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The Impact of Expenditure on Education and R&D: A Computable General Equilibrium Approach

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Abstract

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This paper develops two endogenic elements, human capital and R&D, and analyzes their ripple effect on industry within the Republic of Korea. In particular, the study focuses on investment in education at different levels, developing either skilled or unskilled labor, and its impact on human capital and R&D as resources. According to endogenous growth theory, such resources must be examined in any long-run growth model because they contribute significantly to economic growth.

To address this issue, the Computable General Equilibrium (CGE) model is used to observing linkage effect of investment in critical elements that strongly affect long-term economic growth. For building a CGE model, a Social Accounting Matrix (SAM) is applied R&D and human capital based in the Republic of Korea. For measuring human capital, we classify four levels of education within a labor sector. It is found that with higher investment in skilled labor and higher education, there are positive impacts on economic growth.

In the simulation, investment in education (i.e., in human capital) results in a higher growth rate in every industry sector, increasing GDP. R&D investment was also found to have a positive effect on economic growth but not as much as that of human capital.

Keywords: Human Capital, R&D, Education, Computable General Equilibrium (CGE)

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Chapter 1. Introduction

1.1 Research background

Humans have always valued useful skills and knowledge; however, only relatively recently have they been considered as forms of capital that can be cultivated by deliberate economic investment. As people increasingly recognize the importance of human capital, it has been developing in impact faster than non-human capital and become recognized as a distinct component of the economic system. As a result of this view, humans have come to be quantified as capital, as stressed by Schultz (1961). Since the concept of human capital has emerged, the investment in developing it has been critically discussed. Following the human capital theory developed by Becker (1964), economic growth has different rates depending on the accumulation of human capital over time. For sustained economic growth, human capital accumulation has to be used as a resource, as emphasized by Lucas (1988).

Another key element for economic growth is Research and Development (R&D), as debated in a large corpus of studies. R&D spending and outcomes are relatively easily quantