changes. Accordingly, the analysis on the effect of implementation of R&D policy on private R&D investments, and the analysis on economic results can provide useful implications to the policy maker of the relevant policy.

2.4 Presentation of problems

In 2012, R&D spending by business enterprises occupied 78% of Korea’s total R&D expenditure. It implies that the main agent of R&D investment in Korea is not the government, but the private sector, and the enterprises act as the group that determines the national technology competitiveness. In this context, the government makes efforts to prevent reduction of industrial R&D investment in order to overcome stagnation aspects, which appear repeatedly in the global society, and improve the national technology competitiveness. The South Korean government is implementing various investment-inducing policies in order to encourage the industries to increase their own investments. The R&D policies implemented by the government include the subsidy, tax incentive, financial support, human resource support, public procurement, legal and institutional infrastructure, technology transfer, technology guidance and consultation.

From the viewpoint of supply-push, the tax incentive and state subsidy scheme are the most focused policy instruments. The scale of government subsidy and tax incentive has been on an increasing trend over the last 10 years. However, as we may assume on the basis of the results of empirical studies, it is expected that the effects of each policy means will appear differently due to the institutional characteristics of each policy means and the investment climate in each industry.

The policy makers shall choose adequate policy instruments, on the premise that the intervention of government in innovation activities is reasonable. However, as discussed above, the comparison between the government subsidy and tax incentive on the basis of existing literature is limited. This implies that the current subsidy and tax incentive are being implemented individually without comparison of the effects of each policy means, which is based on the quantified result of institutions.

In this context, this study is aimed at analyzing the individual effects of government subsidy and tax incentive system, which are the typical policy means implemented from the viewpoint of supply-push. And also, it is designed to seek the answer regarding how a correct intervention can be chosen by comparing and evaluating the effect of government subsidy with the characteristics of direct means and the tax incentive with the characteristics of indirect means.

Meanwhile, the importance of demand-pull policies has been recognized through the debates which were proceeding through the 1960s and 1970s. On the whole, most governments have implemented the supply-push policies despite the fact that the importance of demand-pull innovation was recognized in reality (Edler & Georghiou, 2007).

However, when the economists were looking into the reason of slowdown of innovation activity and economic growth, they have recognized the limitation of the policies focused only on supply-push, which could not induce innovation activities sufficiently. Entering the 2000s, the EU and member countries began to be interested in demand-pull policies on innovation in these circumstances. A lot of reports put emphasis on the importance of public procurement and leading market for innovation activities, and the EU recommended its member countries to promote the demand-pull policies (European Commission, 2005, 2007; Aho et al., 2006). As a result, the EU and member countries adopted the demand-pull policies aggressively. The Government of South Korea has also recognized the importance of demand-pull policies, so that the government has been supplementing the institutional strategy in order to carry out such policies (National Science and Technology Council, 2011).

In this context, this study aims to analyze the effects of public procurement on innovation activities from the viewpoint of demand-pull policy. In fact, besides the procurement, various demand-pull policies, such as the regulations, standardization and the policies to promote leading markets, can play an important role in implementation of innovation policies (Blind et al., 2004; Georghiou, 2007). However, considering the fact that the scale of public procurement is much bigger than the scale of other support of policy means, and the effect of procurement policy can be realized relatively faster than others, I have chosen the public procurement among the policy means focused on demand-pull as the subject of analysis.

Especially, this study is aimed at evaluating the effects of national defence procurement among various types of public procurement. There are two reasons why the effects of national defence procurement are analyzed in this study. Firstly, it was considered that the national defense expenditure exceeded 30% of the government budget until the end of 1980s, and even in the 1990s and 2000s, the national defense expenditure formed a greater part of the government budget. Secondly, the government has protected and fostered the defence industry strategically since the initial stage of industrialization of this country. Especially, the government allowed the defence industry market to form a monopolistic structure, restricting the market entry of other competitors, and maintained the market size through procurement of defense products, so that the policy could bring the relevant industry to the reasonable maturity. Accordingly, the defence procurement has had a huge impact on the defence industry.

In this manner, this study is designed to analyze the effects of subsidy and tax incentive from the viewpoint of supply-push, and then the comparative evaluation of the effects of each policy means will be carried out as well. Apart from the evaluation, the effects of procurement which is the typical means of demand-pull policy will be analyzed. The reason why the study was carried out after separating the analysis on R&D policies (subsidy and tax incentive) and the analysis on procurement policy from each other are as follows. Firstly, the purpose of procurement is to purchase goods that will be used for the maintenance of public function, and it has an indirect influence on innovation activities, so it is inappropriate to compare the effects of procurement with the effects of subsidy and tax incentive directly. Secondly, in the case of defence industry, which is considered in a model when analyzing the effects of defence procurement, the prices of goods are determined by the cost-plus contracts on the basis of negotiation, so that it is characterized by the fact it is rarely affected by the R&D policies.

Chapter 3. Construction of knowledge-based SAM

3.1 R&D capitalization process

In this study, the knowledge-based SAM has been constructed in order to analyze the economic effects of knowledge capital that has been accumulated from R&D investments. The knowledge-based SAM can be defined as a social accounting matrix in which the economic flow that includes the knowledge capital is described by reflecting the knowledge capital as an independent factor of production through the capitalization process of R&D. The capitalization of R&D refers to the dealing with the R&D costs, which used to be dealt with as an intermediate consumption as intangible fixed assets (Intellectual Property Products).

The System of National Accounts 1993 (SNA 1993) recommended enterprises to deal with the R&D investment-related expenditure as an intermediate consumption (current expenditure), which was not a capital expenditure and consumed in a production process. That was because it was difficult to establish a clear standard for identification, evaluation and depreciation of such assets in practice, despite the fact that the R&D investment was close to the fixed investment as it was implemented to get income in the future (Son, 2005).

However, the System of National Accounts 2008 stipulates that the R&D expenditure shall be dealt with as a formation of fixed capital, expanding the range of fixed capital assets. In this system, the previous account name of intangible fixed assets was changed into the intellectual property products, as the range was expanded, and the R&D was incorporated into the intellectual property products, along with mineral exploration and evaluation, computer software and databases, entertainment, literary and artistic originals, and other IPPs.

The studies on CGE model, which constructed the SAM including knowledge capital, include the studies of Zürn et al. (2007), Sue Wing (2003), Garau and Lecca (2013). The knowledge-based SAM suggested in the existing studies were constructed by setting up a hypothesis discretionally. Zürn et al. (2007) estimated the R&D transactions among industries by applying the transaction share among industries as a weighted value, according to the method suggested by Terlecky (1974). Garau and Lecca (2013) identified the R&D transactions among industries by applying the weighted value based on the Yale Technology Matrix (YTM). Meanwhile, Sue Wing (2003) set up a hypothesis that the specific R&D-intensive industry was an industry where the R&D service was produced, and then Sue Wing interpreted that the transaction between the R&D service-producing industry and other industries represented the transaction of R&D. However, in those existing studies, the R&D transaction was estimated on the basis of the discretional hypothesis set up by the researcher, so that there might be much room for improvement as it may distort the actual details of knowledge transactions.

3.2 Method for construction of SAM

When considering the limitation of existing studies and the fact that the System of National Accounts and input-output (I-O) tables differ from country to country, it is inappropriate to apply the method for construction of SAM suggested by the existing studies, as it is.

Accordingly, this study aims to construct the knowledge-based SAM with 2009 as the base year, by applying the knowledge-based SAM suggested by Yang et al. (2012), which is focused on the economic structure in Korea. They constructed the basic SAM in which the labor and physical capital, and then they expanded it into the SAM that included the knowledge capital, so that they could construct the knowledge-based SAM. At this time, the reflection of knowledge capital in the SAM means the capitalization of R&D, and the capitalization of R&D was carried out according to the System of National Accounts 2008 and recommendation of OECD (2010).

The outline of construction procedure for the knowledge-based SAM is as follows. Above all, the structure of knowledge-based SAM is formed by adding the following two accounts into the basic SAM in which the labor and physical capital are included as factors of production. Firstly, the 'knowledge account' is added in conventional value added accounts. After capitalizing the R&D, the knowledge, which is regarded as a product, is reflected in the SAM as an independent account in consideration of a production system where the knowledge is an input factor of production separated from labor and capital. The value of 'knowledge' added into the accounts of value-added means the value-added generated from the knowledge capital. Secondly, the 'knowledge capital formation' which is distinguished from the fixed capital formation is added into the ‘investment account’.

Table 2. Structure of the knowledge-based SAM

		Production		Value-added			Institutions		Investment			Tax				Rest of the world		Total
		Domestic goods	Imported goods	Labor	Capital	Knowledge	Households	Government	Physical capital	Knowledge capital		Indirec tax	Capital income tax	Labor income tax	Tariff	Export	Import	
										Private	Public							
Production	Domestic goods	S(1,1)					S(1,5)	S(1,6)	S(1,7)	A7	A9					S(1,12)		S1
	Imported goods	S(2,1)					S(2,5)	S(2,6)	S(2,7)	A8	A10							S2
Value-added	Labor	S(3,1)																S3
	Capital	S(4,1)																S4
	Knowledge	A1																K1
Institutions	Households			S(5,3)	S(5,4)	A2		S(5,6)										S5
	Government								S(6,7)			S6,8)	S(6,9)	S(6,10)	S(6,11)			S6
Investment	Physical capital						S(7,5)	S(7,6)									S(7,13)	S7
	Knowledge capital: Private						A3	A5										K2
	Knowledge capital: Public						A4	A6										K3
Tax	Indirec tax	S(8,1)																S8
	Capital income tax	S(9,1)																S9
	Labor income tax	S(10,1)																S10
	Tariff		S(11,2)															S11
Rest of the world	Export																S(12,13)	S12
	Import		S(13,2)															S13
Total		S1	S2	S3	S4	K1	S5	S6	S7	K2	K3	S8	S9	S10	S11	S12	S13	

And now, we need to reflect a proper value in the newly added accounts, and adjust the existing value of other accounts due to the newly added account. To achieve this, it is required to confirm how the R&D expenditure has been dealt with in the I-O table, which is the basic data system for preparation of SAM. If the R&D expenditure has not been reflected in the I-O table, the breakdown of R&D expenditure by industry and the breakdown of expense spent for R&D implementation shall be estimated separately, and then the R&D expenditure shall be reflected in the SAM on the basis of the estimation.

By the way, in Korea, the R&D including the R&D in self-account is regarded as a separate production activity, not an ancillary activity, when estimating the I-O table. And also, the current expenditure on R&D is dealt with as an intermediate consumption, and the capital expenditure on R&D is reflected in the formation of fixed capital. Therefore, the key point in preparation of knowledge-based SAM is to identify the details of R&D expenditure, which has been reflected in the current I-O table as an intermediate consumption and fixed capital formation, and capitalize the value and prevent the accounts from overlapping with the other reflected in advance.

By the way, there is the 'research institute' industry producing 'R&D goods' in the industry classification of the I-O table. And it is separated from other industries. Accordingly, the details related to R&D expenditures by industry can be identified through the transactions between each industry and the 'research institute' industry. Therefore, the transactions among industries can be identified without using the assumption of existing studies[5].

3.2.1 Creation of value-added knowledge

The first stage is to capitalize the current expenditure on R&D activities. The ordinary expenditure is reflected in the details of intermediate consumption in the I-O table. According to the small-sized industry classification of the I-O table, the 'research institutes (148)' industry and the 'research and experiment in enterprise (149)' industry belong to the industry which manufacture R&D products. Accordingly, the details of R&D expenditure in each industry can be identified through checking the transactions between those two industries and other industries.

Because the details of R&D expenditure (intermediate consumption) in each industry have been identified, the value-added created by knowledge can be estimated. As the R&D expenditure, which used be dealt with as an intermediate consumption, has been capitalized, the R&D expenditure is not an intermediate consumption any more.

[5] The Bank of Korea (2011) specified that the R&D expenditure in the I-O table was reflected on the basis of the Frascati Manual.

Therefore, the breakdown of R&D expenditure is eliminated from the SAM, and all or some of the value will be reflected as the value-added created by the knowledge capital.

Table 3. Generation of value-added knowledge

			Production		
			Domestic goods		
			S1	S2	S3
Production	Domestic goods	S148	A	C	E
		S149	B	D	F
Value-added	Knowledge capital		0	0	0

(Before adjustment)

			Production		
			Domestic goods		
			S1	S2	S3
Production	Domestic goods	S148	0	0	0
		S149	0	0	0
Value-added	Knowledge capital		A + B	C + D	e + f

(After adjustment)

3.2.2 Dealing with current expenditure as knowledge capital formation

The knowledge capital formation account in the vertical axis of Table 2 shows the breakdown of expenditure in which the R&D expenditure provided by households or the government is spent for R&D activities among each of industry. By the way, the 'research institutes (148)' industry and the 'research and experiment in enterprise (149)' industry are the industries that carry out R&D, so that the breakdown of those industry may be regarded as the spending for R&D activities. Accordingly, the values of these accounts shall be eliminated from the breakdown of intermediate transactions, and they are reflected in the knowledge capital formation account.

By the way, the System of National Accounts 2008 and the OECD (2010) recommend that all the expenditures (including R&D expenditure) of manufacturers, which are aimed at sales and profit, be dealt with as intermediate consumption. Therefore, not all the expenditure of 'research institutes (148)' industry and the 'research and experiment in enterprise (149)' industry have to be capitalized. And the R&D expenditure of market producers shall remain as the intermediate consumption. It is required to refer to the I-O table which has been subdivided into 403 basic sectors. According to the classification of

403 basic sectors, the 'research institutes (148)' industry can be subdivided into the 'research institutes(public) (357)', 'research institutes(private, non-profit) (358), and 'research institutes(commercial) (359)' industry, and the 'research and experiment in enterprise (149)' industry in the small-sized industry classification may be reclassified into the 'research and experiment in enterprise (360)' on the basis of 403 basic sectors. Among the four basic sectors, the 'research institutes(commercial) industrial, 359th industry, belongs to an industry that carries out R&D for profit, so that all the breakdown of R&D expenditure of this industry shall remain as the intermediate consumption just the way it is.

Accordingly, after eliminating the 'industrial research institute (359)', the expenditure column of the rest of three industries is moved to the knowledge capital formation account. At this time, the breakdown of 'research institutes(public)', 'research institutes(private, non-profit) sector is recorded in the 'public R&D' account, and the breakdown of 'research and experiment in enterprise' will be recorded in the 'private R&D' account.

Table 4. Dealing with current expenditure on R&D

<table>
<tr><th rowspan="3"></th><th colspan="4">Production</th><th colspan="3">Investment</th></tr>
<tr><th colspan="4">Domestic goods</th><th rowspan="2">Physical capital</th><th colspan="2">Knowledge capital</th></tr>
<tr><th>S357</th><th>S358</th><th>S359</th><th>S360</th><th>Private</th><th>Public</th></tr>
<tr><td>Production</td><td rowspan="7">A</td><td rowspan="7">B</td><td></td><td rowspan="7">C</td><td></td><td rowspan="7">0</td><td rowspan="7">0</td></tr>
<tr><td>Value-added</td><td></td><td></td></tr>
<tr><td>Institutions</td><td></td><td></td></tr>
<tr><td>Investment</td><td></td><td></td></tr>
<tr><td>Tax</td><td></td><td></td></tr>
<tr><td>ROW</td><td></td><td></td></tr>
<tr><td>Total</td><td></td><td></td></tr>
</table>

(Before adjustment)

<table>
<tr><th rowspan="3"></th><th colspan="4">Production</th><th colspan="3">Investment</th></tr>
<tr><th colspan="4">Domestic goods</th><th rowspan="2">Physical capital</th><th colspan="2">Knowledge capital</th></tr>
<tr><th>S357</th><th>S358</th><th>S359</th><th>S360</th><th>Private</th><th>Public</th></tr>
<tr><td>Production</td><td rowspan="7">0</td><td rowspan="7">0</td><td></td><td rowspan="7">0</td><td></td><td rowspan="7">C</td><td rowspan="7">A + B</td></tr>
<tr><td>Value-added</td><td></td><td></td></tr>
<tr><td>Institutions</td><td></td><td></td></tr>
<tr><td>Investment</td><td></td><td></td></tr>
<tr><td>Tax</td><td></td><td></td></tr>
<tr><td>ROW</td><td></td><td></td></tr>
<tr><td>Total</td><td></td><td></td></tr>
</table>

(After adjustment)

3.2.3 Dealing with capital expenditure as knowledge capital formation

The capital expenditure on R&D is subdivided into machinery, land and building, and computer software, and the capital expenditure occupied 9.5% of the total R&D expenditures in 2009. In the I-O table, the R&D expenditures regarding machinery, land and building, are reflected in the tangible fixed assets, and the computer software is reflected in the intangible fixed assets. Therefore, in order to avoid double counting the capital expenditure, the amount equivalent to the capital expenditure on R&D shall be deducted from the fixed capital formation, and then the same amount shall be reflected in the knowledge capital formation.

It is not clear in what the item of expenditure of 'machinery' among the capital expenditure has been paid. Accordingly, it is assumed that the R&D investment activities regarding machinery have been carried out in the five industries such as general machinery and equipment, electronic and electrical equipment, precision instruments, transport equipment, and furniture and other manufactured products on the basis of the large-sized industry classification in the I-O table. And the expenditure regarding land and buildings is related to the 'construction' industry, which belongs to the large-sized industry classification in the I-O table, so that the amount which falls into the item of 'land and building' shall be deducted from the value of fixed capital formation of the construction industry, and the same amount shall be reflected in the account of knowledge capital formation. Finally, the expenditure related to the computer software among the capital expenditures is connected to the 'real estate and business service' industry, which includes the computer software industry. Accordingly, the relevant amount shall be deducted from the account of 'real estate and business service' industry among the fixed capital formation accounts, and then the same amount shall be reflected in the knowledge capital formation.

Chapter 4. Analysis on the effect of government R&D policies

4.1 Background and purpose of study

The R&D is the source of technological innovation and the determinants of economic growth. In recognition of such things, the government has been making great effort to jump up to the knowledge-based economy. Over the last 10 years, the R&D investment of government has increased by an average of 13.6% every year, and the degree of R&D intensity has reached 4.03% of GDP. However, the scale of R&D investment is still lower in comparison with the advanced countries.

Along with the government R&D investment which has been increasing steadily, the direct subsidy from the government has been increasing year by year, and the scale and ranges of tax incentive for R&D has been expanding as well. For example, the tax credit related to human resources and R&D expenditure, which has occupied 75%-84% of tax expenditure regarding R&D for the last 5 years, has been changed from a temporary item to a permanent deduction item since 2009. It may be assumed that the recent upward trend of R&D investment in the industry is associated with the aggressive investment-inducing policies of the government.

The subsidy has originated from the system in which the government directly provides financial support to specific R&D activities, so it may be characterized by the high degree of intervention by the government. The tax expenditure is a means to reduce the burden of corporate tax regarding the fiscal payment caused by R&D activities of enterprises through the tax privilege. We may expect that the tax expenditure will ensure the efficiency in respect that it does not distort the functioning of market, the benefit is applied to enterprises indiscriminately, and above all, the decision on investment is left to the market. Due to the merits of policy means, both of them are used simultaneously.

Table 5. Present condition of R&D-related tax expenditure and tax credit

(unit: hundred million won)

Year	Total R&D-related tax expenditure	Tax credit for research and human resources development costs	Percentage of tax credit in tax expenditure (%)
2000	9,792	6,890	70.4
2001	9,111	6,426	70.5
2002	9,527	6,867	72.1
2003	13,950	11,597	83.1
2004	12,564	12,398	98.7
2005	13,224	9,782	74.0
2006	13,120	9,478	72.2
2007	16,429	14,080	85.7
2008	18,620	15,331	82.3
2009	20,244	15,535	76.7
2010	23,452	18,571	79.2
2011	27,643	23,341	84.4
2012	30,606(p)	24,977(p)	81.6

Source: The Ministry of Strategy and Economy, Budget for Tax Expenditure (each year)

Table 6. Present condition of national R&D project investment

(unit: hundred million won)

Year	Total R&D investment	National and public research institute	Government-supported research institute	University	firm	Government ministry	Others
2002	46,984	4,572	19,450	10,609	7,589	-	4,764
2003	49,036	4,281	21,135	11,141	8,145	-	4,334
2004	59,847	4,059	26,001	13,233	10,035	-	6,518
2005	77,904	4,408	34,081	18,273	12,199	-	8,944
2006	87,639	5,649	39,094	19,014	15,053	2,520	6,309
2007	95,745	5,452	40,628	21,978	16,071	4,608	7,008
2008	109,936	6,225	45,526	26,555	21,414	2,603	7,613
2009	124,145	6,683	49,718	30,120	28,185	1,007	8,433
2010	136,827	7,090	55,113	33,956	28,683	3,024	8,960
2011	148,528	7,319	57,099	37,672	32,330	3,744	10,363

Source: Science and Technology Council, National R&D project survey and analysis (each year)

By the way, we need to pay attention to the fact that the growth rate of subsidy is twice as high as the growth rate of tax expenditure as the subsidy amount has increased by an average of 17.7% every year in comparison with the tax expenditure which has increased by an average of 9.1% every year, which was boosted by the expansion of R&D policies.

(unit: hundred million won)

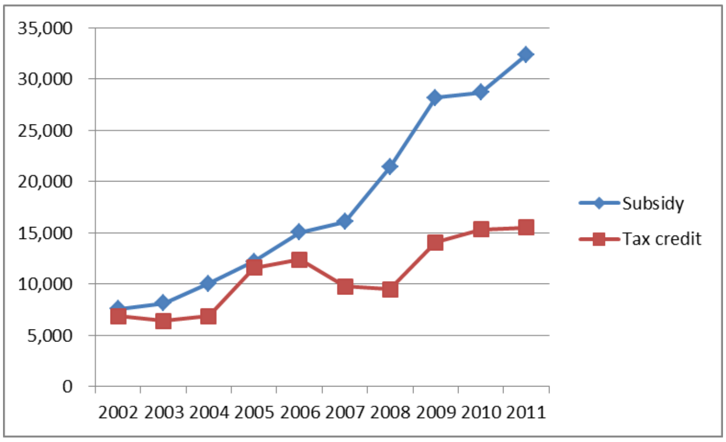


Figure 3. Trend of government support for R&D over the last 10 years

According to the Figure 3, we may infer that the Korean government is likely to prefer the subsidy system as a policy means to promote R&D. It seems that the government has been attracted by the fact that the subsidy system has immediacy, easiness of execution and high degree of government intervention, while the tax expenditure system cannot be implemented promptly because of the approval process based on the tax law, and the system has an institutional nature regarding the low level of government control. And the phenomenon of preference for the direct support policy means like a subsidy seems to be in line with the recent situation in which the government-led science and technology policies are promoted aggressively. However, it is doubtful that the preferences for such policy means are based on the strict policy impact analysis.

When the government decides to intervene in the private R&D activities, the issues the government has to consider are how to choose effective policy means in order to promote the private R&D investment. Furthermore, in the recent situation where the demand for welfare is increasing, the government R&D investment is not expected to continuously increase as before. Accordingly, the scale of subsidy is expected to have no upward trend as before. And also, the government policies regarding tax expenditure need to be efficient in respect that it is based on the budget expenditure of the government, though it is carried out in an indirect form. In this context, the National Assembly of Korea has prepared a legal basis on which the management of achievement can be carried out by the enactment of the Special Tax Treatment Control Law (Clause 4 of Article 142) which was revised and put into effect in 2013.

Therefore, this study is aimed at analyzing the individual effects of government subsidy as a direct means and the tax incentive as an indirect means among the major policy means, which have been implemented to promote the private R&D investment by the government, and carrying out a comparative evaluation of the results of analyses by using the CGE model. Along with this, this study aims to analyze the effects of each investment-inducing policy on economic growth in consideration of the fact that the technology policy is to induce economic growth through technological changes in the long run.

4.2 Analytical framework

4.2.1 Inter-industry technology flows

4.2.1.1 Recognition of spillover effect

Enterprises improve their productivity through technological changes which are obtained from their own R&D activities. However, the technology, a fruit of R&D activities, has a unique characteristic regarding the fact that the technology cannot be monopolized by the enterprise (Arrow, 1962). Due to the characteristics of technical knowledge as public goods, even enterprises that have not engaged in R&D can improve their productivity freely via the results of R&D achieved by other enterprises. Moreover, there are many results of studies which show that the productivity has improved largely due to the spillover effects rather than their own R&D activities (Griliches, 1998a).

Griliches (1979) divided such spillover effects into two types, the rent spillover and knowledge spillover effect. The rent spillover is related to the transactions (purchase flow) of goods (capital goods or intermediate goods), in which a technology developed by other enterprise is embodied. In the background of this concept is the fact that the aspects of qualitative improvement is not reflected in the price of goods, of which the quality has been improved through innovation activities, due to a new competition pressure and price elasticity of demand. Accordingly, other enterprises, which apply such goods to their own production process as input factors of production without paying additional costs, will enjoy a part of product innovation as a spillover effect (Griliches, 1979, 1992; Verspagen, 1997). Griliches (1979) took the computer industry as an example of rent spillover. The computer industry has brought about technological innovation through cutting-edge R&D. The productivity of computer industry cannot be measured by using a standardized method, and the benefit of productivity improvement cannot be completely monopolized. Other industries will receive differential benefits according to the amount of purchase of goods from the computer industry.

On the other hand, the pure knowledge spillover is not directly connected with transactions of goods, because it is based on the fact that knowledge has the characteristics of public goods. This works through various channels such as the mobility of researchers, patent information, reverse engineering, scientific journals, and information exchange at seminars (Los, 1997; Verspagen, 1997; Maurseth & Verpagen, 2002). Griliches (1979) paid attention to the relationship between the photographic equipment industry and scientific instrument industry, taking it as an example of pure knowledge spillover. Though there are not many transactions between the two industries, they benefit from each other's R&D as the fields of technology they belong to are similar to each other.

4.2.1.2 Tracking the technology flows

As mentioned above, most economists have acknowledged that the knowledge of technology, which has been obtained through R&D activities, has a unique characteristic regarding the spillover effect, and it has impacts on the productivity of other industries (Verspagen). In this context, the empirical studies on the effects and direction of spillover effects have been carried out vigorously. In order to estimate the spillover effect, the first work to be done is to measure the size of external knowledge stock, which causes the spillover effect in an industry.

The amount of benefit obtained by an industry through the spillover effect is associated with the size of external knowledge stock, and it can be commonly expressed as the sum of weighted values of the knowledge stock of other industries as follows (Griliches, 1979; Los, 1979).

$$IRE_j = \sum_i \omega_{ij} RE_i \quad \forall i \neq j$$

In this equation, 'i' is the industry producing the spillover, 'j' is the industry which is the beneficiary of the spillover effect. RE_i is the knowledge stock of external industries, and the weighted valued ω_{ij} is the degree of effect of the knowledge stock of industry 'i' on the productivity of industry 'j'. Accordingly, IRE_j is the sum of the weighted values of the external knowledge stocks that has effect on industry 'j' .

The weighted value refers to the degree of benefit of external R&D capital, which is granted to each enterprise or industry, and it also means the economic and technological distance among enterprises. If an industry gets further away from external knowledge, the spillover effect will decrease. So, a question is raised on how to measure the weighted values representing the technological distance among enterprises or industries (Antony & Grebel, 2008).

Griliches (1979) argued that there was not sufficient theoretical or factual knowledge regarding the work in which the correct weight values of external R&D stocks could be obtained. And he argued that such a problem should be solved in an empirical manner, though it was very difficult. Accordingly, it is required to establish the method in advance, in which the producer and beneficiary exchange such effects in order to identify the spillover effects of R&D and deal with the problems to be measured (Griliches, 1998a).

According to the survey research carried out by Mohnen (1996), the factors such as product domain between the two industries, type of R&D, patent classification, input-output flow, mobility of research manpower, qualification of research manpower, and research cooperation agreement shall be considered in order to measure the weighted values. The factors mentioned above can be divided into two views on the basis of the spillover type. The first one is the view that the technology is spreading out after it is embodied in the goods (embodied knowledge spillovers), and the other is the view that the technology is spreading out through various channels other than the goods (disembodied knowledge spillovers).

4.2.1.3 Flow of technology based on embodied knowledge

Some researchers thought that the technology was spread outside through the inter-industry transactions of products in which the innovation was embodied. In this viewpoint of methodology, the background is inherent in the idea that enterprises are dealing with the knowledge accumulated inside as intermediate goods. From this viewpoint the industry will benefit from the external knowledge in proportion to the goods they purchase (Los, 2000). Measuring the flow of technology based on the embodied knowledge among industries by using the I-O table is related to the rent spillovers (Griliches, 1992; Los, 1997). In the pioneering works carried out by Brown and Conrad (1967), and Terleckyj (1974), the I-O table was used to consider the transactions of goods among industries. Since then, the methodology was applied in the many follow-up studies[6].

Though the earlier studies considered the transactions of intermediate goods as the transactions of goods among industries, some follow-up studies measured the weighted

[6] The studies dealing with transactions among industries on the basis of I-O table include the studies carried out by Terleckyj (1980), Griliches (1979, 1984), Sveikauskas (1981), Odagiri (1985), Goto and Suzuki (1989), Wolff and Nadiri (1993), Wolff (1997), and Keller (2002), and we may refer to the survey researches carried out by Nadiri (1993), Griliches (1995), and Mohnen (1996) as well.

values, focusing on transaction flow of capital goods rather than the intermediate goods, in consideration of the fact that the capital goods was playing a role in delivery of the spillover effects (Wolff & Nadiri, 1993).

Especially, the measurement methodology for knowledge spillover through goods transactions have been applied to the studies which were aimed at analyzing the effects of foreign trade on economic productivity of a country (Antony & Grebel, 2008). Coe and Helpman (1995) put emphasis on the rent spillovers among countries, shedding light on the relationship between the knowledge of technology embodied in the goods, which were traded between countries, and the total factor productivity. Keller (1999) used the methodology of Coe and Helpman (1995) in order to analyze the productivity of various sectors in the G7 countries. And also, Keller (2001) carried out survey researches on the literature in which the relationships between the goods transactions through foreign trade and the total factor productivity were dealt with.

4.2.1.4 Flow of technology based on disembodied knowledge

Disembodied knowledge may be spread out through migration of researchers, patent information, science and technology journal, and seminars, so that it is difficult to identify the source of the flow of technology based on disembodied knowledge accurately (Maurseth & Verspagen, 2002). A lot of authors of literature used the patent citation data in order to measure the spillover of the knowledge created through innovation (Antony & Grebel, 2008). The studies, in which this methodology was applied, acknowledged that such patent citations data were a measure of knowledge spillovers (Maurseth & Verspagen, 2002). However, in reality, the pure knowledge spillover has a broader range than the flow of technology which is captured from patent citation, so that the patent-based information accounts for a part of pure knowledge spillover (Maurseth & Verspagen, 2002).

Despite such limits, the merit of patent data is that it helps figure out the flow of technology between the producers of knowledge and the beneficiary as patent documents also contain citations to previous patents. On the other hand, patents have been recognized as useful indexes with which a lot of studied related economics may identify R&D activities and technological changes (Griliches, 1990). The studies in which patent-based information was used in order to measure the knowledge spillover include Jaffe et al. (1993), Jaffe and Trajtenberg (1996, 1998), Caballero and Jaffe (1993), Jaffe et al. (1993), Jaffe and Trajtenberg (1996, 1998), Verspagen and De Loo (2000).

Despite the usability of patent-based information, patent data could not be used frequently as it could not provide the data at industrial level, which was needed by economics studies focused on R&D and productivity (Kortum & Putnam, 1997). However, the difficulty in matching the codified technological knowledge to specific industrial sectors was overcome by the Yale technology concordance (YTC) scheme suggested by Evenson et al. (1991) (Antony & Grebel, 2008).

The Yale technology concordance provided the spillover matrix by connecting the International Patent Classification (IPC) with the International Standard Industrial Classification (ISIC). Since then, the spillover effect could be estimated by using the matrix of flow of technology in many studies carried out by Fikkert (1997), Evenson (1997), Verspagen (1997), Los and Verspagen (1999), Keller (2002). Evenson and Johnson (1997), Kortum and Putnam (1997) confirmed the usability of Yale technology concordance in their studies.

4.2.1.5 Selection of the estimation method for technology flows

In fact, both the rent spillovers and pure knowledge spillovers are acting as an important factor in the endogenous growth theory (Verspagen, 1997). And when analyzing the spillover effects on the whole economy, it is impossible to divide the spillover effects occurring between producers and beneficiaries into rent spillovers and pure knowledge spillovers (Meijl, 1995). Nevertheless, the studies focused on spillovers shall select one between rent spillovers and pure knowledge spillovers to reflect it a model. The result of study may differ according the selection approach, so that the selection of estimation method for flow of technology is one of the important works.

Due to the growing interest in patent citation and the development of computer software that help find out the specific patent with ease, the patent data has been used as indexes, with which we may measure the size and direction of spillovers (Griliches, 1998a).

However, the studies focused on estimation of the flow of technology on the basis of such patent data have several problems and limits (Griliches, 1990; Verspagen & De Loo, 2000). Among the problems, this study aimed at reflection of spillover effect at the industrial level has to pay attention to the two. Firstly, the propensity to patent differs from industry to industry (Scherer, 1983). According to Scherer, the concentrated industries aiming to increase market share and profits and the firms, which have been diversified across industries and countries have higher patenting propensities. On the other hand, the industries, of which the principal user of innovation is the government, are likely to have a lower propensity to acquire new patents. That is because the government pays more attention the systems-based innovations rather than the innovation of specific products, and it is more difficult to acquire a patent in the fields of systems-based innovations. And in most cases, the ownership of outcomes from innovation, which has been carried out by public contracts, belongs to the government. Accordingly, there is no substantial motive to innovate and no need for patent. On the contrary, it is essential to protect the patent related to the technology for pharmaceutical industry, because it can be copyed in the development process. Typically, the share of innovations which are patented is higher in such industries (Verspagen & De Loo, 2000).

Secondly, the measurement of flow of technology by using patent-based information is on the assumption that the spillover has been delivered from the cited patent to the citing patent. By the way, the judgment regarding the technological connection between patents is not made by the inventor, but the patent office. Therefore, it is not clear whether the knowledge of cited patent has been delivered to the citing patent (Verspagen & De Loo, 2000). In their study, in which some US patents were used as materials, Jaffe et al. (1998) argued that the patent information was useful to measure the spillover effect of technology, but it could cause errors.

On the other hand, Keller (1997) compared the results of regression analysis on the relationship between total factor productivity and R&D on the basis of YTC matrix with the results of regression analysis on the data regarding the flow of technology on the basis of I-O table. According to Keller, there was not a clear difference between the results of regression analysis based on the YTC and the results of regression analysis based on the I-O table. Therefore, he concluded that it was impossible to determine whether the technology flow table of YTC could capture the technology flows among industries more effectively than that of the I-O table. Meanwhile, Keller (2002) analyzed the effects of own R&D and external R&D on the total factor productivity by using the technology flow table based on the I-O table and YTC matrix. Keller (2002) argued that the technology flows based on the I-O table appeared to have a better statistic result than the technology flows based on the YTC matrix.

As a result, it is more reasonable to estimate the technology flows by using the I-O table in this study in which the spillover effect of knowledge among industries is reflected. Accordingly, the technology flow table was prepared on the basis of the transaction flow of the I-O table of the base year. And then, the external R&D stock that had impact on industrial productivity was estimated by using the technology flow table.

4.2.2 Investment model

The typical investment theories, in which the policy variables of tax support may be reflected, include the investment theory of Jorgenson (1963, 1967), Hall and Jorgenson (1967), who introduced the concept of user cost of capital, and the Tobin's (1969) Q theory. Both models are based on the idea that investments occur when a producer decides to raise the current capital stock level to the optimal capital stock level in order to maximize the profit. This basic principle of investment model refers to the decision-making on investment in consideration of the marginal condition, which was suggested by Fisher (1930), and it is positioned on the extension of decision-making model in which the investment is decided by comparing the marginal cost with the marginal profit that can be obtained from 1 unit of marginal investment.

First of all, in the investment model of Jorgenson (1963, 1967), an enterprise that is able to predict the future completely will seek profit-maximization in a perfectly competitive market[7]. According to Jorgenson's model, the changes in user cost of capital, in which the variables of investment-inducing policy have been considered, will cause a change in the level of capital stock from the current level to the desired level of capital stock. Actual investments occur in order to adjust the gap between the current level of capital stock and the level of desired capital stock that has been changed.

In a circumstance without a variable of tax, the process where the level of desired capital stock is determined is as follows. When an enterprise borrow assets from another firms in order to obtain capital services, the rental rate of capital inputs can be calculated in the following equation.

$$\begin{aligned} q(t) &= \int_t^{\infty} e^{-r(s-t)} c(s) e^{-\delta(s-t)} ds \\ &= \int_t^{\infty} e^{-(r+\delta)(s-t)} c(s) ds \end{aligned} \qquad \text{Eq. (1)}$$

where, q : price of capital goods

r : discount rate

c : cost of capital services

δ : rate of replacement

t : time when the capital goods are acquired

s : time when the capital service are supplied

If the equation is differentiated against the time when the capital goods were obtained, we may derive Equation (2) below.

$$c = q(r+\delta) - \dot{q} \qquad \text{Eq. (2)}$$

Here, $\dot{q} = dq/dt$, so that it refers to the inflation, or appreciation or gain in capital.

[7] The investment model of Jorgenson explained in this clause was cited from Jorgenson (1963, 1967), Hall and Jorgenson (1967).

And then, if it is supposed that there is no gain in capital, Equation (3) can be derived.

$$c = q(r + \delta) \qquad \text{Eq. (3)}$$

Left side of Equation (3) is the rental price of capital from the standpoint of the owner of capital, and it also means the user cost of capital from the viewpoint of lessee. Now in order to analyze the effects of tax incentive on investment, the tax variables such as the corporate tax rate, tax credit rate, depreciation rate are applied, so that Equation (3) can be expanded to Equation (4).

$$q(t) = \int_t^{\infty} e^{-r(s-t)}[(1-u)c(s)e^{-\delta(s-t)} + u(1-k)q(t)D(s)]ds + kq(t) \qquad \text{Eq. (4)}$$

where, τ : corporate tax rate

k : investment tax credit rate

$D(s)$: depreciation (the proposition of the original cost of an asset of age s that may be deducted from income for tax purpose)

Now if 'z' is defined as the present value of the depreciation deduction on one dollar's investment after applying the tax credit, the following equation is composed.

$$z = \int_0^{\infty} e^{-rs} D(s)ds \qquad \text{Eq. (5)}$$

Accordingly, Equation (3) can be expanded to Equation (6) which represents the user cost of capital in which the tax variable is applied.

$$c = q(r + \delta)\frac{(1-k)(1-\tau z)}{1-\tau} \qquad \text{Eq. (6)}$$

Meanwhile, Jorgenson (1963), Hall and Jorgenson (1967) assumed the Cobb-Douglas function as a production function of firms as follows[8].

$$Y(L,K) = a\left[L^{\alpha}K^{\beta}\right], \quad where\ \alpha+\beta=1 \qquad \text{Eq. (7)}$$

Accordingly, when the exogenous output (Y), the price of output (PY) and the user cost of capital (C) are given, the desired level of capital stock below can be derived, under the condition that the marginal product of capital is the same as the rental price of capital.

$$K^{+} = \beta \cdot \frac{PY \cdot Y}{C} \qquad \text{Eq. (8)}$$

In this regard, K^{+} is the desired level of capital stock to meet the profit-maximization condition. By using Equation (8), the relationship between the desired level of capital stock and tax variables can be identified. In short, when the corporate tax rate or tax credit rate are lowered, the user cost of capital will be lowered, so that the desired level of capital stock will be raised.

The capital stock in Equation (8) is the theoretically desired level of capital stock that may maximize the profit, so that there may exist a gap between the theoretically desired level of capital stock and the current level of capital stock. The producers try to narrow the gap through actual investment expenditures. It is required to formulize the process, in which the changes in the desired level of capital stock in a model lead to an actual investment, in an investment model. Hall and Jorgenson (1967) judged that the demand for investment could not immediately result in actual investments due to the additional costs to adjust the level of capital stock. The assumed that the actual investments, which were affected by the changes in the desired level of capital stock, were carried out for

8 The more genralized type of function is the CES function as follows.

$$Y(L,K) = a[\alpha L^{\rho} + \beta K^{\rho}]^{1/\rho}, \quad where\ \alpha+\beta=1$$

Jorgenson (1963) introduced the Cobb-Douglas function on the assumption that the value of substitution elasticity among input factors was 1. And Jorgenson and Stephenson (1969) argued that the unit elasticity of substitution was in accordance with the actual data.

multiple time periods, instead of introducing the adjustment cost of capital. The actual investment behavior can be described through the distributed lag function in which the time-phased weighted values are applied. And Hall and Jorgenson assumed that the replacement investment was in proportion to the level of capital stock under their assumption of a constant rate of replacement. In this regard, the total demand for investment can be expressed in the following equation.

$$ID_t = \sum_{s=0}^{\infty} \mu_s \Delta K^{+}_{t-s} + \delta K_t \qquad \text{Eq. (9)}$$

where, $\Delta K^{+}{}_{t-s} = K^{+}_{t-s} - K^{+}_{t-(s+1)}$

μ_s: proportion of change in desired capital in period t-s that results in investment expenditures in period t.

Therefore, the net investment can be expressed as the weighted average of the change in the desired level of capital stock which occurred in the past as follows.

$$NID_t = ID_t - \delta K_t = \sum_{s=0}^{\infty} \mu_s \Delta K^{+}_{t-s} \qquad \text{Eq. (10)}$$

And now, the course of performance, in which the investment demand is materialized into actual investments, can be expressed completely by estimating the coefficient of distributed lag function. Hall and Jorgenson (1967) assumed that the changes in the desired level of capital stock during the first two periods had a considerable effect on investments, and the effects of the changes that happened during the previous period was reduced geometrically. Under such assumption, Equation (10) can be expressed as Equation (11) again.

$$NID_t = \mu_t \Delta K^{+}_t + \mu_{t-1} \Delta K^{+}_{t-1} + (1 - \mu_t - \mu_{t-1}) NID_{t-1} \qquad \text{Eq. (11)}$$

If, in that expression, I replace K^+ in Equation (11) with K^+ in Equation (8), then

$$NID_t = \alpha\gamma_0 \Delta \frac{PY_t \cdot Y_t}{C_t} + \alpha\gamma_1 \Delta \frac{PY_{t-1} \cdot Y_{t-1}}{C_{t-1}} - \omega NID_{t-1} + \varepsilon_t \qquad \text{Eq. (12)}$$

Hall and Jorgenson (1967) specified the coefficients in Equation (9) by estimating the coefficient of Equation (12), so that they could explain the capital investment in the USA during the period between 1931 and 1963. They argued that the fitted investment functions could describe the actual investment expenditures successfully despite the considerable variability in levels of gross investment during the relevant period.

Tobin's Q is defined as the ratio of the market value of a firm to the replacement cost of its assets. If the value of Q is bigger than 1, the net investment will increase, but if it is smaller than 1, the net investment will decrease.

Summers (1981) derive the tax adjusted Q, in which tax variables were considered, in order to explain the relationship between the variables of tax incentive[9].

$$Q = \frac{\frac{\lambda}{p}\left(\frac{1-c}{1-\theta}\right) - 1 + k + z + \beta}{(1-\tau)} \qquad \text{Eq. (13)}$$

where, τ : corporate tax rate

c : capital income tax rate

θ : dividend tax rate

k : investment tax credit

λ : change in a firm’s value resulting from a unit increment to the capital stock

z : present value of the tax savings from the depreciation deductions arising

9 As for the contents regarding tax adjusted Q, the study of Summers (1981) was mainly referred to.

on a new investment of one dollar

δ : rate of economic depreciation of the capital stock

β : debt ratio (= debt / capital stcok)

p : price of goods (overall price level)

Along with this, the following relationship between Q and the investment (I) has been derived by introducing the quadratic adjusted cost function (ϕ), in order to reflect the process, in which the investment is realized after the decision on investment is made by a producer, in the model.

$$\left(\phi + \frac{I}{K}\phi^{'}\right) = \frac{\frac{\lambda}{p}\left(\frac{1-c}{1-\theta}\right) - 1 + k + z + \beta}{(1-\tau)} \qquad \text{Eq. (14)}$$

The right side of the equation above represents the value of Q. Through Equation (14), we may know that the Q model for tax adjustment considers the capital cost as a variable explaining the investments. However, the shadow price, λ, which represents the change in a firm's value resulting from a unit increment to the capital stock, cannot be observed.

Accordingly, Hayashi (1982) solved the empirical problem by replacing the shadow price with an observable value in Equation (15).

$$\lambda = \frac{V-B}{K} \qquad \text{Eq. (15)}$$

$$Q = \frac{\frac{V-B}{pK}\left(\frac{1-c}{1-\theta}\right) - 1 + k + z + \beta}{(1-\tau)} \qquad \text{Eq. (16)}$$

where, V : market value of a firm's equity

B : present value of the tax savings due to depreciation deductions
on existing capital
pK : nominal value of capital stock

Both Jorgenson's investment model, in which the user cost of capital is used, and the investment model based on the Q theory, which has been suggested by Tobin (1969), Summers (1981), Hayashi (1982), are regarded as a neoclassical approach based on a firm's optimizing behavior, and they are considered to have provide solid theoretical foundations for the investment models (Kwack, 2005).

In this study, the investment model suggested by Hall and Jorgenson (1967), in which the user cost of capital is considered, has been selected between the two investment models in which the variables of tax incentive can be reflected. The reason is as follows. Firstly, there are many obstacles to measure the value of Q accurately in reality. The value of enterprise in the stock market has high volatility, and there is high probability of errors when measuring the replacement cost of the firm’s assets. So, the estimated Q values may be distorted, and such a problem may cause biased results in predicting investment plans (Griliches & Hausman, 1986; Cummins et al., 1994). In order to solve the problems regarding estimation of the distorted Q value, various estimation methods have been developed, including other studies focused on introduction of proxy variables for Q value (Caballero et al., 1995; Gilchrist & Himmelberg, 1995).

Secondly, the desired capital stock in the investment model suggested by Hall and Jorgenson (1967) is affected by the outputs, along with the user cost of capital. In fact, this is the main reason why their investment model has been criticized. There have been arguments that the major variable that affected the decision-making on investment in the empirical studies, where the investment model of Hall and Jorgenson (1967) was applied, was not the user cost of capital, but the changes in outputs. In short, it is argued that the investment model of Hall and Jorgenson (1967), which is aimed at explaining that the significant variable regarding decision-making on investment is the user cost of capital, is rather playing a role in reconfirming an ‘accelerator effect’, which argues that investments of enterprises are related to the changes in outputs (Eisner, 1969, 1970;

Eisner & Nadri, 1968; Chirinko & Eisner, 1983).

However, it is judged that the reflection of outputs (value-added) in this study, in which the methodology of CGE is applied, is rather appropriate. In partial equilibrium, it may be expected that the investment will increase when the user cost of capital decreases. However, from the viewpoint of general equilibrium, we may not see that reduction of user cost of capital leads to increase in investment. In general equilibrium, the tax credit system will have different degree of impact on each industry, and it will lead to a difference in production capability and growth rate in individual industries. Furthermore, when considering the indirect path on which the spillover effects have impacts on the growth of other industries, we may see relatively fast growth in some industries or slowdown or decrease of growth in other industries from a dynamic point of view[10]. Therefore, it has been judged that the application of the investment model suggested by Hall and Jorgenson (1967), in which the industrial growth may be reflected, is more appropriate than the application of Q-theory, when analyzing the effects of R&D policies on investments from the viewpoint of general equilibrium, where all the transactions among economic units and industries are considered.

4.2.3 Structure of the CGE model

4.2.3.1 Model Outline

The models include households, government and 27 industries representing the main agents of production and consumption. And each industry produces one product. The production sectors make decisions in order to maximize their own profit in the environment of perfectly competitive market, and the households make decisions for utility maximization. The physical capitals and knowledge capitals are accumulated by the each investment determined endogenously, and the financial resources required for the investment are through the savings of the government and households.

The primary input factors of production that will be put into production consist of labor,

[10] We may know that the value-added has an immediate and positive effect on demand for R&D investment through the studies by Bernstein and Nadiri (1988), Guellec and Van Pottelsberghe de la Potterie (2003).

physical capital and knowledge capital. Especially, the knowledge capital has been divided into the private knowledge capital and public knowledge capital, so that the effect of innovation activities of each main agent can be distinguished from each other and evaluated individually in the aspect of R&D. The private knowledge capital means the knowledge stock in which the results of R&D carried out by the private sector have been accumulated, and the R&D activities have been carried out with its own money or government subsidy. On the other hand the public knowledge capital is the knowledge stock in which the results of R&D carried out by the government have been accumulated, and the R&D activities have been carried out with the financial resources from the government itself and the private sector.

The major source of household income is the factor income, and household may obtain transfer income from the government. The government imposes taxes such as the labor income tax, corporate income tax, indirect tax and tariff on households and industries, and the tax revenues are used for savings and consumption, and transfer to household, and so on. As for the international trade with the rest of the world, I assume a small open economy, so that it does not have a significant impact on the foreign sector.

In order to describe and analyze the long-term effect of investment, the recursive dynamic models have been applied. In general, the dynamic mechanisms applied to the CGE model are divided into the inter-temporal dynamics and recursive dynamics. Considering the fact that the industrial R&D investment, which has been paid attention to in this study, responds sensitively to the changes in economic situation, which are caused by uncertain changes in future economic environment, it was judged that the recursive dynamic model was more appropriate than the inter-temporal dynamic model. Figure 4 shows the structure of the CGE model, and full explanation for each will be given later.

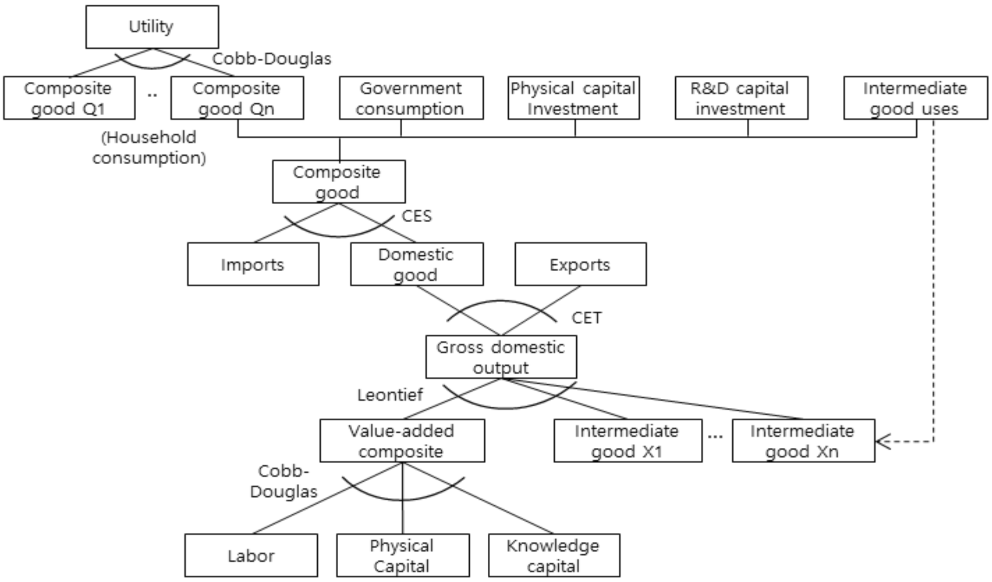


Figure 4. Structure of the Knowledge-based CGE model

The variable and parameters used in this model are presented in Table 7. For your reference the variables are written in capital letters, and the parameters are written in small letters.

Table 7. Symbols of parameters and variables

Sets and indicies	
i	Sectors and goods $i = \{S1, S2, , , S27\}$
rdt	Type of R&D $rdt = \{rdc, rdg\}$
Activity variables	
Z_i	Gross domestic output of the i-th good
VA_i	Value-added composite of the sector i
Q_i	Armington composite goods of sector i
D_i	Domestic goods of sector i
EX_i	Exports of the i-th good
M_i	Imports of the i-th good
L_i	Labor used in sector i
K_i	Physical capital used in sector i
$TINVK$	Total physical capital good
$IVNRD_i$	Knowledge capital good of sector i
$SUPIVNRD_i$	Knowledge capital good of sector i obtained by subsidy
SP	Household savings
SG	Government savings
$TOTSAV$	Total savings
U	Household utility
EFF_i	Efficiency of sector i
Price variables	
PZ_i	Price of the i-th gross domestic output
PVA_i	Price of value-added composite of sector i
PQ_i	Price of Armington composite goods of sector i
PL	Wage
PK	Rental price of physical capital
PH_i	Rental price of knowledge capital
$PINVK$	Price of physical capital goods
$PRDZ$	Price of knowledge capital goods
PM_i	Price of the i-th imported good in domestic currency

PW_i^m	Price of the i-th imported good in foreign currency
PE_i	Price of the i-th exported good in domestic currency
PW_i^e	Price of the i-th exported good in foreign currency
ER	Exchange rate
Tax and income variables	
$LABTAX$	Labor income tax
$CORTAXK$	Capital income tax (physical capital)
$CORTAXH$	Capital income tax (knowledge capital)
$INDTAX$	Indirect tax
$TAXCRE$	Amount of tax credits
HI	Household income
GR	government income
BG	Government debt
SF	Balance of trade
TR	Government transfer
Parameters	
$ax_{j,i}$	Input requirement coefficient of the j-th intermediate input for a unit output of the i-th good
ava_i	Input requirement coefficient of the i-th value-added composite for a unit output of the i-th good
$axrd_{i,rdt}$	Input requirement coefficient of the i-th intermediate input for a unit R&D capital good (by type of R&D)
$avard_{rdt}$	Input requirement coefficient of the value-added composite for a unit R&D capital good (by type of R&D)
gl_t	Population growth rate in period t

4.2.3.2 Production activities

Creation of value-added composite

The value-added composite is produced using labor, physical capital and knowledge capital. In this model, the Constant Elasticity Substitution (CES) function is applied as a production function, so that it allows the knowledge capital to be replaced with the labor and physical capital, which are the traditional and primary input factors of production. Meanwhile, the knowledge capital which is put into the value-added production activities as a direct factor of production is regarded as a private knowledge capital, not a public knowledge capital, and the knowledge capital used in each industry is regarded as a industry-specific asset. When considering the fact that it is difficult to use the knowledge capital required in the agricultural sector in the IT industry, this can be understood as a rational assumption. Accordingly, we may conclude the knowledge capital cannot be mobile among industries.

The impossibility of movement of knowledge capital among industries forms a contrast to the fact that labor and physical capital can be mobile among industries. Accordingly, the producers seeking to maximize profits decide the input demands for labor and physical capital, and the level of value-added composite by adjusting quantities of labor and physical capital, depending on the relative prices, while all the current knowledge capitals, which are accumulated during the previous periods, are used for production of value-added composite. The optimal quantities of value-added composite and input factors in an industry that seeks to maximize profits can be represented by solving the maximizing problem as follows.

$$\begin{aligned} &\underset{VA_i, L_i, K_i}{Max} \quad \pi_i^{va} = PVA_i \cdot VA_i - (PL_i \cdot L_i + PK_i \cdot K_i + PH_i \cdot H_i) \\ &s.t. \quad VA_i = EFF_i \left[\beta_i^l L_i^{\varepsilon_i^{va}} + \beta_i^k K_i^{\varepsilon_i^{va}} + \beta_i^h H_i^{\varepsilon_i^{va}} \right]^{\varepsilon_i^{va}} \\ &where, \quad \beta_i^l + \beta_i^k + \beta_i^h = 1 \quad for\ \forall i \end{aligned} \qquad \text{Eq. (17)}$$

In this formulation, EFF_i is the variable that represents the productivity affected by the spillover of knowledge capital, and the full explanation will be given later. In the value-added production function in the CES type mentioned above, the value of elasticity of substitution for labor, physical capital and knowledge capital in each industry is supposed to be '1'. Accordingly, the production function of value-added composite can be contracted to the Cobb-Douglas function. In this type of production functions the profit-maximizing producers will decide the quantities of value-added composite and the input factors that satisfy the following equations.

$$VA_i = EFF_i \left[L_i^{\beta_i^l} K_i^{\beta_i^k} H_i^{\beta_i^h} \right]$$
$$where, \quad \beta_i^l + \beta_i^k + \beta_i^h = 1 \quad for\ \forall i \qquad \text{Eq. (18)}$$

$$PVA_i \cdot VA_i = PL_i \cdot L_i + PK_i \cdot K_i + PH_i \cdot H_i \qquad \text{Eq. (19)}$$

$$L_i = (\beta_i^l \cdot PVA_i \cdot VA_i)/[(1+t_i^l) \cdot PL] \qquad \text{Eq. (20)}$$

$$K_i = (\beta_i^k \cdot PVA_i \cdot VA_i)/[(1+t_i^k) \cdot PK] \qquad \text{Eq. (21)}$$

$$PH_i = (\beta_i^h \cdot PVA_i \cdot VA_i)/[(1+t_i^h) \cdot H_i] \qquad \text{Eq. (22)}$$

Production of gross domestic output

The gross domestic output of each industry is produced using value-added composites and intermediate goods. The Leontief type production function has been applied to production of gross domestic output just like it is used in the CGE model. The Leontief production function does not allow the substitution between value-added composites and intermediate goods. So, the producer seeking to maximize a profit will face the optimizing problem as follows.

$$\underset{Z_i, VA_i, X_{j,i}}{Max} \quad \pi_i^z = PZ_i \cdot Z_i - PVA_i \cdot VA_i - \sum_j PQ_j \cdot X_{j,i}$$
$$s.t. \quad Z_i = \min\left(\frac{X_{1,i}}{ax_{1,i}}, \frac{X_{2,i}}{ax_{2,i}}, ..., \frac{X_{n,i}}{ax_{n,i}}, \frac{VA_i}{ava_i}\right) \quad for\ \forall i \qquad \text{Eq. (23)}$$

The producer who is facing the problem of profit maximization will determine the quantities of gross output, value-added, and intermediate goods, which satisfy the following equations.

$$X_{j,i} = ax_{j,i} \cdot Z_i \quad for\ \forall\ i, j \qquad \text{Eq. (24)}$$

$$VA_i = ava_i \cdot Z_i \quad for\ \forall\ i \qquad \text{Eq. (25)}$$

$$Z_i = \min(\frac{X_{1,i}}{ax_{1,i}}, \frac{X_{2,i}}{ax_{2,i}}, ..., \frac{X_{n,i}}{ax_{n,i}}, \frac{VA_i}{ava_i}) \quad for\ \forall i \qquad \text{Eq. (26)}$$

On the other hand, the Leontief production function in Equation (26) does not facilitate differentiation, so that there may be a difficulty in numerical computations. So, it is better to replace Equation (26) above with a zero-profit condition (Hosoe et al, 2010).

$$\pi_i^z = PZ_i \cdot Z_i - PVA_i \cdot VA_i - \sum_j PQ_j \cdot X_{j,i} = 0 \quad for\ \forall i \qquad \text{Eq. (27)}$$

And the following unit cost function can be derived if $X_{j,i}$ and VA_i in Equation (27) are replaced by using Equation (24) and (25).

$$PZ_i = ava_i \cdot PVA_i + \sum_j ax_{j,i} \cdot PQ_j \quad for\ \forall\ i \qquad \text{Eq. (28)}$$

Consequently, the produce will determine the quantities of gross output, value-added composite, and intermediate goods that satisfy Equation (24), (25), and (28).

Spillover effects of knowledge

A sector-specific knowledge capital is used as an input factor to produce value-added composites, so it has a direct impact on the relevant sector. But the economic importance of knowledge capital is that it generates the spillover effect. In short, a knowledge capital accumulated in a specific sector can have impact on the productivity of other sector after it is adopted by the relevant sector without charge. In this model, the spillover effect of knowledge capital has been reflected in the following method.

Above all, in the case of private knowledge capital, an industry 'i' selected randomly will benefit from the knowledge capital accumulated by industry 'j' (j≠i). As mentioned in Clause 4.2.1., it has been supposed that the scale of knowledge stock of other industries (namely, external knowledge stock, H_i^s) that affects an industry 'i' would be in proportion with the transaction amount of intermediate goods in the I-O table.

$$H_i^s = \sum_{j \neq i} \lambda_{i,j} \cdot H_j \quad for \ \forall \ i \qquad \text{Eq. (29)}$$

where, H_j: knowledge stock of the industry 'j'

$\lambda_{i,j}$: rate of goods sold to the industry 'i' over goods 'j' (as intermediate goods)

On the other hand, the economic effect of external knowledge stock (H_i^s) on the industry 'i' has been estimated through the elasticity of total factor productivity (TFP) or gross domestic production (GDP). In this study, the elasticity of GDP with respect to the external knowledge stock has been reflected on the basis of the study carried out by Jo (2004). Accordingly, an efficiency variable of an industry can be expressed as a functional relation between the exogenous knowledge stock and elasticity of GDP as follows.

$$EFF_i = f\left(H_i^s, ela_i\right) \qquad \text{Eq. (30)}$$

where, ela_i: elasticity of GDP with respect to external knowledge stocks for the industry 'i'

As shown in Equation (30), the degrees of increase in value-added (i.e. the degree of productivity improvement) caused by an external industry differ from industry to industry. We can understand that it is caused by the capacity to absorb the external knowledge capital and the technological proximity among industries.

On the other hand, the public knowledge capital has the non-rival and non-exclusive nature of public goods that can be used by all industries simultaneously. Accordingly, all the private sectors can improve their productivity by using the public knowledge capital. In this model, the effect of public knowledge capital on productivity has been calculated by reflecting the elasticity of GDP with respect to the public knowledge capital on the basis of the study carried out by Park et al. (2003). Accordingly, the industrial efficiency variable in Equation (30) can be expressed again as the function like Equation (31).

$$EFF_i = f\left(H_i^s, ela_i, HG, elahg_i\right) \qquad \text{Eq. (31)}$$

where, HG: public knowledge stock

$elahg_i$: elasticity of GDP with respect to public knowledge stock for the industry 'i'

In a word, the private knowledge capital can be fully formed by private R&D activities, and the capital has direct impact on its own production as it is used as a factor of production. And also, the knowledge capital of each industry, along with the government and public knowledge capital, creates spillover effects, so that it may have an effect on productivity of other industries.

4.2.3.3 Savings

The financial resources needed for R&D investments are provided through the savings of private sector and government. Korea has a very small scale of R&D investment from overseas, so in this study the foreign savings for R&D have not been considered. In principle, the financial resources for industrial R&D investment are based on the R&D-related savings of households.

$$PRDZ_{rdc} \cdot IDH_i = PSAVRD_i \quad \text{Eq. (32)}$$

where, $PRDZ_{rdc}$: price of private R&D capital goods

IDH_i : demand for investment goods

$PSAVRD_i$: financial resources held by industries (savings)

In short, as shown in Equation (32), when the investment demand of the industry is determined endogenously, the financial resources for R&D investment is supplied through household savings ($PSAVRD_i$) in principle. However, if the government grants subsidies in order to improve the competitiveness of enterprises, the private firm will decide the firm’s own R&D expenditures (savings) in consideration of the government subsidy. In this process, the government subsidy appears to promote or crowd out private investments. In this study, the mechanism, in which the private firms make a decision on the scale of firms’ own investment when receiving government subsidy, has been realized by using the CES function. In short, when the government is engaged in subsidization, the financial resources needed for investments will be supplied through the government subsidy and in-house financing as shown in Equation (33).

$$PRDZ_{rdc} \cdot IDH_i = a\left[\vartheta \cdot PSAVRD_i^{\rho} + (1-\vartheta) \cdot RDSUBSIDY_i^{\rho})\right]^{1/\rho} \quad \text{Eq. (33)}$$

where, $RDSUBSIDY_i$: government subsidy

On the left side of Equation (33) is the financial resource ($PRDZ_{rdc} \cdot IDH_i$) needed for investment of the industry 'i', and the right side represents the process in which the financial resource is supplied by combining the in-house financing and the government subsidy. In principle, the government-led R&D is supplied from the government budget, and some part of the financial resources is provided by the private sector. For the sake of simplicity of the model, the scale of government-led R&D investment has been fixed in comparison with the GDP.

$$GRD = rgrd \cdot GDP + rprd \cdot GDP \qquad \text{Eq. (34)}$$

where, $rgrd$: proportion of government-led R&D investment over GDP

rpr : proportion of private R&D investment aimed at the government over GDP

Meanwhile, the financial resources needed for physical capital is supplied through the savings of households and government, including the capital from overseas. Above all, the scale of financial resources based on the savings of households and government, which is aimed at physical capital, is determined by propensity to save among economic agents. And the propensity to save refers to the proportion of savings of each economic agent in the physical capital investment in the base year. On the other hand, the influx of foreign capital refers to the balance of trade, difference between the amount of export and import.

$$TSAVK = rp \cdot \sum_i (PINVK \cdot IDK_i) + rg \cdot \sum_i (PINVK \cdot IDK_i) + SF \qquad \text{Eq. (35)}$$

where, $TSAVK$: total savings used for physical capital investment

rp, rg : propensity to save regarding the physical capital investment of households and government respectively

SF : balance of trade

In this manner, the financial resources needed for R&D and physical capital investment are supplied from the savings of households and government, and the total savings of each economic agent are as follows.

Total savings of household

$$SP = \sum_i PSAVRD_i + rprd \cdot GDP + rp \cdot \sum_i (PINVK \cdot IDK_i) \qquad \text{Eq. (36)}$$

Total savings of government

$$SG = \sum_i RDSUBSIDY_i + rgrd \cdot GDP + rg \cdot \sum_i (PINVK \cdot IDK_i) \qquad \text{Eq. (37)}$$

In this model, the size of investment of physical capital and R&D capital is determined endogenously, so that the financial resources needed for this investment differ according to the size of investment determined endogenously. In a word, this model is an investment-driven model, of which the size of total savings is determined by investments. So, as the investment demand increases, the savings of households increase proportionally, however, the consumption of households decreases.

4.2.3.4 Physical capital and production of capital goods

The funds supplied through savings are used to purchase physical and R&D capital goods. The physical capital goods are the composite goods produced by inputting domestic goods and imported goods. In other words, when the demand for physical capital goods is determined through an investment function, the quantities of composite goods needed for supply of the physical capital goods can be derived as well.

$$TINVK = INVRES / PINVK \qquad \text{Eq. (38)}$$

$$XV_i = v_i \cdot TINVK \qquad \text{Eq. (39)}$$

The scale of R&D capital goods is determined in the following equation on the basis of scale of savings for R&D investment and the price of capital goods.

$$INVRD_i = PSAVRD_i / PRDZ_{rdc} \qquad \text{Eq. (40)}$$

$$SUPINVRD_i = RDSUBSIDY_i / PRDZ_{rdc} \quad \text{Eq. (41)}$$

$$RDZ_{rdc} = \sum_i (INVRD_i + SUPINVRD_i) \quad \text{Eq. (42)}$$

$$RDZ_{rdg} = (rprd \cdot GDP + rgrd \cdot GDP) / PRDZ_{rdg} \quad \text{Eq. (43)}$$

The R&D capital goods are produced using composite goods and value-added composites. When it is supposed that the production function of R&D capital goods is the Leontief production function of Armington composite goods and value-added, the Armington composite goods and value-added needed for production of R&D capital goods, of which the amount has been determined in Equation (42) and (43), are as follows.

$$RXV_{i,rdt} = axrd_{i,rdt} \cdot RDZ_{rdt} \quad \text{Eq. (44)}$$

$$RVA_{rdt} = avard_{rdt} \cdot RDZ_{rdt} \quad \text{Eq. (45)}$$

$$PRDZ_{rdt} = avard_{rdt} \cdot PRVA_{rdt} + \sum_i axrd_{i,rdt} \cdot PQ_i \quad \text{Eq. (46)}$$

And now, in order to satisfy the demand for the value-added derived from Equation (45), labor and capital is input to produce value-added composites. At this time the Cobb-Douglas function is applied as a production function

$$RVA_{rdt} = a_{rdt} \cdot (RLS_{rdt}^{\eta_{rdt,lab}} \cdot RKS_{rdt}^{\eta_{rdt,cap}}) \quad \text{Eq. (47)}$$

$$RLS_{rdt} = (\eta_{rdt,lab} \cdot PRVA_{rdt} \cdot RVA_{rdt}) / PL \quad \text{Eq. (48)}$$

$$RKS_{rdt} = (\eta_{rdt,cap} \cdot PRVA_{rdt} \cdot RVA_{rdt}) / PK \quad \text{Eq. (49)}$$

4.2.3.5 International trade

It is supposed that a small open economy has been applied to this model. The small open economy implies that an economic scale of a country is so small that the economic activities of the country have no effect on the rest of the world. This assumption is realized as the export and import prices in terms of foreign currency are exogenously given for this economy (Hosoe et al, 2010). Accordingly, the export and import prices in foreign currency are not variables, but parameters of which the values are given exogenously, while the export and import prices of goods in domestic currency are endogenous variables. The two types of price are related to each other through the exchange rate variable.

$$PM_i = ER \cdot (1 + t_i^m) \cdot PW_i^m \qquad \text{Eq. (50)}$$

$$PE_i = ER \cdot PW_i^e$$

where, PM_i, PE_i : import and export price of goods in domestic currency

PW_i^m, PW_i^e : import and export price of goods in foreign currency

As shown in Equation (50), this model reflects fact that tariffs are imposed in foreign trade, and the domestic price of exported and imported goods is expressed by multiplying the foreign price including the tariff by the exchange rate. On the other hand, the imperfect substitution between domestic and imported goods has been reflected in the model through Armington's assumption. The imperfect substitutability between domestic and imported goods implies that the goods produced domestically and the goods imported from a foreign country are separated from each other, though the kinds of the goods are identical. The model represents the imperfect substitution between domestic and imported goods by using the CES function. The Armington composite goods are provided to production and consumption activities.

$$\underset{Q_i, D_i, M_i}{Max} \quad \pi_i^q = PQ_i \cdot Q_i - \left[(1+t_i^m) \cdot PM_i + PD_i \cdot D_i\right]$$

$$s.t. \quad Q_i = \gamma(\psi \cdot M_i^{\upsilon} + (1-\psi) \cdot D_i^{\upsilon})^{\frac{1}{\upsilon}} \qquad \text{Eq. (51)}$$

Through the optimization issue mentioned above, a derived demand for the domestic and imported goods can be deducted (Equation 52), and Equation (53) is induced by normal profit condition.

$$M_i = D_i \left[\frac{PD_i \cdot \psi}{PM_i \cdot (1-\psi)} \right]^{1/(1-\upsilon)} \qquad \text{Eq. (52)}$$

$$PQ_i \cdot Q_i = PM_i \cdot M_i + PD_i \cdot D_i \qquad \text{Eq. (53)}$$

On the other hand, the goods produced domestically are consumed by home consumers, or exported to other countries. Enterprises seeking to maximize profits make a decision on whether their products will be sold in the domestic market or a foreign market, according to the domestic price and export price. In this model, the Constant Elasticity of Transformation (CET) function in Equation (54) has been introduced along with the existing CGE model. As a result, producers shall consider the restriction from the equations (Equation 54 and 55) and the normal profit condition (Equation 56), on which they determine the quantities of goods to be sold in the domestic market, and other goods to be exported.

$$Z_i = \gamma(\theta \cdot E_i^{\varphi} + (1-\theta) \cdot D_i^{\varphi})^{\frac{1}{\varphi}} \qquad \text{Eq. (54)}$$

$$E_i = D_i \left[\frac{PD_i \cdot \varphi}{PE_i \cdot (1-\varphi)} \right]^{1/(1-\varphi)} \qquad \text{Eq. (55)}$$

$$PZ_i \cdot Z_i = PE_i \cdot E_i + PD_i \cdot D_i \qquad \text{Eq. (56)}$$

4.2.3.6 Activities of main institutions in economy

Government

The government imposes tax on the labor income of households, and also the government imposes the corporate tax and indirect tax on the production activities of firms. And the government imposes tariffs on imports of goods. The rules of ad valorem duty have been applied to all the taxes, and the each rate of taxation reflected in this model was determined on the basis of the data presented in the national tax statistics yearbook and the I-O table. On the other hand, the tax revenues collected by the government are consumed by the government first. The consumption scale of each product, regarding the government expenditure, was defined as the increased amount based on the rate of growth of GDP from the initial value in the base year. And the government saves funds to supply financial resources needed for physical capital and R&D investments. After allocating the tax revenues to consumption and savings, the residue is transferred to households.

Iidirect tax

$$INDTAX = \sum_i t_i^Z \cdot PZ_i \cdot Z_i \qquad \text{Eq. (57)}$$

Labor income tax

$$LABTAX = \sum_i t_i^l \cdot PL \cdot L_i \qquad \text{Eq. (58)}$$

Capital income tax (physical capital)

$$CORTAXK = \sum_i t_i^k \cdot PK \cdot K_i \qquad \text{Eq. (59)}$$

Capital income tax (knowledge capital)

$$CORTAXH = \sum_i t_i^h \cdot PH_i \cdot H_i - \sum_i ITC_i \cdot PRDZ_{rdc} \cdot INVRD_i \qquad \text{Eq. (60)}$$

Tariff

$$TARIFF = \sum_i t_i^m \cdot PW_i^m \cdot M_i \qquad \text{Eq. (61)}$$

Government income

$$GR = INDTAX + CORTAXK + CORTAXH + LABTAX + TARIFF + BG$$

Eq. (62)

Government consumption

$$XG_i = rgdp \cdot XG_{i0} \qquad \text{Eq. (63)}$$

Government savings

$$SG = \sum_i RDSUBSIDY_i + rgrd \cdot GDP + rg \cdot \sum_i (PINVK \cdot IDK_i) \qquad \text{Eq. (64)}$$

Transfers to households

$$TR = GR - SG - \sum_i (XG_i \cdot PQ_i) \qquad \text{Eq. (65)}$$

Households

Households get the government transfer, and they also get factor income by providing the production sectors with factors of production such as labor, physical and knowledge capital. Households shall allocate a part of income to tax that is to be paid according to the tax rate determined by the government, and then save a part of income needed for investments. As explained in the items of investment above, the amount of savings from household income has been determined in consideration of the demand of firm's own R&D investments and the proportion to be covered by households in dealing with investment demand of the government and the total physical capital investment.

Labor income

$$LINC = \sum_i PL_i \cdot L_i \qquad \text{Eq. (66)}$$

Physical Capital income

$$KINC = \sum_i PK_i \cdot K_i \qquad \text{Eq. (67)}$$

Knowledge capital income

$$HINC = \sum_i PH_i \cdot H_i \qquad \text{Eq. (68)}$$

Total household income

$$HI = LINC + KINC + HINC + TR \qquad \text{Eq. (69)}$$

Household savings

$$SP = \sum_i PSAVRD_i + rprd \cdot GDP + rp \cdot \sum_i (PINVK \cdot IDK_i) \qquad \text{Eq. (70)}$$

The rest of income, after allocating the income to tax payment and savings, will be used for household consumption. The utility in households is achieved by consuming goods, and households determine the amount of consumption of each product in order to achieve the utility maximization within the available budget. In this model, the utility function of households is supposed to be the Cobb-Douglas function. Accordingly, the decision-making on utility maximization is expressed as the following Equation.

$$\underset{XP_i}{Max} \quad U = \prod_i XP_i^{\alpha_i}$$
$$s.t. \qquad \sum_i PQ_i \cdot XP_i = HI - SP \qquad \text{Eq. (71)}$$

After solving the utility maximization problem, the amount of consumption of each product is determined as follows.

$$XP_i = \alpha_i \cdot (HI - SP) / PQ_i \quad for\ \forall i \qquad \text{Eq. (72)}$$

Market-clearing conditions

Because this model is based on the perfect competitive market system, the goods and factor market shall satisfy the market-clearing conditions. The market clearing of a goods market implies that the supply and demand are well balanced. So, the following constraint shall be satisfied.

Market-clearing condition (goods)

$$Q_i = \sum_j X_{i,j} + XP_i + XG_i + XV_i + \sum_{rdt} RXV_{rdt} \qquad \text{Eq. (73)}$$

On the other hand, even in the factor market focused on labor, physical capital, and knowledge capital, the constraint regarding the balance between demand and supply shall be satisfied (Equation 74, 75, 76).

Market-clearing condition (labor)

$$\sum_i L_i + \sum_{rdt} L_{rdt} = LS \qquad \text{Eq. (74)}$$

Market-clearing condition (physical capital)

$$\sum_i K_i + \sum_{rdt} K_{rdt} = KS \qquad \text{Eq. (75)}$$

Market-clearing condition (knowledge capital)

$$H_i = HS_i \qquad \text{Eq. (76)}$$

Macro closure

In the case of R&D investments, the amount of investment and savings are equal to each other as the financial resources are supplied from the savings of households and government. However, in the case of physical capital they are not equal to each other. This is because the investment regarding physical capital is determined endogenously by an investment function, while the savings for physical capital are determined by the household and government's propensity to save, which is determined exogenously. Accordingly, this model has been designed to make the investments and savings for physical capital be equal to each other by using the debt of government.

Savings for physical capital investment

$$TSAVK = rp \cdot \sum_i (PINVK \cdot INVK_i) + rg \cdot \sum_i (PINVK \cdot INVK_i) + SF \qquad \text{Eq. (77)}$$

Government debt

$$BG = TSAVK - INVRES \qquad \text{Eq. (78)}$$

4.2.3.7 Dynamic process

Labor is an exogenous factor that increases or decreases according to the rate of population growth predicted in advance, while capital investments accumulate as a capital stock on the basis of the endogenous decision made by economic agents. Adopting the general principle of perpetual inventory method, in which physical capital is accumulated, the method has been applied to the knowledge capital in this study according to the recommendation of OECD (2010), so that the knowledge created by R&D may be accumulated and used in the future production activities. As shown in Equation (81), the private knowledge capital is accumulated through the firm's own R&D investment and the investments based on the government subsidy.

On the other hand, the knowledge capital is subject to obsolescence at a constant rate like physical capitals. That is because the economic value that can be obtained through the knowledge capital decreases as the time pass by, though the knowledge capital is an intangible asset and not subject to depreciation in terms of material.

Demographic growth

$$L_{t+1} = (1+g_{lt})L_t \qquad \text{Eq. (79)}$$

Accumulation of physical capital stock

$$K_{t+1} = (1-\delta_k)K_t + TINVK_t \qquad \text{Eq. (80)}$$

Accumulation of private knowledge capital stock

$$H_{i,t+1} = (1-\delta_{i,h})H_{i,t} + INVRD_{i,t} + SUPINVRD_{i,t} \qquad \text{Eq. (81)}$$

Accumulation of public knowledge capital stock

$$HG_{t+1} = (1-\delta_{g,h})HG_t + RDZ_{rdg,t} \qquad \text{Eq. (82)}$$

4.3 Simulation analysis

4.3.1 Simulation scenario

The base year of this model is 2009, and the period of simulation is a total of 22 years from 2009 to 2030. In order to confirm the sustainability of each policy means after the policy shocks, the investment-inducing measure has been inputted during the 5-year period between 2014 and 2018[11]. The 12 periods is long enough to identify the sustainability of effects of policy means after the implementation of the policy is completed.

The analytical purpose of this study is aimed at analyzing the effect of each policy means, and comparing them with each other. Accordingly, it is required to make the government provide support with the same scale, so that all the industries are provided with the same tax credit benefit. And then, the same amount of subsidy as the tax credit amount occurring in every period is supplied to the industries. Other taxes are not raised in order to make up for the reduction of tax revenues, which is caused by the tax credit, or prepare the budget for subsidies. Instead, the amount of transfer to household is reduced, which is equivalent to the amount of tax expenditure or subsidy.

Table 8. Classification of scenarios

Division	Applicable period	Tax credit	Subsidy	Subjects
Baseline scenario	-	-	-	-
Scenario A	T=6 – T=10	7%		All the industries
Scenario B	T=6 – T=10	-	Same scale as the amount of tax credit	All the industries

4.3.2 Simulation results

4.3.2.1 Promotion of R&D investments

It has been found out that the provision of tax credit benefit is more effective to achieve the primary goal, which is to promote private R&D investment at its own expense, than the subsidy support. The reason why the tax benefit is more effective is that

[11] The base year of simulation is year 2009 (T=1). So, the period between 2014 and 2018, when the investment-inducing polity is in effect is called T=6~T=10, and the last year of simulation is called T=22.

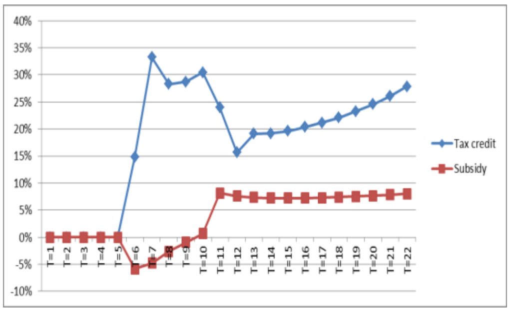
the desired level of capital stock is raised by the reduction of user cost of capital. For this reason, a manufacturer increases investments, which is followed by the increases in knowledge stock, so that the production capacity will be relatively expanded. This will lead to the increase in output and value-added, so that a virtuous cycle occurs, which induces investment demand.

Table 9. Effect on private R&D expenditure (unit: ten billion won)

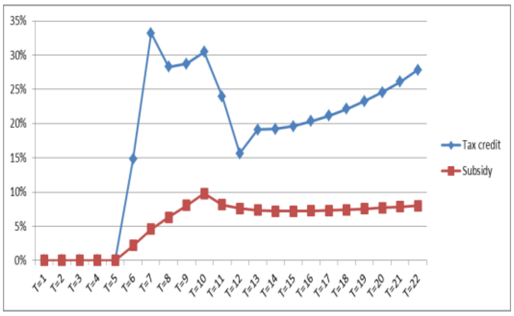
Division	Baseline	Tax credit	Subsidy
Private R&D expenditure	5,928.6	7,578.4 (27.8%)	6,403.7 (8.0%)

* ( ): percentage change from the baseline scenario (final period)

However, what is interesting is that the investment has not increases boundlessly during the period when the tax credit benefit was granted. The desired level of stock and the rate of increase in investment has increased sharply, which is due to the user cost of capital that was lowered during the period between T=6 and T=7 when the tax credit was put into practice, however, the user cost of capital has been changed a little during the period between T=8 and T=10 in comparison with the previous periods. And due to the gradual increase in value-added, there is no big change in desired level of stock. Accordingly, the level of investment is getting higher than that of baseline scenario from the period 8, however, there is no sharp increase like the period between T=6 and T=7. On the other hand, during the period between T=11 and T=12, when the tax credit benefit is not provided any more, the user cost of capital increases again, so that the rate of increase in investment begins to decrease in comparison with the previous period. However, it may be identified that the investment level remains high in comparison with the baseline scenario due to the expanded production capacity (knowledge stock) and the industrial growth (value-added).



Private R&D expenditure



Total R&D investment carried out by the private sector

Figure 5. Dynamic change in private R&D investment

Meanwhile, we may confirm that the discontinuous investing activities occur with a big range of fluctuation in the rate of increase when a policy shock is given, through Figure 5 that shows percentage changes of private R&D expenditures from the baseline scenario. This result has been caused by an investment behavior, with which the industry is responding to the exogeneous policy shocks, and such an investment behavior is realized by an investment model implemented. Though the rapid changes in investment level in this model has been relieved a little due to the time lag when the investment demand leads to an actual investment, the rate of change in investment in comparison with the baseline scenario appears to be discontinuous as the policy shock has a substantial impact on the industrial investment level from the time when the policy shock is applied.

The case, in which the big fluctuation in increase of investment is caused by a tax credit in this manner, can be identified in some empirical studies, in which the effects of R&D-related tax credit that was introduced in the USA in 1981 on the private R&D investments were estimated. For example, Baily et al. (1985), who carried out an analysis on the R&D activities of 12 R&D-intensive manufactures during the period between 1982 and 1985, found out that the private R&D investments had increased at an average annual rate of 7.3% in comparison with the predicted value based on the historical data. Mansfield (1985), who carried out an analysis on the R&D activities of 6 R&D-intensive manufactures, argued that the expenditure on R&D in the private sector increased at an average annual rate of 10% and 23% in 1981 and 1982 respectively, in comparison with the existing trend. Brown (1985) argued that the R&D investment had increased by 25% during the period between 1981 and 1984, due to the introduction of the tax credit system in 1981. Cordes (1989) argued that the actual R&D investments in 1981 1982, 1983, and 1984 were higher than the predicted values by 8.7%, 17.4%, 25.5%, and 26.8%, respectively.

The government subsidy appeared to have no effect on the user cost of capital and the desired level of stock in the period when it was paid, however, the payment of subsidy crowded out a part of private R&D investment, which led to a reduction of total private R&D investment with internal funds. However, what we need to pay attention to is that the gap between the baseline scenario and the investment level is narrowing during the period between T=6 and T=10, when the subsidy is paid, despite the increase in the scale of subsidy. Furthermore, from the period T=10, the level of private R&D expenditure is getting higher than the case where the subsidy is not paid, though the size is small, and then the investment is maintained at the higher level than the baseline scenario continuously. On the other hand, the subsidy has not fully crowded out the private R&D investment, so that the total scale of sectoral R&D investments, including the subsidy provided by government in each period, increases higher than the baseline scenario.

Accordingly, when the subsidy is granted, the level of industrial knowledge stock remains higher than that of the baseline scenario, and also the level of desired capital stock, which has been relatively expanded due to the value-added, remains higher than that of the baseline scenario. As a result, the investment gap between the baseline scenario and Scenario B decreases gradually despite the crowding-out effect of the subsidy. After all, during the simulation period and afterwards, including the period T=10 when the subsidy is granted, the investment activity is stronger than that of the baseline scenario.

4.3.2.2 Accumulation of knowledge capital stock

In both the case of tax credit benefit and the case of subsidy, the level of knowledge capital stock was higher than that of baseline scenario. When the tax credit benefit is provided, the difference of private knowledge stock between the baseline scenario and scenario A (tax credit) increases sharply due to the sharp increase in investment. Even after the provision of tax benefit, the investment level rises relatively, so that the difference with the baseline scenario is maintained continuously as shown in Figure 6. As a result, the stock level appears to have increased by 22.2% from the baseline scenario in the last period.

Though a part of private R&D expenditure is crowded out, when the subsidy is granted, the knowledge capital stock appears to have increased higher than the baseline scenario because of the increases in total R&D investment. Even after the provision of subsidy is terminated, the gap is maintained at a fixed level, so that it has increased by 7.2% in comparison with the baseline scenario.

Table 10. Effect on private knowledge stock

Division	Baseline	Tax credit	Subsidy
Private knowledge stock	30,309.1	37,035.6 (22.2%)	32,491.5 (7.2%)

* ( ): percentage change from the baseline scenario (final period)

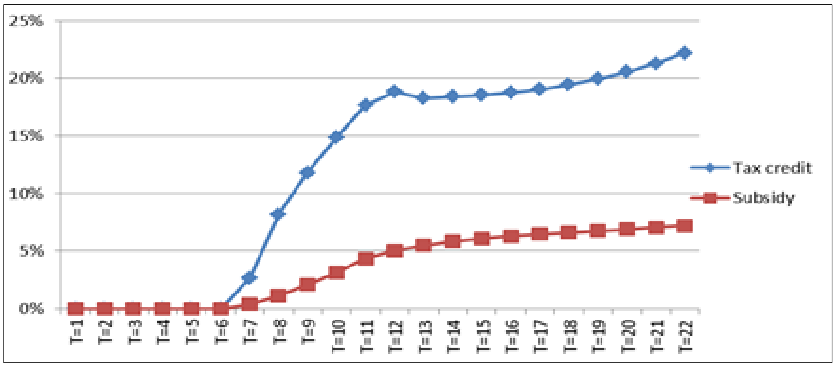


Figure 6. Dynamic change in private knowledge stock

4.3.2.3 GDP at factor cost

The GDP is used as a major index to represent the effect of a policy means on economic results. During the first two periods when the tax credit is provided the GDP decreases a little bit, but since then it increases sharply. The reason why the GDP decreases during the first stage of the tax credit is that the value-added created by the labor and physical capital falls down due to the price reduction of labor and physical capital despite the rise in income on the basis of the knowledge capital. However, value-added created by the factors of production such as labor and physical capital can remain at a higher level than the baseline scenario due to the increase of wage and rental price of physical capital through the next periods, while value-added created by the knowledge capital still remains at a higher level than the baseline scenario. According to the analysis on the difference in each factor income, the knowledge capital accounts for 40%~60% of the causes of the gap in the GDP.

On the other hand, when implementing a subsidy policy, the level of GDP is equal to the baseline scenario or higher than that, which has been consistent since the beginning of the implementation of investment-inducing policy. During the first two periods when the subsidy is provided, the price of physical capital drops relatively, however, the wage increases, so that the value-added created by labor and physical capital remains at the higher level than that of the baseline scenario. On the other hand the value-added created by knowledge capital remains at the higher level than that of the baseline scenario. After all, the provision of subsidy has raised the GDP growth rate by 0.82% in comparison with the baseline scenario on the basis of the final period. As the knowledge-based income accounts for 10%~30% of factors that cause such a gap, so that we may know the knowledge capital plays a less role than that in the tax credit system.

Table 11. Effect on GDP (unit: trillion won)

Division	Baseline	Tax credit	Subsidy
GDP	1,683.4	1,717.9 (2.05%)	1,697.2 (0.82%)

* ( ): percentage change from the baseline scenario (final period)

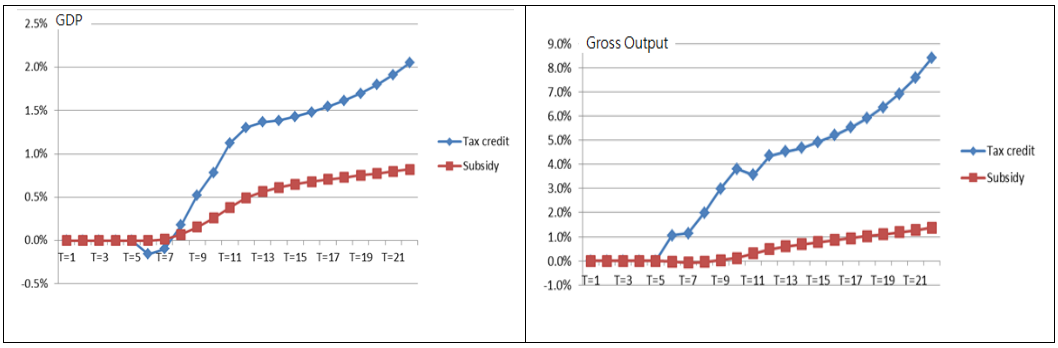


Figure 7. Dynamic change in GDP and gross output

4.3.2.4 Gross output and output by industry

The increase in R&D investments, which has been caused by the tax credit, results in the expansion of production capacity. As a result, the gross output has increased in comparison with the baseline scenario and Scenario B. In Scenario B, in which the government subsidy is provided, the gross output remains at the higher level than the baseline scenario, though the level is lower than the case of tax credit. There might be a difference, but the gap between the baseline scenario and both cases appear to be on the rise as the time pass by. The reason why the gross output has increased in this manner is that the level of knowledge capital increases relatively, though the level of physical capital is a little lower than the baseline scenario, and the production capacity of each industry has expanded in comparison with the baseline scenario, and the knowledge capital accumulated in the economy has improved the productivity through the spillover effect.

Table 12. Effect on gross output (unit: trillion won)

Division	Baseline	Tax credit	Subsidy
Gross output	5,309.9	5,756.9 (8.4%)	5,395.7 (1.6%)

* ( ): percentage change from the baseline scenario (final period)

The economy has been expanded in terms of gross output due to the provision of tax incentive. However, from the viewpoint of output of each industry, we may see that some industries can benefit from the tax support intensively, but the others cannot, which results in the polarization among the industries.

In the introduction of the tax incentive, the gross output has increased by 8.4% in comparison with the baseline scenario in the final period, and the percentage may be converted to 446.97 trillion won (Table 13). However, as shown in Figure 8, this final figure is based on the calculation in which 328.28 trillion won has decreased in some industries including the 'education, health and social work' industry, and the 775.25 trillion won has increased in the specific industries including the 'electronic and electrical equipment' industry. To put in concretely, 46.5% out of 775.25 trillion won is connected to the increase amount of the output in the 'electronic and electrical equipment' industry. And the transportation equipment industry accounts for 23.0% of the total increase amount. And the basic metal products industry accounts for 14.8% of the increase amount. In short, as shown in Figure 8, the increase in gross output is based on the result in which some industries including 'electronic and electrical equipment' industry have soared in comparison with others. On the other hand, the industries, of which the output has reduced in comparison with the baseline scenario, include the 'food, beverages and tobacco products', 'real estate and business services', and the 'education, health and social work' industry. Among them, the decrement of output in the 'food, beverages and tobacco products' industry occupied 14.5% of the total decrement, which is the highest percentage.

Table 13. Change in gross output by scenario (unit: trillion won)

Division	Sum of increased gross output (A)	Sum of decreased gross output (B)	Increase in gross output (C = A + B)
Tax incentive	775.25	-328.28	446.97
Subsidy	137.41	-51.60	85.81

* Final period

There are several explanations about why the output of some industries has increased, but the output of other industries has decreased, when the R&D investments increases all across the country. Above all, the industries of which the output has increased are the industries that increased considerable amount of investment through tax incentive, which resulted in a higher level of growth. In fact, the effective corporate tax rates of such industries have appeared to decrease much more than other industries. This implies that the industries with a bigger distribution coefficient of knowledge and large scale value-added can benefit more from the tax incentive, even though the same tax credit rate has been applied. The second reason of increase in output is that the relevant industry has benefit relatively more from the spillover effect from other industry. Especially, the 'transportation equipment', 'precision instruments' and 'general machinery and equipment' industry have benefited relatively more from the spillover effects of external knowledge stock. The spillover effects derived from external knowledge other than its own knowledge capital acted as a factor that increased the gap among industries.

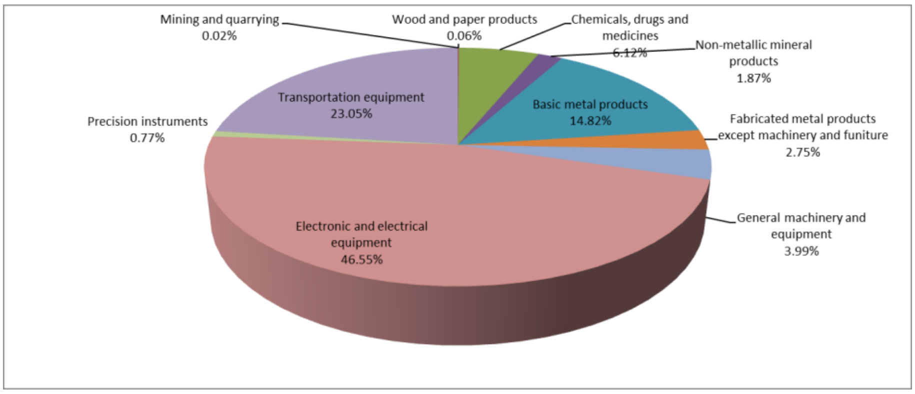


Figure 8. Percentage of increase in output of each industry in the introduction of tax incentive

On the contrary, there are many industries of which the growth rate slows down relatively in comparison with the baseline scenario despite the tax incentive. The industries of which the output has decreased include the 'agriculture, forestry and fishing', ‘food, beverages and tobacco products’, ‘textile and apparel’, ‘printing and reproduction of recorded media’, and ‘petroleum and coal products’ industry. The characteristic of such industries is that the rate of increase in R&D investment is low, which results in the slowdown in accumulation of knowledge stock, and they benefit less from indirect spillover effects of knowledge stock of other industries. The effective corporate tax rate declines slightly in comparison with others, so that they benefit less from the tax credit in reality. On the other hand, when implementing the tax credit, the wage and rental price of physical capital rise relatively, so that the price of goods produced by the industries, such as food and grocery and agricultural and fishery industry where the proportion of labor and physical capital is high, will rise as well. As a result, the competitiveness of such industries is weakened, and the demands for goods of such industries will decrease as well.

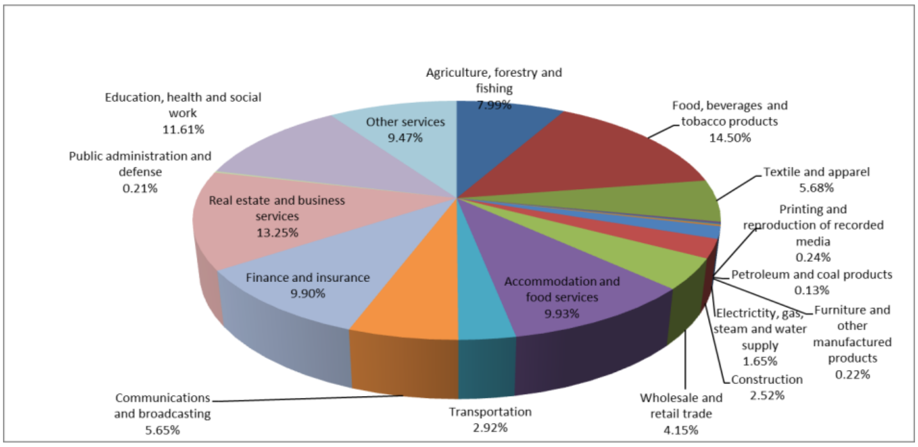


Figure 9. Percentage of decrease in output of each industry in the introduction of tax incentive

In this way, the tax incentive has caused a phenomenon in which the gap in growth among industries is deepened. This implies that the tax credit seems nominally to provide equal benefit to all the industries, but the benefit is concentrated on the knowledge capital-intensive industries.

As shown in Table 12 and 13, the gross output has increased by 1.6% from the baseline scenario when the subsidy is provided. However, like the tax incentive, this final figure is based on the result in which the output of some industries has increased, but the output of other industries has decreased. The sum of increased output of 11 industries, including 'electronic and electrical equipment' industry, reached 137.41 trillion won, and the sum of decreased output of 16 industries, including 'agriculture, forestry and fishing' industry, reached 51.60 trillion won. And because the gap is relatively small, we may conclude that the subsidy plays a positive role in mitigating the phenomenon, in which industrial growth is concentrated in specific industries, better than the tax credit.

4.3.2.5 Factor price

When the tax credit was provided, the wage decreased slightly during the three periods from T=6 to T=8, and since then, it appeared to increase slightly. This is because the rental price of knowledge capital has dropped, which resulted in the drops in relative prices of other factors. However, the wage rose higher than the baseline scenario from the period T=9. This is because the demand for labor has increased due to the increase in output despite the drops in relative prices. On the contrary, in the case of subsidy support, the wage is at the level similar to the baseline scenario or increases slightly.

The rental price of physical capital has appeared to increase in both policy means. This is due to the increase in demand for physical capital according to the increase in output and expansion of value-added.

Table 14. Effect on wage and rental price of physical capital

Division	Baseline	Tax credit	Subsidy
Wage	1.5687	1.5690 (0.02%)	1.5741 (0.34%)
Rental price of physical capital	0.093	0.095 (2.68%)	0.093 (0.99%)

* ( ): percentage change from the baseline scenario (final period)

4.3.2.6 Tax revenue

When implementing the tax credit, it was expected that the tax revenue would increase because the gross output and value-added increased. However, against to researcher's expectation, the level of government revenue was lower than that of baseline scenario when implementing the tax credit. The major reason of decrease in government revenue is related to the decrease in indirect tax. Though the gross output has increased in comparison of the baseline scenario, the outputs of some industries have decreased (Figure 9). Especially, the government revenue decreased in the industries to which high indirect tax rate was applied as the output of such industries decreased a lot in comparison with other industries.

In the case of subsidization, it was expected that the tax revenue would increase due to increase in gross output, however, the tax revenue in the last period decreased slightly. Like the tax credit, the main reason is that the growth of the industry, to which high indirect tax rate is applied, is lower than that of the baseline scenario. However, when considering the fact that the differences in growth rate among industries, when introducing government's subsidy, is smaller than the gap in growth rate when implementing the tax credit, we may confirm that the tax revenue is at the level similar to that of the baseline scenario or decreases slightly.

Table 15. Effect on tax revenue (unit: trillion won)

Division	Baseline	Tax credit	Subsidy
Tax revenue	295.25	284.78 (-3.5%)	294.02 (-0.4%)

* ( ): percentage change from the baseline scenario (final period)

4.3.2.7 Physical capital investment

In the case of tax credit, the physical capital investment decreased by 3.8% in comparison with the baseline scenario in the final period. When providing the tax benefit, the value-added of each industry expanded, so that it was expected that the physical capital would increase. But the rental price of physical capital increased according to the increase in economic scale. After all, the negative effect of rise in rental price of physical capital on shrinkage of investment was bigger than the positive effect of increase in value-added on expansion of investment. Therefore, the investment in physical capital decreased. The provision of subsidy has caused a slight decrease in investment for the same reason, however, the rate of decrease was smaller than that of tax credit.

In this way, when implementing the R&D policies, the decrease in physical capital investment can be understood as the transition to a knowledge-based economy by replacing physical capital with knowledge capital. But there is no doubt about the importance of physical capital. Therefore, the policy makers have to introduce additional policies that supplement the physical capital investment policy when setting up a investment-inducing policy for promotion of R&D investment.

Table 16. Effect on physical capital investment (unit: trillion won)

Division	Baseline	Tax credit	Subsidy
Physical capital investment	531.36	510.92 (-3.8%)	527.26 (-0.8%)

* ( ): percentage change from the baseline scenario (final period)

4.3.2.8 Discussion on results

The simulation presented above is aimed to compare the effects of the two policy instruments, so that the results have been derived by establishing the amount of tax credits, which occur when the government provides tax support benefit, as the subsidy for each industry. However, if a comparison between the policy instruments is not considered, the various methods of subsidization, so that the effects of subsidy may differ. In this context, in this study, an additional study has been carried out in order to look into the effects according to the methods of subsidization. In short, the beneficiaries of subsidy are divided into the non-manufacturing industrial group and the manufacturing industrial group, which is different from the existing method of subsidization. Accordingly, all the government subsidies have been applied to the non-manufacturing industrial group in the first simulation, and the government subsidy has been granted only to the manufacturing industrial group in the second simulation. At this time, the government subsidy is provided only during the period between T=6 and T=10 as mentioned above, and the scale of subsidy granted at each period is the same amount as the amount of tax credits, which occurs when the tax incentive is introduced in Scenario A.

Table 17. Classification of industrial groups that are beneficiaries of subsidy

Division	Contents
Non-manufacturing industrial group	13 industries including ‘agriculture, forestry and fishing’, ‘mining and quarrying’, ‘electricity, gas, steam and water supply’, ‘construction’, ‘wholesale and retail trade’, ‘accommodation and food services’, ‘transportation’, ‘communications and broadcasting’, ‘real estate and business services’, ‘public administration and defense’, ‘education, health and social work’, and ‘other services’ industry
Manufacturing industrial group	14 industries including ‘food, beverages and tobacco products’, ‘textile and apparel’, ‘wood and paper products’, ‘printing and reproduction of recorded media’, ‘petroleum and coal products’, ‘chemicals, drugs and medicines’, ‘non-metallic mineral products’, ‘basic metal products’, ‘fabricated metal products except machinery and furniture’, ‘general machinery and equipment’, ‘electronic and electrical equipment’, ‘precision instruments’, ‘transportation equipment’, ‘furniture and other manufactured products’ industry

The results of analysis suggest that the application of subsidy to non-manufacturing industrial groups, which are characterized by non-R&D-intensive sector, is more effective than granting a subsidy to the manufacturing industrial groups that are classified into a R&D-intensive industrial group, in terms of private investment promotion and economic growth. This is because the non-manufacturing industrial groups, in which their own self-financed R&D investment has not been activated, can increase the investment through subsidies, and the accumulation of knowledge capital formed by the increase in investment through the subsidies leads to additional R&D activities with their own money.

On the contrary, the knowledge-based manufacturing industry carry out relatively active investments with their own resources even though they do not receive government subsidies. However, though different methods of subsidization are applied, the fact that the effect of tax incentive is bigger than the effect of subsidy has not been changed.

Table 18. Comparison of the results regarding the methods of subsidization

(unit: ten billion won)

Division		Baseline	Tax credit	Subsidy
Non-manufacturing industry support	Private R&D investment	5,928.6	7,578.4 (27.8%)	6,800.6 (14.7%)
	GDP	168,339.9	171,791.7 (2.05%)	171,519.1 (1.89%)
	Gross output	530,990.6	575,687.7 (8.4%)	548,237.7 (3.2%)
Manufacturing industry support	Private R&D investment	5,928.6	7,578.4 (27.8%)	6,533.4 (10.2%)
	GDP	168,339.9	171,791.7 (2.05%)	169,893.4 (0.92%)
	Gross output	530,990.6	575,687.7 (8.4%)	544,885.7 (2.6%)

* ( ): percentage change from the baseline scenario (final period)

On the other hand, in this study, the individual effects of each policy means have been analyzed by applying the subsidy and tax incentive policy separately, and it has been concluded that the effect of tax incentive is better than effect of subsidy on the basis of the analysis. However, it is considered that searching for an optimal policy mix is a meaningful attempt because various policy means are used simultaneously in reality. In consideration of such necessities, an additional analysis in which the subsidy and tax incentive are applied simultaneously has been carried out. The purpose of the analysis is to find out the optimal ratio of subsidy and tax incentive in order to maximize the effect of policy within the available budget.

To achieve this, a simulation test has been carried out by adjusting the ratio of subsidy of each policy means, which has been presented in Scenario A (or B). Figure 10 shows the results.

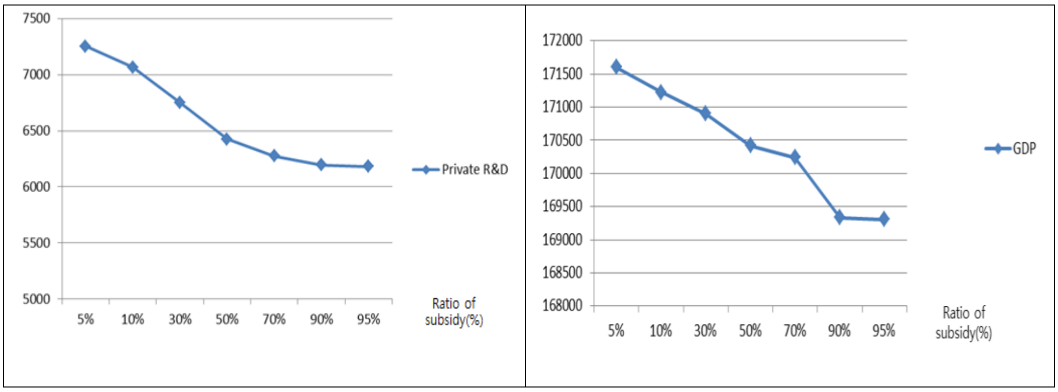


Figure 10. Effect of policy according to the changes in ratio of subsidy

According to the result, we may see that the degree of effects in terms of private R&D promotion and GDP decreases when reducing the scale of tax credit and increasing the rate of subsidy at the same time. On the basis of the result, it is desirable to provide the tax incentive first within the limit of the budget that is available. However, the attempts to determine appropriate ratio of such policy means had limited success in adjusting the substitutional or complementary effect that may occur between the two policies. Some studies carried out by the researchers such as Guellec and Van Pottelsberghe de la Potterie (2003), and Mohnen and Röller (2005) have dealt with the theme. Because the analyses in this study are carried out on the level of industry, relevant studies at the subordinate level shall take precedence. Accordingly, the result presented above are considered to be limited results of studies, which have been derived in the state where the two policies are regarded as disconnected with and independent from each other.

Finally, in this study, a total of 22 years from 2009 to 2030 has been selected as a simulation period, and the 5-year period between 2014 and 2018 has been selected in order to apply the subsidy or tax incentive. The selection of simulation period is focused on the confirmation of sustainability of policy means, so that persistence of effect can be identified after completion of the policy means. Due to the study setting like this, it was not possible to clarify the implications regarding the period of the support or time. In order to supplement the shortfall, the period of government support was varied so that the effect could be analyzed.

However, though the period of government support is established as 7 or 10 years, which may result in a variation of the effects of policy means (promotion of private R&D investment, or GDP) due to the changes in period and scale of government support, we may know that there would be no change in the fact that the effect of tax incentive is bigger than that of subsidy as shown in Table 19.

Table 19. Effect of policy according to the period of government support

(unit: ten billion won)

Division		Baseline	Tax credit	Subsidy
Policy shock for 10 years	Private R&D expenditure	5,928.6	7,666.3 (29.31%)	6,942.9 (17.11%)
	GDP	168,339.9	172,366.4 (2.39%)	171,458.3 (1.85%)
	Gross output	530,990.6	582,458.5 (9.69%)	549,867.3 (3.55%)
Policy shock for 7 years	Private R&D expenditure	5,928.6	7,366.7 (24.26%)	6,558.4 (10.62%)
	GDP	168,339.9	171,350.6 (1.79%)	170,239.9 (1.13%)
	Gross output	530,990.6	570,637.6 (7.47%)	542,792.8 (2.22%)

* ( ): percentage change from the baseline scenario (final period)

As shown in the result of analysis, this study has confirmed that as the period of government support increases, the effect of policy gets bigger. But this study cannot present any implication regarding the optimal time (or period). Such limitation of this study is caused by applying the recursive dynamics to the CGE model.

In the recursive dynamic model, all the decisions, including investments, are made through an myopic way, so that the environmental changes that occurred in the past, or will happen in the future, cannot have an effect on the decision making in the present period. In short, only the changes in exogenous environment in the present affect the decision making in the current period.

Although this study cannot present any implication regarding the optimal period (or time) for policy implementation, this is a very important factor when designing a policy. So, it is required to expand this model by referring to the relevant studies which have dealt with such a theme. For example, there are studies in which the evaluation and comparison of temporary tax incentive and permanent tax incentive have been carried out. Abel (1982) argued the application of the temporary tax incentive for a limited time in an economic recession because the temporary tax incentive was more effective than the permanent tax incentive. On the contrary, Park and Kim (2006) derived an opposite result, and argued that continuous tax support was effective. Meanwhile, regarding a dynamic effect of subsidy, we may refer to the study carried out by Klette et al. (2010). As for the capital accumulation method, they argued that if an accumulation method, in which a learning effect had been reflected, was applied instead of the perpetual inventory method, the fact that government would subsidize could change the firm's own R&D investment before and after subsidization. On the other hand, we may refer to the studies carried out by Hall (1992), Guellec and Van Pottelsberghe de la Potterie (1997, 2003), when referring to the analysis on the effects of the stability of government policies on industrial investments.

4.4 Sub-conclusion

4.4.1 Summary and policy implications

Both the direct support method represented by the subsidy and the indirect method represented by the tax incentive have achieved the primary goal of policy to promote the private R&D investment. However, the indirect support method of tax credit is more effective than the direct support method of subsidy to promote private R&D activities. The same result has been identified in the analysis in which the ratio of subsidy and tax incentive was adjusted. Accordingly, this study supports the results of existing studies carried out by Hall and Van Reenen (2000), Avellar (2011), Guellec and Van Pottelsberghe de la Potterie (2003) and Wu et al. (2007), who argue that the indirect means were more effective than the direct means.

The difference between the two types of policy, regarding the effect of private investment promotion, is caused by the institutional characteristics. In short, the effect of tax credit benefit is based on the mechanism in which the desired level of capital stock changed by the decrease in user cost of capital promotes the investment demand. The subsidy, in which the financial resources for the private R&D investment is provided by the government, has a kind of income redistribution effect, however, it does not have a direct effect on the changes in the desired level of capital stock in each industry. Besides, the government subsidy crowds out a part of sector's own self-financed R&D activities, so that it is likely to reduce the investments with in-house financial resources in comparison with the situation where the subsidy is not granted.

This result implies that though it is necessary for the government to intervene into the market, it has to choose an indirect support method. That is because it is more effective to allow the private sector to decide the level of voluntary investment in consideration of overall environment regarding production activities. In the case of subsidy, the government grants the subsidy to the industry without considering the investment environment in the industry. So, the effect is relatively small, even though the primary goal to promote the investment in the private sector may be achieved.

The policies of tax credit and subsidy have shown the positive effect in terms of investment promotion and overall economic growth. However, both policy means promote the growth of knowledge capital-intensive industry, while they bring about the slowdown in growth of the industries that are not R&D-intensive. Especially, the tax credit benefit has the possibility to bring about a polarization in terms of industrial growth. This is because the substantial benefit is concentrated on some industries even though the nominal benefit is equal to each other all across the industries. On the other hand, the direct subsidy from the government mitigates the unbalanced industrial growth by slowing down the concentration of knowledge capital in comparison with the tax credit.

In a word, it is effective to allow the private sector to decide the investment level according to their voluntary decision-making through the indirect support method. However, if the government policy is completely dependent on the voluntary decision-making of private sector, some industries that show lack of enthusiasm may decrease the use of industries' own R&D resources, so that the effective support from the government may not be carried out when the industrial growth is slowing down. Therefore, it is required to make efforts to provide supplementary effects to the part of industry through a direct intervention, though the indirect support method is applied first.

On the other hand, in this study, the investment level is endogenously on the basis of investment function without establishing an exogeneous relationship between the two types of investment. When implementing the policy of R&D investment promotion by using this model, there has been a trend in which the physical capital investment decreases. Accordingly, the policy makers shall identify various factors that may cause reduction of physical capital investment during the process in which the R&D policies are implemented, considering introduction of policies that are able to make up for the reduction. However, there is a logical risk if we judge on the basis of this result that the R&D investment has effect on the physical capital investment. That is because there is a possibility that the relationship between the two types of investment may change according to the specific value of elasticity of substitution between the physical and knowledge capital in the value-added production function introduced in this model. The studies on this shall be expanded from now on.

4.4.2 Significance of study and future research

Many existing studies have been focused on the effects of each policy means on the private R&D investments. They provide the justification of government R&D policies by confirming the positive effects of each policy means. When the government intervenes into the market on the basis of the justification, what the policy maker shall consider is how to choose the most effective policy means among various policy means. By the way, the existing studies have failed to provide many implications regarding the issue how to choose a proper policy means.

The significance of this study is that the effects of direct and indirect support methods have been compared in one analysis framework, meeting such a demand for studies. Furthermore, this study is aimed at the analysis of effects of R&D policies on economic growth, as well as the private investments, by reflecting the spillover effects of R&D investments and knowledge capital in the CGE model which embraces the economic activities of industry, households and government.

However, this study has some limitations as follows. Firstly, in this study, the individual effects have been derived by applying the subsidy and tax incentive separately. However, the government is implementing various policy means such as the subsidy and tax incentive simultaneously. Accordingly, in order to maximize the effects of policies, we have to look for a direction to the optimal policy mix in which the direct and indirect policy means are combined with each other. In order to carry out such studies, a profound examination regarding the substitutional and complementary relationship among each policy shall take precedence. Secondly, this study has not dealt with the themes about the time and period of government support despite the importance of such discussions. To achieve this, it is required to apply an inter-temporal dynamic model, and carry out studies on dynamic investment-inducing effects according to the various methods for capital accumulation and the stability of government support. Thirdly, this study is focused on the fact that the investment level appeared to be lower than the optimal level due to the market failure. However, the market failure takes place in terms of the composition of R&D (Tassey, 1996). Accordingly, a discussion on R&D policies focused on correcting the market failure regarding the composition of R&D such as the basic, applied and development research, shall be in progress in the future.

Chapter 5. Analysis on the effect of defence procurement

5.1 Background and purpose of study

Unlike the concept of 'supply-push', which is related to the policy means of government affecting the provision of new technologies, the concept of 'demand-pull' is related to the policy means of government affecting the scale of market regarding the new technologies.

The advanced industrial countries, including Korea, have been concentrated on the use of supply-push policy means. However, the governments that recognized the limitation of supply-push policy in promoting innovation activities gradually began to pay attention to the demand-pull policies, and the importance of public procurement as a typical policy means has come to the fore.

The public procurement has been applied as a part of industrial policy instruments (Dalpé, 1994). The public procurement as an industrial policy allows the public agencies to promote the innovation activities of industries by using the purchasing power in the market, so that it can develop the industries. Especially, the public agencies can protect the newly established industries, in order to help them get on the track by providing them with opportunities to sell the products. And also, the firms that have carried out a public procurement can grow to be matured firms as they obtain the opportunities to enlarge the common market for the product (Premus et al, 1985). The economists also have been interested in public procurement as a means of industrial policy, and the representative studies have been carried out by Rothwell and Zegveld (1981), Rothwell (1984), and Geroski (1990). Edler and Georghiou (2007) suggested the importance of local demand, market and system failures, and the improvement of public policy and services as the rationale in which the procurement policy is used as an industrial policy.

This study is focused on the analysis of the effects of defence procurement, which is a part of public procurement, on the private innovation activities. The Korean government has implemented a variety of policies aimed at protecting and fostering the defence industry strategically. Due to the characteristics of defence industry, the demand of the government has more effect on the structure and innovation activities than any other policy means. In the case of USA, the procurement policies regarding the national defense and aerospace field have played an important role in protecting and fostering the newly established enterprises and industries (Bollinger et al., 1983).

Accordingly, this study is designed to examine the effects and limitations of defence procurement policies by focusing on the effects of defense expenditures, which form the greater part of the government expenditures, on the innovation activities. In this study, the effects of defence procurement are divided into two types to be analyzed. Firstly, all the expenditures related to national defense are regarded as the defence procurement, so that the effects of defence procurement on innovation activities are analyzed. The defense expenditures include the purchase of ordinary goods and services, as well as the weapon systems, in order to maintain the national defense function. Accordingly, the defence procurement represents the transactions with other industries, as well as the defence industry[12]. And then, the effects of the procurement limited to high-tech weapon systems on the investment of the defence industry will be analyzed.

The defence industry is one of the typical capital-intensive industries, so that the scale of defence procurement may cause a big change in the investment level. Especially, our defence industry absolutely depends on the domestic demand, so that there is a strong possibility that changes in government policy leads to the changes in the structure of industry.

[12] The defence industry may be defined as 'the industry engaged in research and development of material that are needed for military purpose to defend the country' (National defense white papers, 2006).

5.2 Theoretical backgrounds and empirical studies

5.2.1 Demand-pull policies and national defence procurement

In this clause, the difference between the public procurement and defence procurement, which is a special case of public procurement, will be discussed, focusing on the characteristics of defence procurement. It is expected that the effects will increase when designing and implementing the defence procurement policies in consideration of such characteristics.

The reason why the defence procurement has a significant effect on innovation activities carried out by the industry participating in the procurement market is that the national defense section requires the completeness of cutting-edge technologies. In most cases of defence procurement, it is required to develop the products or services (Edquist et al. (2000) called this kind of procurement the developmental procurement) that do not exist at the time of placement of order. Accordingly, we may frequently observe the cases in which the costs and period of time for product development are changed in order to satisfy the product performance requested by the military (Dalpé, 1994; Hartley, 2007).

While the defence procurement puts emphasis on developmental procurement, the public procurement consists mostly of adaptive procurements, in which the existing goods or services are required (Edquist et al., 2000). The adaptive procurements put a bigger emphasis on the application of existing goods or services in specific (local) environment than development of new technologies. This characteristic of public procurement can found in the study carried out by Lember et al. (2011). After carrying out the studies on the characteristics of procurement in the Baltic nations they confirmed that the public procurement in those countries did not present requirements regarding R&D efforts and the innovations induced by procurement had nothing to do with the development of new technologies. Yaslan (2009), who had carried out 30 case studies on public procurement of information technology in Turkey, found out that the procurement was not closely related to the radical innovations. He argued that the procurement policy had effect on the gradual innovations for commercial application and inducement for organizational and process innovation rather than a radical innovation.

On the other hand, the theoretical foundation of hypothesis that the defence procurement is more effective than the public procurement can be derived by focusing on the specific conditions to secure the successful procurement policy, which was suggested by Geroski (1990) as mentioned above in Clause 2.2.2. According to Geroski, the requirements for a successful procurement policy include the application of high-level product and technology standard provided by the main agency for procurement, clear needs which the efforts of innovation is aimed at, provision of market for new products and services, and boosting competition among providers.

By the way, the defence procurement is very closely connected to the requirement for success, which has been mentioned by Geroski (1990). The military provides the market with clear information regarding the necessary weapon systems in order to maintain and improve military strength, and asks the market to develop such systems. The manufacturers, who are interested in the purchase intent of the military, put resources in the product development, which satisfies the requirements presented by the military. Especially, the technological demand for the weapon systems requested by the military is specified in the Required Operational Capability (ROC), and it is used as a standard when the military makes a final decision on whether the weapon system developed by the producer is a success or failure. And the national defense section allows specific enterprises to have a monopolistic and oligopolistic status in the fields of weapon system development in consideration of economic, strategic and technological factors. Furthermore, the government controls the entry to the defence industry by prohibiting enterprises other than the enterprises designated by the state in advance to develop, produce and distribute defense-related products. As a result, the enterprises participating in the defence procurement market can capture a market of certain size. Along with this, when the defense section selects a company as a provider of weapon systems, it will purchase the entire quantity from the relevant company, so that the enterprise selected as a provider may expect considerable amount of economic profit. Accordingly, the technological competition will take place vigorously in the monopoly and oligopoly system occupied by a few enterprises. Under such an institution, the concentration of demand and mass purchase created by the national defense section as a monopoly buyer plays a major role in developing the technology of industry (Dalpé, 1994).

And also, there are many research institutes established by the military authority in order to develop weapon systems, and the Armies, Navies and Air forces have studied the 'demand' itself regarding the weapon systems equipped with cutting-edge technology in order to maintain the dominant position in terms of military strength against the explicit or potential enemy. Therefore, the national defense section can play a better role as a user than any other institutions carrying out public procurement. Considering the characteristics of defence procurement, it may be assumed that the defence procurement can be more effective in inducing innovations than any other public procurement.

However, some characteristics mentioned above may be regarded as the reason by which the defence procurement works inefficiently. For example, the defense section puts technological performance ahead of everything, however, the over-specialized technology cannot be used commercially in the private market. These factors reduce the effect of inducement of private R&D activities (Lichtenberg, 1989). And also, in the monopolistic and oligopolistic status of the defence industry, a small number of producers allow them to avoid mutual competition, so that they may reduce development activities and costs. And they may be reluctant to invest resources for R&D due to the lack of attraction to improve the productivity.

5.2.2 Economic characteristics of defence industry

Understanding the unique characteristics of defence industry is essential to design a government policy and evaluate the effect of the policy. In this clause, we will examine the characteristics of the defence industry, especially the economic characteristics. The defence industry, which is directly connected to the national security, is a strategic industry, so that the characteristics may include the monopolistic and oligopolistic status of both the consumer and provider, uncertainty, and the importance of technological capacity and R&D activities

5.2.2.1 Bilateral monopoly and oligopoly market

The defence industry is operated in an imperfectly competitive market, where both the supply and demand side have the bilaterally monopolistic and oligopolistic market structure (Hartley, 2007). Firstly, on the supply side, a small number of enterprises centered around conglomerates form the monopolistic and oligopolistic market structure. In order to foster the defence industry strategically and improve the defense capacity, the Korean government has designated specific enterprises which may produce military supplies. Though an enterprise has technologies that can be applied to the weapon system development usefully, the enterprise cannot enter the market without an approval from the government. Accordingly, the provider's monopolistic and oligopolistic status is very clear in Korea.

On the other hand, on the demand side, the government is the only consumer. There is no commercial demand for weapon system because it is system for construction of defense capacity required for national security. In addition, the government has put strict restrictions on sales of weapon system, as well as production. Accordingly, the government has the only position as a buyer of the products from the defence industry, and it has also a great influence on the structure of defence industry. And unlike the practice in general industries, the development of weapon system commences only after the demand for the weapon system has been specified by the buyer, namely the government. Therefore, the defence industries are aimed at development and production of the products that satisfy the specific government demand. So, the technology needed for production of weapon system is considerably specialized.

It is very difficult to reach a general conclusion on whether such a monopolistic and oligopolistic structure of defence industry invites a market inefficiency. In general, the principle aimed at achievement of the economy of scale in the defence industry is regarded as an efficient policy for defence industry (Hartley, 2006). Rogerson (1995) argued that it was uneconomical that a number of enterprises produced an identical weapon system, and it was desirable to buy products in quantity from specific businesses and reduce financial expense, when considering that relatively few kinds of weapon systems were purchased. Therefore, Rogerson (1995) concluded that it was common that almost all major weapon systems were produced by a supplier. And he argued that the existence of substitutional relationship between weapon systems to some extent may create positive competition in certain circumstances, however, a complete substitution regarding major weapon system could not exist and the effect of competition was limited.

In the case of Korea, inducing competition into the defence industry market may be regarded as uneconomical in the circumstance where the export of weapon systems and the government demand for weapon systems is limited. When considering the fact that the rate of operation in the enterprises that belonged to the manufacturing industry was 77.2% in 2008, while the rate of operation in the defence industry was 60.3% in the same year[13], it is judged that such a logic is rational to some extent.

On the contrary, some countries intentionally maintain the monopolistic and oligopolistic structure in the domestic market defence industry even in the circumstance where the procurement through competition or cooperative production is considered to be economical. Hartely (1995) pointed out that European NATO allies were maintaining their domestic defence industry market as a monopolistic and oligopolistic structure in order to foster the domestic defence industry, even though it was more economical and feasible to produce or purchase weapon systems, going through comparative advantage.

5.2.2.2 Uncertainty

The uncertainty inherent in defence industry is prevalent throughout the full process including technology development, prototype fabrication, end product development and mass production, sales and demand (Rogerson, 1995). Peck and Scherer (1962), and Scherer (1964) divided the uncertainty in procurement process into the internal uncertainty and external uncertainty. The internal uncertainty is caused by technological unknowns. Most of weapon system development demands a technological capacity that is

[13] Defense Acquisition Program Administration (2010), Defense Acquisition Program, Administration Statistics Annual Report.

superior than the existing technology level. In short, the relevant public agency demands a new technology the agency regards as necessary in order to build strong defense capacity in the future, though it does not exist at present. Accordingly, there may be a considerably high uncertainty, and it takes a long time to design a new weapon system. During the period of designing, the military may change their request regarding a technology development for a new field, which they want to apply to the weapon system. So, such uncertainty exists throughout the production process, including the prototype fabrication and production of end goods.

Hartley (2007) clearly shows the uncertainty which is inherent in the defence industry by presenting the cases in which the development expense increases much higher than the initial plan and the development is retarded in a process of weapon system development.

Table 20. Cases of cost escalation and delays

Project	Initial cost estimate($ billions)	2005 cost estimate($ billions)	Delay (months)
A400M airlifter	4.8	4.6	15
Astute nuclear-powered submarine	4.5	6.1	43
Nimrod MR4 destroyer	4.9	6.7	89
Type 45 destroyer	9.6	10.3	18
Eurofighter Typhoon	29.2	33.3	54
US sample of 26 weapons projects: R&D costs	120.4	164.9	26
US Joint Strike Fighter	189.8	206.3	18
US Expeditionary Fighter Vehicle	8.1	11.1	Na

Source: Reedited by Hartley (2007) on the basis of NAO (2005), GAO (2006)

According to Table 20, the expense for the Nimrod program in the UK increased by 36.7%, from initial budget of 4.9 billion dollars to 6.7 billion dollars, and the completion of development was delayed for 89 months. And in the case of Expeditionary Fighting

Vehicle in the USA, the expense increased by 37.0%. The R&D expense of the 26 weapon system development project in the USA increased by 40.0%, from 120.4 billion dollars to 164.9 billion dollars, and the completion was delayed 26 months in average.

The external uncertainty refers to the uncertainty of demand for weapon system. The government may change the policy from the procurement of weapon systems through development of domestic enterprises to the procurement through import due to political or economic reasons. And due to budget restrictions or increase in development expense, the number of products, which was in the initial plan, may be reduced, or the plans for development or procurement can cancelled altogether or put off. Such cases can be found out easily in the process of weapon system procurement. And in case of technical faults in the weapon system at the initial stage of the long-term procurement process, the additional mass production and procurement plan are postponed, and the initial products are subject to technical supplement. In this way, most cases of weapon system procurement have high uncertainty in comparison with other products equipped with cutting-edge technology.

An example of decrease in demand for weapon system due to the increase in development expense, namely the rise in unit price for purchase, is the case of F-22A Raptor. The US Department of Defense initially planned to produce 750 F-22A Raptors at the average price of 69 million dollars, however, the price rose by 122%, as the procurement price reached 153 million dollars, which was estimated figure in 2004. Accordingly, the mass production plan was changed as the quantity was reduced from 750 to 183 (GAO, 2004, 2006; Hartley, 2006).

As mentioned above, the weapon system development programs have relatively high possibility to fail, and the internal uncertainty such as development cost overrun and delay in delivery is high. And at the same time, the external uncertainty such as changes in demand itself exists at all times.

5.2.2.3 Importance of technological capacity and R&D

In general, the armed forces have to consider the performance of weapon system as the first priority when making a decision on weapon system procurement. In most cases, the weapon system development is carried out after the technological demand, which is judged by the armed forces, is determined in the concrete, which is so-called 'First confirm, then develop'. Especially, the technological demand is described in the Required Operational Capability (ROC) in details. The criterion of success or failure is based on whether the technology development satisfies the ROC or not, so the top priority of defence industry is to develop the technology that meets the ROC. Accordingly, in the process of weapon system acquisition, the performance and reliability of technical aspect, rather than the economic aspect including the expense, is regarded as the top priority (Kim et al., 2012). Such characteristics present a contrast to the general industries which consider the 'price vs. performance' and 'cost vs. quality'.

According to Kirkpatrick (1995), the actual cost per unit of combat plane had risen by 10% every year in the USA and UK. Pugh (1993, 2007) argued that the weapon system expense other than combat planes had risen by 10% every year, and there had been no change in the trend of rise in unit cost even after the cessation of the cold war. The reason why the unit production costs for weapon system rose was not because of the inefficiency procurement process, but because of technological arms race (Hartley, 2007).

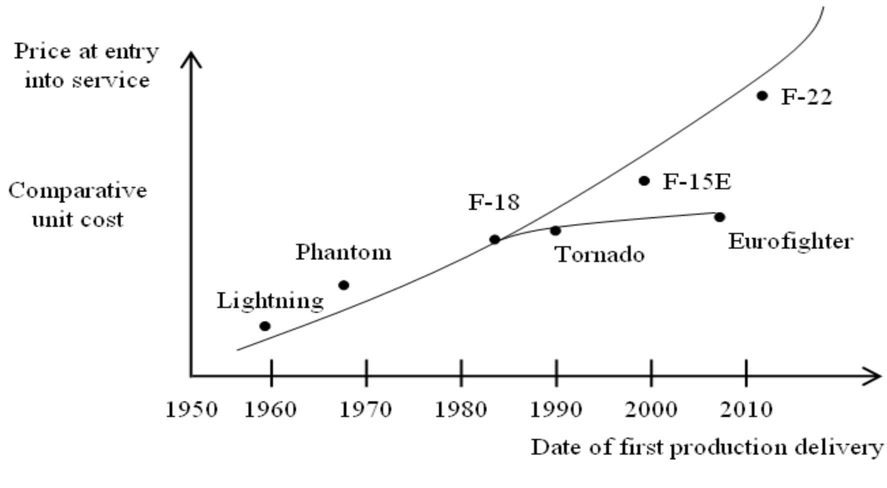


Figure 11. Trend of unit production cost for combat planes
Source: Hartley (2007)

In this way, the importance of R&D in the defence industry increases continuously because each country seeks for the excellent next generation weapon system, which is better than the current weapon system. Rogerson (1995) concluded that the innovative technology in the defence industry is as important as tangible products, emphasizing the importance of R&D.

5.2.3 Empirical studies

The empirical studies on the effects of defence procurement on innovation activities are as follows. Sherwin and Isenson (1966), and Greenberg (1966) emphasized the influence of defence procurement on innovation activities on the basis of the evaluation of 'HINDSIGHT' project. They argued that the Department of Defense had shown the importance of 'need' in the 710 major defense innovation projects, such as aircrafts, satellite, and the missile system. And Sherwin and Isenson (1967) argued that 95% of technology development was boosted by the demand of defense, which had been recognized, and only 0.3% technologies were boosted by the development of science and technology, which were not intended for.

Utterback and Murray (1977), who carried out a study on electronic industry, argued that the defence procurement created the innovative environment and encouraged the enterprises to accept high-level technological standards. And they also argued that the Department of Defense, which was the initial user of innovative products, played an important role in innovation activities by placing initial orders with relatively new enterprises.

Lichtenberg (1988) argued that the contract of defence procurement increased the R&D investment in enterprises. According to Lichtenberg (1988), when the government procurement increased by 1 dollar, the private R&D investment increased by 9.3 cents. On the other hand, when the sales that were not related to the government increased by 1 dollar, the private R&D investment increased by 1.7 cents, so that he suggested that the effect of defence procurement appeared to be bigger than that of other procurement. On the basis of these studies, he estimated that the half of the private R&D investment (about

52.8%) was caused by the increase in government procurement during the period between 1979 and 1984.

Saal (2001) estimated the effect of defence procurement on the total factor productivity of the manufacturing industry in the USA. He proved that the defence procurement indirectly promoted the R&D investment by presenting the fact that the defence procurement had a positive effect on the total factor productivity. According to Saal (2001), when the defence procurement increased by 1% in the industry which was directly related to the defence procurement, the total factor productivity increased by an annual average of 0.9%, and when the defence procurement increased by 1% in the remaining 169 industries, the total factor productivity increased by an annual average of 0.03%.

Draca (2013) carried out a regression analysis at the enterprise level on the basis of major procurement contracts of the US Department of Defense, which were concluded during the period between 1966 and 2003. After estimating that the elasticity of private R&D with respect to defence procurement was 0.065, Draca concluded that the defence procurement had a significant effect on innovation activities of enterprises. And he applied the 'commercial demand' variable, along with the defence procurement to an analysis, so that he estimated that elasticity of private R&D with respect to defence procurement was 0.045, and its elasticity with respect to commercial demand was 0.038. On the basis of result, he suggested that the defence procurement had a more effect on innovation activities than the commercial demand.

5.3 Dataset and model construction

5.3.1 Construction of social accounting matrix

As mentioned above, this study aims to analyze the effect of two types of defence procurement such as the total defense budget and the procurement limited to weapon system on innovation activities. To achieve this, the SAM in which the total defense expenditure is reflected and the SAM in which the defense expenditure limited procurement of weapon system is reflected have been prepared.

Firstly, the SAM in which the total defense expenditure is reflected has been constructed as follows. The government, which is one of the main institutions of economy, is divided into the administration government and the Ministry of Defense, so that the Ministry of Defense is defined as a main agent of economy.

And then the specific values regarding the income and expenditure of the 'Ministry of Defense' account are allocated. Firstly, the administration government allocates the budge to the Ministry of Defense, and then deducts the same amount from the goods consumption of the existing 'public administration and defense' industry. In this regard, as for the size of budgets allocated to the Ministry of Defense, the budge allocated to the goods consumption after excluding the personnel expenses, transfer payment, repayment, and disbursements from the total defense expenditure in 2009 (MB in Figure 11).

On the other hand, the Ministry of Defense consumes the goods by using the allocated budget in order to maintain the defense function (K8 in Figure 12). In this regard, the consumption structure of the Ministry of Defense in each industry is reflected as the results in which the details of defense expenditure are classified into each industry on the basis of the full statement of budget expenditure prepared by the Ministry of Defense and the Defense Acquisition Program Administration (DAPA). Finally, the output of relevant industry shall be reduced because the goods of 'public administration and defense' led by the government has been deducted. If this is interpreted in a different way, the details of expenditure in the 'Ministry of Defense' account has been deducted from the exiting expenditure column of 'public administration and defense' industry because the expenditure column of the 'Ministry of Defense' account represents the part of exiting expenditure column of 'public administration and defense' industry.

		Production		Value-added			Institutions			Investment			Tax	Rest of the world		Total
		Domestic goods	Imported goods	Labor	Capital	Knowledge	Households	Government	MOD	Physical capital	Knowledge capital: Private	Knowledge capital: Public		Export	Import	
Production	Domestic goods															K1
	Imported goods															K2
Value-added	Labor															K3
	Capital															K4
	Knowledge															K5
Institutions	Households															K6
	Government															K7
	MOD							MB								K8
Investment	Physical capital															K9
	Knowledge capital: Private															K10
	Knowledge capital: Public															K11
Tax																K12
Rest of the world	Export															K13
	Import															K14
Total		K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	

Figure 12. SAM with the account of Ministry of Defense

Secondly, the SAM is prepared, which is aimed at analyzing the effect of the expenditure related to weapon system acquisition on R&D investment of the defence industry. For this reason, it is required to establish a new account by separating the defence industry from the existing SAM. In order to carry out such a work, we need to consider how properly define the defence industry. The problem regarding how to define the defence industry leads to the problem on how to determine the range where the goods produced by enterprises are regarded as related to the defence industry.

As pointed out by Hartley (2007), when defining the defence industry, we need to include the activities such as repair and maintenance, service support, and R&D, as well as the production of military supplies.

According to 2011 statistics annual report of the Defense Acquisition Program Administration, there were 91 registered defense-related enterprises in Korea. The 91 enterprises were producing the military supplies. However, according to Ann et al. (2011), there were 1,100 domestic enterprises engaged in defence industry if the primary and secondary subcontractors other than the 91 enterprises designated as the defence industry by the state were included. In order to carry out accurate analysis, the subcontractors shall be included along with the enterprises designated as the defence industry. However, there is another difficulty to define the defense-related enterprise in this manner. Above all, in

Korea, there is no accurate data regarding the subcontractors which are connected to the designated enterprises. Secondly, it is difficult to judge how deeply the sales, assets and human resources of subcontractors are connected to the defence industry, even though there exists the data regarding the subcontractors. The subcontractors themselves may not be able to make such a judgment, as well as the examiner, and they may not know whether the relevant subcontractor is related to the defence industry or not. And in the case of enterprises engaged in dual-use production for both civilians and the military, it is not clear how to deal with (Hartley & Hooper, 1995). In addition, the problem will be more complicated when considering the direct and indirect services, such as maintenance and repair, disposal, service support, which are provided by the private factor in order to maintain the defense function. In consideration of practical problems like this, in this study, the defence industry is defined as the defense-related enterprises designated by the state.

And now, we will apply the series of transactional information regarding the production of goods and supplying the goods to the market to the SAM. To achieve this, it is required to identify the transactional information of defence industry, which has been reflected already in the existing industrial classification system of the I-O table, and then reflect it in the separate defence industry account. By the way, the details of product and sales scale, along with the total amount of sales in the defence industry are included in the 'Financial Statement Analysis of Defence Industry' published by the Korea Defence Industry Association (KDIA). On the basis of the data, it is possible to determine to which industry each enterprise belongs in the existing industrial classification system of the I-O table, and identify the proportion of the sales of defense-related enterprise in the total sales in the defence industry. According to the analysis, the defence industries are scattered across 8 industries such as the ‘chemicals, drugs and medicines’, ‘basic metal products’, ‘fabricated metal products except machinery and furniture’, ‘general machinery and equipment’, ‘electronic and electrical equipment’, ‘precision instruments’, ‘transportation equipment’ and ‘furniture and other manufactured products’ industry.

On the other hand, the Financial Statement Analysis of Defence Industry has divided the sales of each designated defence industry, input of intermediate goods, new physical and R&D investment scale, human resources, asset scale, corporate tax payment record into defense and non-defense sector in order to provide the data. On the basis of the data, it is possible to identify the proportion of intermediate goods, and the proportion of value-added such as wage and operating surplus in comparison with the total sales. According to the analysis, the intermediate goods accounted for 71.4 % of the total sales, which reached 8.7692 trillion won in 2009, and the value-added accounted for 28.6%.

Accordingly, on the basis of total sales, it is possible to allocate a specific value to the newly added 'defence industry' account by applying the proportion of defence industry in each industry, and the proportion of intermediate goods, value-added, and tax in the sales. For example, the account of defence industry, which is engaged in the ‘chemicals, drugs and medicines’ industry (S8), can be derived as follows.

	Production								
	Domestic goods								
	S8	S10	S11	S12	S13	S14	S15	S16	S29
Production	A1	B1	C1	D1	E1	F1	G1	H1	0
Value-added	A2	B2	D2	D2	E2	F2	G2	H2	0
Tax	A3	B3	D3	D3	E3	F3	G3	H3	0
Total	A	B	D	D	E	F	G	H	0

(Before adjustment)

	Production				
	Domestic goods				
	S8	S10	...	S16	S29
Production	A1-MILOUT*INT*Di	B1	...	H1	MILOUT*INT*Di
Value-added	A2-MILOUT*DV*Di	B2	...	H2	MILOUT*DV*Di
Tax	A3-MILOUT*DT*Di	B3	...	H3	MILOUT*DT*Di
Total	A	B	...	H	0

(After adjustment)

Figure 13. Procedure for reflecting the account of defence industry

MILOUT = Sales in the defence industry (base year)

Di = Proportion of sales made by industry 'i' related to the defense supplies in the total sales made by whole defence industry

where, i $\in$ {8, 10, 11, 12, 13, 14, 15, 16}

INT = Proportion of intermediate goods in the total sales made by whole defence industry

DV = Proportion of value-added (before tax) in the total sales made by whole defence industry (vector)

DT = Proportion of tax in the total sales made by whole defence industry (vector)

In short, after applying the proportion of sales made by chemical product industry among the total sales made by the whole defence industry to the input of intermediate goods, value-added and tax, the value of each item is deducted from the account of chemical product industry, and then it is reflected in the account of defence industry. If this method is applied to every industry that belongs to the defence industry, a new account of defence industry can be reflected (K2 in Figure 14).

	Production – Domestic goods – Ordinary Industry	Production – Domestic goods – Defence Inudustry	Production – Imported goods – Ordinary Industry	Production – Imported goods – Defence Inudustry	Value-added – Labor	Value-added – Capital	Value-added – Knowledge	Institutions – Households	Institutions – Government	Investment – Physical capital	Investment – Knowledge capital – Private	Investment – Knowledge capital – Public	Tax	Rest of the world – Export	Rest of the world – Import	Total
Production – Domestic goods – Ordinary Industry																K1
Production – Domestic goods – Defence Inudustry									DP					DEX		K2
Production – Imported goods – Ordinary Industry																K3
Production – Imported goods – Defence Inudustry									FP							K4
Value-added – Labor																K5
Value-added – Capital																K6
Value-added – Knowledge																K7
Institutions – Households																K8
Institutions – Government																K9
Investment – Physical capital																K10
Investment – Knowledge capital – Private																K11
Investment – Knowledge capital – Public																K12
Tax																K13
Rest of the world – Export																K14
Rest of the world – Import																K15
Total	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	

Figure 14. SAM with the account of defence industry

All the goods produced by the defence industry are supplied to the final demand such as government demand and export, so it cannot be used as an intermediate demand. Especially, the proportion of the government demand is critical as it occupied 96% of the total sale made by the defence industry in 2010. And the rest of 4% was exported (Ann et al., 2011). Accordingly, the fact that 96% of defence industry products was purchased by the government (DP in Figure 14)_and the rest of 4% was exported (DEX in Fig. 14) in 2009 has been reflected in the SAM created in this study. Meanwhile, the government purchased 1.9862 trillion won worth of weapon systems from abroad in 2009[14], and it has been reflected in the SAM (FP in Figure 14).

There exist the data needed for the computing process of model other than the data that shall be reflected in the SAM directly. For example, the stock level of physical capital and knowledge capital is required for the production function of the defence industry. In this regard, the scale of physical capital is announced in the Financial Statement Analysis of Defence Industry, however, the knowledge capital accumulated through R&D is not specified in the relevant data. Therefore, in order to obtain the knowledge capital stock in the base year, Equation (83) used by Shin (2002) is applied to estimate the stock.

$$BS_0 = BI_0 \left[\frac{1+g}{g+\delta} \right] \qquad \text{Eq. (83)}$$

where, BS_0: knowledge stock in the base year

BI_0: R&D investment in the base year

5.3.2 Model structure

In order to analyze the defense section, the model presented in Chapter 4 was used as a basis, however, it was partly modified to build a model in order to analyze the investment-inducing effect of defence procurement.

Above all, the Ministry of Defense or defence industry, which was newly added to the existing social accounting matrix, has been reflected as an activity variable. The Ministry of Defense consumes goods according to the expenditure structure that has been established in order to carry out defense function after receiving the budget from the administration government. In a word, the Ministry of Defense functions as a main agent of economy within the model like the administration government. On the other hand, the defence industry carries out production and investment activities, and the accumulated

[14] Source: Defense Acquisition Program Administration (2010), Statistics annual Report.

knowledge capital stock through the activities may affect the economic growth through various channels, so that we need to consider it carefully.

The defence industry creates other industry's demand by using the goods from other industry as intermediate goods in the production process. However, basically the defence industry in Korea is small in terms of scale, so that it is expected that the effect of demand creation will be relatively limited. Above all, what we expect through the growth of defence industry is focused on the effect of knowledge capital stock on economic growth, namely the economic effect of 'spin-off'. The 'spin-off' means the technology diffusion in a special type which is related to the technology transfer from the defense section to private section (Weston & Gummett, 1987).

In order to evaluate the economic effect caused by changes in defense technology, it is required to understand the mechanism and process with which the defense R&D stocks affect the economy (Weston & Gummett, 1987; Hartley, 2006). However, the studies carried out so far do not help us to completely understand what defense R&D project creates the spin-off. Though the spin-off occurs, we do not have enough understanding of the sweep and degree of the spillover effect.

One of the major causes of the difficulty in empirical study is that there exists the lag effect in the process in which the R&D expenditure affects the technological changes and the economic growth. Because the result of study may be affected according to the method to reflect the time lag, the time lag of knowledge stock shall be paid attention to. However, the issue of time lag is one of the sources of debate that can be solved in a relevant study, and there is no common sense of the estimated value of lag period (Chakrabarti & Anyanwu, 1993). Therefore, Hartley (2006) argued that the lag period should be estimated by an empirical method rather than a theoretical approach.

Despite the difficulty, the spin-off effect of defense R&D investment or knowledge stock on the economy of a country was analyzed by some econometricians. There are typical domestic literatures written by Park et al. (2003), Lee et al. (2006), Lee et al. (2007), Jo et al. (2010). And foreign literature was written by Poole and Bernard (1992).

Table 21. Spin-off effects of defense knowledge stock

Division	Major contents
Park et al. (2003)	· Elasticity of GDP with respect to defense R&D stock: 0.043 · Elasticity of TFP with respect to defense R&D stock: 0.02 - Defense R&D time lag: 2 years, obsolescence rate: 10%
Lee et al. (2006)	· Elasticity of TFP with respect to defense R&D investment (flow) - Time lag; 0, 8, 9, 10 years => 0.07% · Elasticity of TFP with respect to defense R&D investment (stock) - Time lag 8 years => 0.09%
Lee et al. (2007)	· Measurement of value-added creation effect through defense R&D - Transfer technology to the enterprise producing prototypes and carrying on transactions with ADD
Jo et al. (2010)	· Elasticity of GDP with respect to ADD R&D stock: 0.392 · Elasticity of GDP with respect to defense R&D stock: 0.383 - Obsolescence rate: 0.058
Poole and Bernard (1992)	· Effects of the defense-intensive industries' R&D stock on TFP - Aviation and Electronic industry: negative - Shipbuilding and Chemical industry: negative

In this study, both the knowledge stock of public section and the defence industry has been regarded as public goods, so that the knowledge stock of defence industry is considered to have an effect on the productivity of overall economy. Accordingly, the total factor productivity of the industry 'i' is represented by a knowledge stock function of defence industry along with other industries public section knowledge stock. In this study, as for the effects of knowledge stock of defence industry, the result of study carried out by Park et al. (2003) has been reflected.

$$EFF_i = f(H_i^s, HG, HD) \qquad \text{Eq. (84)}$$

where, H_i^s : external knowledge stock

HG : public knowledge stock

HD : knowledge stock of defence industry

5.4 Simulation analysis

5.4.1 Simulation scenarios

In order to evaluate the effect of defence procurement, the defense expenditure excluding personnel expenses was increased by an annual average of 3% in Scenario A, and in Scenario B, the defense expenditure was increased by an annual average of 5%, so that the effect of changes in the size of defence procurement on private R&D investment could be analyzed.

On the other hand, in order to analyze the effect of weapon system procurement (spending beneficial expense for defense capacity) on the R&D investment of defence industry, the size of weapon system in the baseline scenario C was increased by an annual average of 7%, while the size of weapon system in the comparison scenario D was increased by an annual average of 9%, so that the effect of changes in the size of weapon system procurement on R&D investment of defence industry could be analyzed.

Table 22. Scenarios for analysis of defence procurement effect

Division		Period	Annual increase rate of defence procurement	Annual increase rate of weapon system procurement
Defence procurement	Baseline scenario A	Whole period	3%	-
	Comparison scenario B	Whole period	5%	-
Weapon system procurement	Baseline scenario C	Whole period	-	7%
	Comparison scenario D	Whole period	-	9%

5.4.2 Simulation results

It was found out that the increase in defence procurement promoted the R&D investment in the industry. Table 23 shows the changes in the level of R&D investment, which happened during the simulation period. When the annual average increase rate of defence procurement rose from 3% to 5%, the total accumulated R&D investment increased by 9.96 trillion won during the simulation period. This is 1% higher than the baseline scenario A.

Table 23. Effect on private sector's total R&D investment (unit: trillion won)

Baseline scenario A		Comparison scenario B		Difference
Amount of defence procurement	Total R&D investment	Amount of defence procurement	Total R&D investment	Total R&D investment
448.8	991.6	565.9	1,001.6	9.97 (1.0%)

* Aggregate during the whole simulation period

The sensitivity in which the R&D investment responds to the changes in defence procurement at the national level has been expressed as a elasticity index. According to the result, the elasticity of total R&D investment with respect to defence procurement was 0.039, and when the defence procurement increased by 1 won, the demand for R&D capital goods increased by 0.0851 unit. The innovation activity-inducing effect of defence procurement, which has been confirmed in this study, may be regarded as rational, when considering the fact the elasticity of investment with respect to sales for the manufacturing industry by Sung (2001) was 0.03, and the result of Lichtenberg (1988), who suggested that when the government procurement increased by 1 dollar, the private R&D investment increased by 9.3 cents.

Meanwhile, looking into the changes in R&D investment in each industry, we may see that though the absolute level of R&D investment throughout the country has increased both in the baseline scenario A and the comparison scenario B, there are some industries where the R&D investment has decreased relatively in the comparison scenarios in comparison with the baseline scenario. The reason why the R&D investment has relatively decreased in some industries is that there are some industries of which the scale has been reduced due to the changes in industrial structure during the process of increasing defense expenditure. This is because even though the investment and output have been expanded in terms of absolute size both in Scenario A and B, the investment and output of some industries in the comparison scenario B (5% of annual increase in defense expenditure) have declined more than those of baseline scenario A (3% of annual increase in defense expenditure), which seems to be caused by the distribution ratio of defense expenditure among industries and the forward and backward linkage effects that occur in the dynamic process.

Table 24. Increase and decrease in R&D investment

(unit: ten billion won)

Sum of increased investment (A)	Sum of decreased investment (B)	Change in total investment (C = A + B)
1,030.5	34.0	996.5 (1.0%)

* Aggregate during the whole simulation period

On the contrary, the R&D investment has increased in the knowledge-intensive industry centered around a manufacturing industry. The industries in which the R&D investment has increased due to the defence procurement include the ‘wood and paper products’, ‘petroleum and coal products’, ‘chemicals, drugs and medicines’, ‘non-metallic mineral products’, ‘basic metal products’, ‘fabricated metal products except machinery and furniture’, ‘general machinery and equipment’, ’electronic and electrical equipment’, ’precision instruments’, ’transportation equipment’, ’public administration and defense’ industry. Most expansion of investment caused by defence procurement took place in the electronic and electrical equipment (72.3%), transportation equipment (8.8%), general machinery and equipment (7.0%), chemicals, drugs and medicines (4.90%) industry. The reason why the increase in R&D investment has been concentrated on a part of industries is that the relevant industries form a greater part in the defence procurement. And the second reason is that such industries are knowledge-intensive industries where the proportion of knowledge capital as a production factor is high. Though the demand increases on a similar scale, the knowledge-intensive industries respond to the change more sensitively than others.

Table 25. Proportion of R&D increase by industry (unit: ten billion won)

Industry	Total investment in the scenario A	Total investment in the scenario B	Changes in total investment (C=B-A)	Percentage (%) (C/D)*100
Wood and paper products	94.9	95.2	0.3	0.03
Petroleum and coal products	144.2	144.6	0.5	0.05
Chemicals, drugs and medicines	7,428.4	7,479.3	50.9	4.94
Non-metallic mineral products	506.0	509.8	3.7	0.36
Basic metal products	2,011.6	2,037.4	25.8	2.50
Fabricated metal products except machinery and furniture	671.3	675.9	4.6	0.45
General machinery and equipment	4,408.7	4,480.5	71.8	6.97
Electronic and electrical equipment	54,065.5	54,810.2	744.7	72.27
Precision instruments	2,970.8	3,007.9	37.1	3.60
Transportation equipment	6,300.9	6,391.8	90.9	8.82
Public administration and defense	379.2	379.4	0.2	0.02
Total	-	-	1,030.5 (D)	100

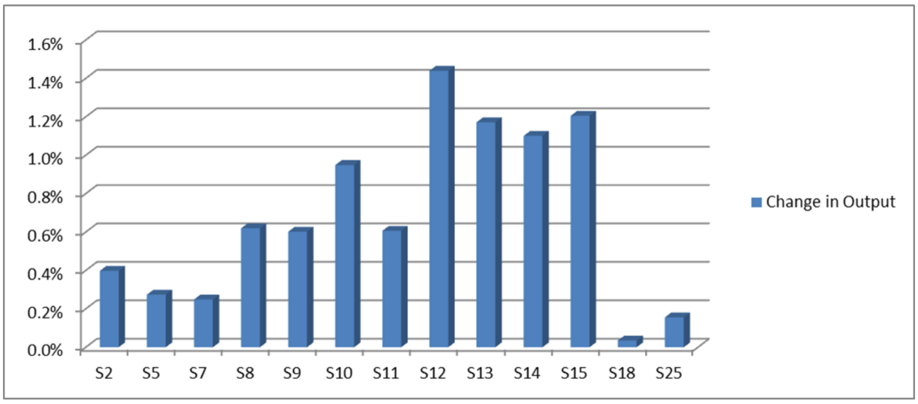
Due to the increase in scale of defence procurement, the GDP and gross output increased, so that the GDP and gross output in the comparison scenario B have increased by 0.05% and 0.27% respectively, in comparison with the baseline scenario.

Table 26. Effect on GDP and gross output (unit: trillion won)

Baseline scenario A		Comparison scenario B		Difference	
GDP	Gross output	GDP	Gross output	GDP	Gross output
30,268.0	93,571.2	30,283.2	94,005.1	15.2 (0.05%)	254 (0.27%)

* Aggregate during the whole simulation period

However, in terms of output at the industrial level, we may identify the strong growth in the knowledge-intensive industry centered around the manufacturing industry. The cause of occurrence of this phenomenon is similar to the cause of occurrence of difference in the R&D investment level among industries. Figure 15 shows the changes in output of each industry, in which the output in the comparison scenario B has increased higher than that of the baseline scenario A. In Figure 15, we may confirm that the general machinery, electric and electronic equipment, precision device, and transportation equipment industry have a strong growth in comparison with the gross output of the economy which has increased by 0.27%.



* S2: Mining and quarrying, S5: Wood and paper products, S7: Petroleum and coal products, S8: Chemicals, drugs and medicines, S9: Non-metallic mineral products, S10: Basic metal products, S11: Fabricated metal products except machinery and furniture, S12: General machinery and equipment, S13: Electronic and electrical equipment, S14: Precision instruments, S15: Transportation equipment, S18: Construction, S25: Public administration and defense

Figure 15. Change in output according to the increased defence procurement

On the other hand, the procurement limited to weapon system has also increased the R&D investment in the defence industry. The annual average increase rate of weapon system procurement has increased from 7% (in the baseline scenario C) to 9% (in the comparison scenario D), the R&D investment in the defence industry has increased 30.5% from the baseline scenario C.

Table 27. Effect on total R&D investment level of defence industry

(unit: ten billion won)

Baseline scenario C		Comparison scenario D		Difference
Amount of defence procurement	Total R&D investment of defence industry	Amount of defence procurement	Total R&D investment of defence industry	Total R&D investment of defence industry
65,304.0	1,695.0	50,900.3	2,212.2	517.2 (30.5%)

* Aggregate during the whole simulation period

* ( ): Percentage change from the baseline scenario C

This implies that when the weapon system procurement increases by 1 won, the demand for R&D capital goods increases by 0.153 unit. The reason why the effect of weapon system procurement is bigger than the defence procurement effect is that the government occupies most of the sales in defence industry, so that the increase in the weapon system procurement is directly connected to the sales and R&D investment of defence industry.

On the other hand, the elasticity of defence industry's R&D investment with respect to weapon system procurement was 1.078, so that we can understand that the R&D investment of defence industry responds to the changes in the scale of weapon system procurement sensitively. That is because the defence industry has a high level dependence on the defence procurement. And also, due to the relatively small R&D investment scale of the existing defence industry, the rate of change of the R&D investment scale of defence industry has been changed a lot in comparison with the rate of change in the weapon system procurement. Therefore, the elasticity of R&D investment with respect to weapon system procurement is relatively bigger than its elasticity with respect to defence procurement. The sensitive response of R&D investment level of defence industry to the changes in defence procurement scale is well illustrated in Figure 16. The rate of change in variables presented in Figure 16 represents the increase amount in comparison with the baseline scenario C, which is expressed by percentage. We may identify that the R&D investment of defence industry is sensitively responding to the changes in weapon system procurement scale through Figure 16.

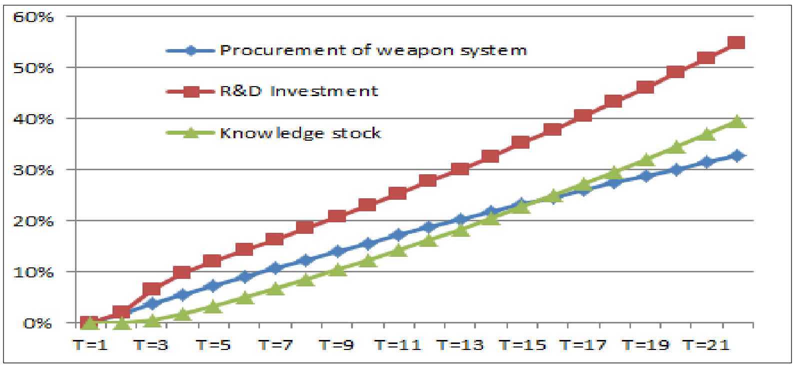


Figure 16. Dynamic effect of weapon system procurement

Figure 17 illustrates the dynamic trend of GDP according to the changes in the weapon system procurement. We may see that as the weapon system procurement increases, the GDP increases as well. The GDP increases by 0.21% from the baseline scenario C in 2030. There may be two reasons why weapon system procurement and the GDP increases simultaneously. Firstly, the increase in weapon system procurement can expand the production of defence industry. Meanwhile, the increase in production of defence industry may cause the demand for goods in the other industry. In short, a backward linkage effect takes place. Secondly, the R&D investment of defence industry increases, which leads to a continuous increase in knowledge capital as well. The increased knowledge capital of defence industry cause a spin-off effect on the private sector, so that it can play a role in improving the productivity of each industry. When considering the fact that the scale of defence industry in the base year was 0.32% of the total economy, we may assume that the reason of increase in GDP is caused by the spin-off effect that is mainly created by the knowledge stock of defence industry rather than the backward linkage effect of defence industry.

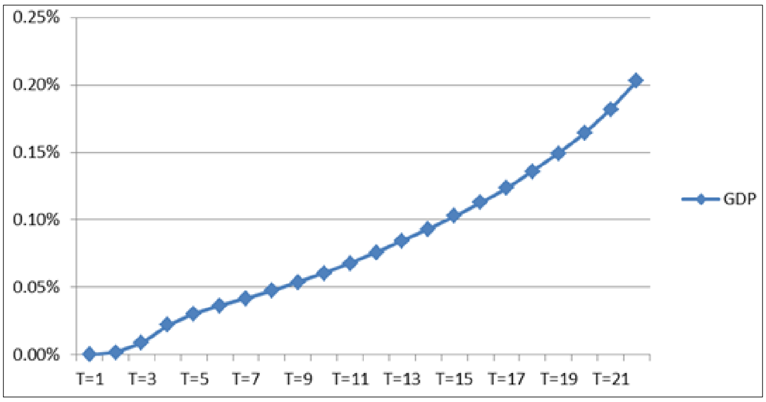


Figure 17. Dynamic change in GDP

* Percentage change from the baseline scenario

5.5 Sub-conclusion

5.5.1 Summary and policy implications

The defence procurement, which is defined as a special type of public procurement, has appeared to be effective to induce innovations. The effects of defence procurement appeared to be similar to the existing studies regarding commercial demand. On the other hand, the effect of weapon system procurement on the investment of the defence industry was much bigger than that of defence procurement.

The difference is caused by the following reasons. Firstly, the defence procurement includes the purchase of general goods along with the weapon systems that demands technological innovations. And the proportion of defence procurement in the total economy is relatively low. On the contrary, the weapon system procurement demands the goods in which the cutting-edge technologies are embedded and it forms an ever-greater part of the defence industry market. Accordingly, the weapon system procurement has a considerable effect on the structural changes in the defence industry.

These results provide the following policy implications. When considering the influence of defence procurement on innovation activities in the private sector, it is judged that it will be effective to help new technology-based firms to put the wheels in motion by implementing procurement policies aimed at such firms. Secondly, the weapon system procurement has a relatively small effect on overall economy, though it has a great influence on the activities and growth of the defence industry. This is due to the small scale of current defence industry, and the lack of demand for the goods produced by the defence industry, which is because such goods cannot be used as an intermediate goods in the other industry. Accordingly, it is required to make efforts to develop dual-use technologies under the collaboration between the private and defense section at the initial stage defense technology development as much as possible.

5.5.2 Significance of study and future research

By reflecting the defence procurement and details of expenditure in this study, the effect of the defence procurement on the private innovation activities has been analyzed. If the defence procurement is applied to the industrial policy-making process on the basis of the results of this study, the useful guideline for an industrial policy design can be obtained, which helps predict the effect at the national and industrial level.

However, as mentioned above, in order to analyze the effects of defence procurement, it is required to consider the indirect demand creation effect, along with the direct demand creation effect. When considering the fact that the defence procurement accounts for a small part of the total market, the interest in indirect effects seems to be reasonable.

And also, this study is limited to the analysis of investment-inducing effect according to the demand creation, so that it is required to evaluate the effect by promoting competition in procurement process, or using other policy means simultaneously. The primary purpose of defence procurement is not focused on inducing innovations of relevant industry (enterprise), but maintenance of defense function, it is expected that when the defence procurement goes side by side with other means, the effect will be much bigger.

Such analytic studies can be carried out in accordance with the development of the contract system for defence procurement. Current procurement contracts designed for the defence industry are concluded mainly in the form of cost-reimbursement contract. When the contractor is guaranteed to make up for costs by the government, there is no incentive for the enterprise to lower the cost. So, it is difficult to expect the response to the inducement like the tax incentive and subsidy. On the other hand, in the case of fixed price contract, the defence industry seeking to maximize the profit will develop and produce the relevant product by inputting the lowest cost under the terms and condition regarding the quantity and price, which have been decided according to the negotiation with the government. In this case, the defence industry will make a decision on investment activities in response to the incentive policy of the government. Accordingly, the quantitative analysis on the relevant effect in the process, in which various systems are developed in order to promote innovation activities of defence industry, is expected to present useful index for decision making when setting up the policies needed for defence industry.

Chapter 6. Conclusion

6.1 Summary and policy implications

In this study, the effects of the subsidy and tax incentive, which are the typical policy means from the viewpoint of 'supply-push', and the procurement, which is the typical policy means of the 'demand-pull' policy, have been analyzed. Prior to such analyses, in Chapter 2, the goals of policy means have been examined by applying the various investment-inducing policies, which have been implemented by the government, to the analysis framework suggested by king et al.(1994). And then the mechanism and institutional characteristics in which each investment-inducing policy have impacts on innovation activities.

In Chapter 3, the recommendations of the System of National Accounts, which encouraged enterprises to capitalize R&D investments, were examined, and then the knowledge capital that was newly formed on the basis of the capitalization was reflected in the SAM.

In Chapter 4, the effects of subsidy and tax incentive has been analyzed by constructing the CGE model, in which the knowledge capital specialized in the industry, along with the physical capital, is used as a factor of production. Before analyzing the CGE model, the inter-industry technology flows in which the knowledge capital creates spillover effects and affects the productivity of other industries have been examined. And also, an investment model has been reviewed, in which the policy variables that have an impact on producer's investment-related decision-making are considered. According to the analysis, both the subsidy and the tax incentive had a positive effect on the total R&D investment of the private sector. Among them, the tax incentive appeared to have bigger investment-inducing effect than the subsidy, which resulted in the difference in the level of knowledge assets. And in the long run, the result had a considerable influence on the GDP.

In Chapter 5, the effect of defence procurement on innovation activities has been analyzed from the viewpoint of 'demand-pull' policy. In this study, the defence procurement has been divided into two categories, which are defined as the overall defense expenditure and the procurement limited to weapon system respectively. In order to review the channel through which the defence procurement is related to the R&D investment, the static and dynamic effects of public procurement on innovation activities were examined. And the characteristics of defence procurement that can be separated from the general procurement have been discussed. In order to carry out the analysis, the 'government' defined as a main institution of economy in the existing SAM has been divided into 'administration government' and the 'Ministry of Defense'. And the total defense expenditure was defined as defence procurement, so that a SAM in which the details of relevant account are reflected has been constructed. On the other hand, in order to examine the effects of weapon system procurement, the defence industry was separated from the existing industrial classification system of the I-O table, so that a SAM in which the defence industry is reflected as a separate industrial account has been constructed.

According to the analysis, it has been identified that the two types of defence procurement have a positive impact on the innovation activities in the industry. In the defence procurement, all the goods from overall industries are purchased, while the weapon system procurement is engaged in purchase of goods provided only by the defence industry. Due to the bilateral monopolistic and oligopolistic structure of the defence industry, which sells all the products to the Ministry of Defense, except for the quantity to export, the R&D investment of defence industry was very sensitively responding to the increase in weapon system procurement.

On the basis of the results in this study, the following implications for policy may be presented. Though both the subsidy and tax incentive support the R&D activities with financial resources from the viewpoint of supply-push policy, it appears that tax incentive is relatively better. Above all, it is because of the market-oriented characteristics of tax incentive. Even though the subsidy itself has various merits, it is required to understand the production activities and investment environment of the beneficiary in order to make it work in a correct manner (Anex, 2000). However, it is very difficult for the government to figure out overall environment of various industries and grant proper subsidy in reality.

Therefore, when planning to support R&D activities all across the industries, it is necessary to consider the application of tax incentive first, which is an indirect means. Accordingly, in order to overcome the weak point of tax incentive, which is slow due to going through the tax law-related procedure, the policy makers have to prepare flexible schemes for application of tax incentive, so that the policy can induce an optimal investment activity in the fast-changing economic situation. In addition, the preference for government subsidy with biased view shall be reviewed.

Secondly, though the tax incentive appeared to be more effective means, the tax credit scale and the effective tax rates showed a considerable difference even when the equal tax credit rate was applied. It means the tax credit benefit is concentrated on specific industries. Theoretically, the tax incentive is designed to provide equal opportunities, however, in reality, it has been confirmed that it is an inequitable system as the benefit is concentrated on knowledge-intensive industry which has paid attention to innovation activities (Surrey, 1970; Heaton, 1981). The current tax incentive system applies differential tax rates according to the size of enterprise, but all the R&D investments qualify for equal tax remission. Accordingly, it is desirable to consider differentiation of the degree of tax benefit by establishing industrial groups that show clear difference in terms of innovation tendency and capacity.

Thirdly, it is required to supplement the fault of tax incentive that may bring about severe gap in the investment level and growth of each industry. This phenomenon is caused by the fact that the tax incentive is an ex-post method for support. If the decision-making of actual investment is fully left to the market, the industry with poor investment environment will slow down the investment activities, so that it will have a bad effect on growth and the industry will be caught in a vicious circle. The tax incentive, which cannot take an action for such industries in advance, will cannot overcome the limitation as an ex-post support. On the other hand, the subsidy system enables the government to support the industry without investment demand (intention), and it is helpful to mitigate the gap in capacity in comparison with tax incentive. Accordingly, it is required to select proper policy means in consideration of industrial environment (Bollinger et al., 1983). The government needs to subsidize centering around the industries which lack innovation capacity. In short the direct and indirect means shall be mixed properly as the direct assists the indirect.

Fourthly, though both the general defence procurement and weapon system procurement had a positive impact on innovation activities, the weapon system had relatively bigger effect. This is mainly because the scale of weapon system procurement accounts for an ever-greater part of the sales made by the defence industry. Accordingly, the government shall make an effort to help specific industry, which the government plans to protect and foster, to maintain the capacity through continuous government procurement. In addition, the government shall design a procurement policy to promote innovative effort in advance, and make close collaboration among public agencies in order to exercise purchasing power in a specific market.

6.2 Significance and limitation of study, future research

In this study, the effects of subsidy, tax incentive and procurement on the industrial R&D investment has been analyzed. The differences between this study and the other literature, in which the qualitative and econometric analysis regarding R&D policies, are as follows.

Firstly, the effects of subsidy and tax incentive have been dealt with a lot through foreign and domestic literature. However, most analyses carried out by them are limited to specific policy means, or the direct or indirect comparison is limited though two types of policy variable are included in an analysis model, because the scales of variable are different from each other. In this study, the effect of each policy has been analyzed on the basis of identical analysis framework and dataset, and the results have been compared and evaluated, so that it was possible to identify relatively effective policy means.

Secondly, the effects of defence procurement suggested by this study are expected to be used as an useful reference as there are not sufficient domestic and foreign literature in which the effects of defence procurement are analyzed in a econometric method. In addition, it will be helpful for the decision makers setting up policies at the industrial level because this study has classified the degrees of benefit after dividing the effects of defence procurement by industries.

Thirdly, only the partial effects of policies were reflected in the existing studies. The policy support changes the investment patterns in the industry, and the changed level of investment affects the output, which is reflected in the investment activities again. The full effect of policy is analyzed by capturing such flows. In this study, a model is used, in which the transactions among industries, the transaction between the industry and other main institutions of economy are reflected. Furthermore, the significance of this study is that the full effect of policy has been measured by reflecting the spillover effect of knowledge stock which has been accumulated as a result of R&D investment.

Fourthly, the existing studies are limited to the measurement of effects which represent the relationship between the R&D policy and the private investment. In this study, the effects of each policy means on economic growth has been analyzed, including analysis of the degree of effects on innovation policies. Accordingly, this study has provided the foundation on which the degree of achievement of ultimate policy purpose, which is aimed at making the innovation policy induce technological changes, and inducing the economic growth through the technological changes.

Fifthly, in this study, the knowledge-based CGE model has been constructed in order to analyze the policy means, and then several knowledge-based SAMs have been constructed, which are needed for implementation of the relevant models. The CGE model may consider the characteristics of knowledge capital as a public goods by reflecting the knowledge capital as both a direct factor of production and a factor that creates the spillover effect. And the significance of this study is that it has provided a analysis framework that can analyze various policy variable in the future by including the investment model that responds to the policy variable into the CGE model.

On the other hand, the knowledge-based SAM presented in this study has derived the knowledge capital accounts by separating the R&D transactions from the I-O table, which provides the basis on which the SAM is constructed, excluding the researcher's assumption as much as possible, unlike the methods used in the existing studies. In addition, in Chapter 5, the SAM has been constructed, to which the Ministry of Defense and defence industry account are added. In each SAM, the details of national defense expenditure, that includes the purchase of weapon system, are classified by industries, and the details of expenditure of defence industry, which has been differentiated from the existing industrial classification system of the I-O table, is reflected separately. The dataset constructed in this study is expected to widely used to evaluate various policy variables, including the R&D policy, in the future.

However, despite the significance of study, there are several limitations, which shall be supplemented in the future.

Firstly, the investment function applied to this model is limited to several variables such as value-added, user cost of capital, and distribution coefficient. Many empirical studies have suggested various factors that have significant effect on the decision making of R&D investment. The investment function in this model shall be expanded to include various policy variables that have critical effects on private investments.

Secondly, this study has analyzed the subsidy, tax incentive and procurement individually. But the government implements policy means with various viewpoints at the same time. So, in order to maximize the effect, the optimal policy mix of direct, indirect, supply-push and demand-pull policies shall be pursued.

Thirdly, in this model, the assumption of small open economy was applied, due to the lack of data. As a result, it was not possible to consider the effect of Korea on the global market. But when considering the fact that our proportion of foreign trade is getting bigger, we need to develop a large country model.

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Appendix: System of equations

Production

$$VA_i = EFF_i\left[L_i^{\beta_i^l} K_i^{\beta_i^k} H_i^{\beta_i^h}\right] \quad where,\ \beta_i^l + \beta_i^k + \beta_i^h = 1 \quad for\ \forall i$$

$$PVA_i \cdot VA_i = PL_i \cdot L_i + PK_i \cdot K_i + PH_i \cdot H_i$$

$$L_i = (\beta_i^l \cdot PVA_i \cdot VA_i)/[(1+t_i^l)\cdot PL]$$

$$K_i = (\beta_i^k \cdot PVA_i \cdot VA_i)/[(1+t_i^k)\cdot PK]$$

$$PH_i = (\beta_i^h \cdot PVA_i \cdot VA_i)/[(1+t_i^h)\cdot H_i]$$

$$X_{j,i} = ax_{j,i} \cdot Z_i \quad for\ \forall\ i, j$$

$$VA_i = ava_i \cdot Z_i \quad for\ \forall\ i$$

$$PZ_i = ava_i \cdot PVA_i + \sum_j ax_{j,i} \cdot PQ_j \quad for\ \forall\ i$$

External knowledge stock and Productivity

$$H_i^s = \sum_{j \neq i} \lambda_{i,j} \cdot H_j \quad for\ \forall\ i$$

$$EFF_{i,t} = ela_i \cdot \left(\frac{H_{i,t}^s - H_{i,0}^s}{H_{i,0}^s}\right) + elahg_i \cdot \left(\frac{HG_t - HG0}{HG0}\right)$$

User cost of capital and Investment

$$UC_{rdt} = PRDZ_{rdt} \cdot (r + \delta_{i,h})\frac{(1 - ITC_i - t_i^h \cdot z)}{1 - t_i^h} \quad for\ \forall\ rdt$$

$$UC_k = PINVK \cdot (r + \delta_k)$$

$$H_{i,t}^+ = (\beta_i^h \cdot PVA_i \cdot VA_i)/UC_{rdc}$$

$$K_{i,t}^+ = (\beta_i^k \cdot PVA_i \cdot VA_i)/UC_k$$

$$IDH_{i,t} = \sum_{s=0}^{\infty} \mu_s \Delta H^{+}{}_{i,t-s} + \delta_{i,h} H_{i,t}, \quad where\ \Delta H^{+}{}_{i,t-s} = H^{+}_{i,t-s} - H^{+}_{i,t-(s+1)}$$

$$IDK_{i,t} = \sum_{s=0}^{\infty} \mu_s \cdot \Delta K^{+}{}_{t-s} + \delta_h \cdot K_t, \quad where\ \Delta K^{+}{}_{t-s} = K^{+}_{t-s} - K^{+}_{t-(s+1)}$$

$$PINVK = \sum_i \varpi_i \cdot PQ_i$$

$$PRDZ_{rdt} = avard_{rdt} \cdot PRVA_{rdt} + \sum_i axrd_{i,rdt} \cdot PQ_i$$

$$INVRES = \sum_i PINVK \cdot IDK_i$$

Savings

$PRDZ_{rdc} \cdot IDH_i = PSAVRD_i$ (The case without subsidies)

$PRDZ_{rdc} \cdot IDH_i = a\left[\vartheta \cdot PSAVRD_i^{\rho} + (1-\vartheta) \cdot RDSUBSIDY_i^{\rho})\right]^{1/\rho}$ (The case with subsidies)

$$SP = \sum_i PSAVRD_i + rprd \cdot GDP + rp \cdot \sum_i (PINVK \cdot INVK_i)$$

$$SG = \sum_i RDSUBSIDY_i + rgrd \cdot GDP + rg \cdot \sum_i (PINVK \cdot INVK_i)$$

$$TSAV = SP + SG + SF$$

R&D capital goods

$$INVRD_i = PSAVRD_i / PRDZ_{rdc}$$

$$SUPINVRD_i = RDSUBSIDY_i / PRDZ_{rdc}$$

$$RDZ_{rdc} = \sum_i (INVRD_i + SUPINVRD_i)$$

$$RDZ_{rdg} = (rprd \cdot GDP + rgrd \cdot GDP) / PRDZ_{rdg}$$

$$RXV_{i,rdt} = axrd_{i,rdt} \cdot RDZ_{rdt}$$

$$RVA_{rdt} = avard_{rdt} \cdot RDZ_{rdt}$$

$$RVA_{rdt} = a_{rdt} \cdot (RLS_{rdt}^{\eta_{rdt,lab}} \cdot RKS_{rdt}^{\eta_{rdt,cap}}) \quad where,\ \eta_{rdt,lab} + \eta_{rdt,cap} = 1\ for\ \forall\ rdt$$

$$RLS_{rdt} = (\eta_{rdt,lab} \cdot PRVA_{rdt} \cdot RVA_{rdt}) / PL$$

$$RKS_{rdt} = (\eta_{rdt,cap} \cdot PRVA_{rdt} \cdot RVA_{rdt}) / PK$$

$$TINVK = INVRES / PINVK$$

$$XV_i = \nu_i \cdot TINVK$$

Armington function

$$Q_i = \gamma(\psi \cdot M_i^{\upsilon} + (1-\psi) \cdot D_i^{\upsilon})^{\frac{1}{\upsilon}}$$

$$M_i = D_i \left[\frac{PD_i \cdot \psi}{PM_i \cdot (1-\psi)} \right]^{1/(1-\upsilon)}$$

$$PQ_i \cdot Q_i = PM_i \cdot M_i + PD_i \cdot D_i$$

Constant Elasticity of Transformation (CET) function

$$Z_i = \gamma(\theta \cdot E_i^{\varphi} + (1-\theta) \cdot D_i^{\varphi})^{\frac{1}{\varphi}}$$

$$E_i = D_i \left[\frac{PD_i \cdot \varphi}{PE_i \cdot (1-\varphi)} \right]^{1/(1-\varphi)}$$

$$PZ_i \cdot Z_i = PE_i \cdot E_i + PD_i \cdot D_i$$

Trade Balance

$$PM_i = ER \cdot (1 + t_i^m) \cdot PW_i^m$$

$$PE_i = ER \cdot PW_i^e$$

$$SF = \sum_i PW_i^m \cdot M_i - \sum_i PM_i^e \cdot E_i$$

Tax revenues

$$INDTAX = \sum_i t_i^Z \cdot PZ_i \cdot Z_i$$

$$LABTAX = \sum_i t_i^l \cdot PL \cdot L_i$$

$$CORTAXK = \sum_i t_i^k \cdot PK \cdot K_i$$

$$CORTAXH = \sum_i t_i^h \cdot PH_i \cdot H_i - \sum_i ITC_i \cdot PRDZ_{rdc} \cdot INVRD_i$$

$$TARIFF = \sum_i t_i^m \cdot PW_i^m \cdot M_i$$

Government

$$GR = INDTAX + CORTAXK + CORTAXH + LABTAX + TARIFF + BG$$

$$XG_i = rgdp \cdot XG_{i0}$$

$$SG = \sum_i RDSUBSIDY_i + rgrd \cdot GDP + rg \cdot \sum_i (PINVK \cdot IDK_i)$$

$$TR = GR - SG - \sum_i (XG_i \cdot PQ_i)$$

Households

$$LINC = \sum_i PL_i \cdot L_i$$

$$KINC = \sum_i PK_i \cdot K_i$$

$$HINC = \sum_i PH_i \cdot H_i$$

$$HI = LINC + KINC + HINC + TR$$

$$SP = \sum_i PSAVRD_i + rprd \cdot GDP + rp \cdot \sum_i (PINVK \cdot IDK_i)$$

$$U_t = \prod_i XP_i^{\alpha_i}$$

$$XP_i = \alpha_i \cdot (HI - SP) / PQ_i \quad for\ \forall i$$

GDP at factor cost

$$GDP = LINC + KINC + HINC + LABTAX + CORTAXK + CORTAXH$$

Market-clearing conditions

$$Q_i = \sum_j X_{i,j} + XP_i + XG_i + XV_i + \sum_{rdt} RXV_{rdt}$$

$$\sum_i L_i + \sum_{rdt} L_{rdt} = LS$$

$$\sum_i K_i + \sum_{rdt} K_{rdt} = KS$$

$$H_i = HS_i$$

Macro closure

$$TSAVK = rp \cdot \sum_i (PINVK \cdot INVK_i) + rg \cdot \sum_i (PINVK \cdot INVK_i) + SF$$

$$BG = TSAVK - INVRES$$

Dynamic process

$$K_{t+1} = (1 - \delta_k) K_t + TINVK_t$$

$$H_{i,t+1} = (1 - \delta_{i,h}) H_{i,t} + INVRD_{i,t} + SUPINVRD_{i,t}$$

$$HG_{t+1} = (1 - \delta_{g,h}) HG_t + RDZ_{rdg,t}$$

$$L_{t+1} = (1 + g_{lt}) L_t$$

Abstract (Korean)

비록 일부 경제학자들에 의해서 시장실패(market failure)의 존재 여부에 관한 비판적 시각이 제기되고 있지만 시장실패는 정부가 민간의 투자 활동에 개입하는 정당성을 제공한다. 정부가 이러한 시장실패를 치유해야 한다고 믿는 상황에서 정부가 수행해야 하는 작업은 크게 두 가지다. 우선, 정부 주도로 연구개발을 수행하여 민간 부문에 기술을 이전할 수 있다. 이 경우 정부 기관 연구소는 사회적 수익률이 높은 반면 사적 수익률이 낮은 연구개발 과제를 수행하여 사회적 효용을 제고시킬 수 있다. 둘째, 민간의 투자를 활성화시키는 다양한 정책을 시행하여 사회가 바람직하다고 판단되는 수준까지 투자를 유인하는 것이다.

현재 한국의 경우 민간의 연구개발 투자는 총 연구개발 투자에서 상당한 비중을 차지하고 있으며, 민간 부문은 국가의 연구개발 역량을 결정짓는 주체이다. 따라서, 국가가 기술 변화를 통해 지속적 성장을 이루기 위해서는 무엇보다 민간 부문의 투자 활동이 활성화되어야 한다. 이러한 맥락에서 정부는 민간 부문의 투자를 촉진시키기 위한 다양한 유인 정책을 시행 중에 있다.

우리나라를 포함한 대다수 국가들이 공통적으로 시행 중인 연구개발 투자 유인 정책으로는 조세 지원, 보조금 지원, 금융 지원, 인력 지원, 공공 조달, 법ㆍ제도적 인프라, 기술이전거래, 기술 지도 및 자문 등이 있다. 이와 같이 다양한 정책수단들이 고유한 정책적 목적을 가지고 활용되고 있는 가운데, 민간의 혁신 활동을 활성화시키기 위해 정부가 어떻게 자원을 효과적으로 할당시켜야 하는가에 대한 논의가 부각되고 있다.

공급주도(supply-push) 관점에서 보조금과 조세 지원 제도는 가장 중심적으로 활용되고 있는 정책 수단이다. 보조금과 조세 지원은 혁신 활동에 필요한 재원을 지원한다는 측면에서 유사한 기능을 발휘하지만 보조금은 정부 개입의 정도가 높은 직접 수단인 반면, 조세 지원은 간접 수단이라는 상반된 특

징을 지니고 있다. 따라서, 효율적으로 정책을 설계하기 위해서는 두 정책 수단의 효과를 상호 비교·평가한 결과를 토대로 정책 수립이 이루어져야 한다. 그러나, 기존의 대다수 실증연구들은 각 정책 수단을 개별적으로 분석하고 있어 상대적으로 우수한 정책 수단이 무엇인지에 대한 시사점을 제공하는데 제한적이다.

한편, 수요견인(demand–pull) 정책은 경제학자들의 논쟁을 통해 그 중요성이 인정되어 왔지만, 대다수의 정부들은 주로 공급주도 정책들을 시행해 왔다. 그러나 최근 들어 유럽연합과 회원국을 중심으로 공급주도 혁신 정책의 한계점이 제기되고, 수요견인 정책이 적극적으로 도입되고 있다. 우리 정부도 수요견인 정책의 중요성을 인식하고 이를 시행하기 위한 제도적 장치들을 보완하고 있다.

이러한 맥락에서 본 연구는 공급주도 관점의 대표적 유인 정책 수단인 보조금과 조세 지원의 효과를 비교·평가 한다. 이와 함께 수요견인 정책의 대표적 수단인 공공 조달 중에서 정부의 지출 비중이 높은 국방 조달의 효과를 분석한다.

본 연구 목적을 달성하기 위해서 지식기반 연산일반균형모형을 도입한다. 본 연구에서 제시된 모형은 지식을 자본으로서 간주하고, 노동과 물적 자본과 함께 지식 자본을 생산요소로서 활용한다. 아울러, 지식 자본은 외부 경제에 파급효과를 창출시키는 원천이다. 본 모형을 운용하기 위해서 2008 국민계정체계와 OECD(2010)의 권고안에 따라 지식을 자본화하고 그 결과 형성된 지식 자본을 새로이 계정에 반영한 지식기반 사회계정행렬을 구축하였다.

본 논문의 연구 결과 보조금과 조세 지원 정책은 모두 민간의 연구개발 투자를 촉진하는데 효과적이었다. 그러나, 상대적으로 조세 지원이 보조금보다 효과적인 것으로 나타났다. 이러한 결과는 시장중심의 의사 결정을 통해서 투자 활동을 유도하는 것이 효과적인 정부 개입 행위임을 보여주는 것이다. 이와 함께 정부의 직접적 개입 수단을 효과적으로 적용하기 위해서는 사전에 정부가 각 산업의 생산 및 투자 환경을 정확히 파악해야 함을 시사한다. 한편,

국방 조달을 일반적 국방 조달과 무기체계에 한정된 국방 조달로 구분하여 분석한 결과, 두 경우 모두 민간의 투자를 촉진시키는 효과를 보였다. 특히, 무기체계 조달의 효과가 상대적으로 크게 나타났는데, 그 이유는 방위산업 시장에서 국방 부문의 구매가 차지하는 비중이 절대적으로 높기 때문이다.

본 연구는 기존의 문헌들과 다음과 같이 차별화된다는 점에서 의미를 지닌다. 첫째, 동일한 자료체계와 분석 모형을 활용하여 보조금과 조세 지원 제도의 효과를 직접적으로 비교·평가한다. 둘째, 국방 조달의 투자 유발 효과를 산업별로 구분하여 제시한다. 셋째, 기존 연구가 유인 정책의 부분적 효과(partial effect)를 분석한 것인데 반해, 본 연구는 투자 활동의 변화에 따른 산업의 성장과 지식자본의 파급효과를 반영한 정책의 전체 효과(full effect)를 측정한다. 넷째, 각 정책수단이 혁신 활동과 경제 성장에 미치는 효과를 분석한다. 따라서, 기술변화를 통해 경제 성장을 유도하려는 혁신 정책의 궁극적 목적이 달성된 정도를 계량적으로 평가한다. 다섯째, 본 연구에서 제시된 지식기반 사회계정행렬과 연산일반균형모형은 향후 다양한 정책을 평가할 수 있는 토대를 제공한다.

주요어: 투자 유인 정책, 국방 조달, 시장실패, 지식 자본, 연산일반균형모형
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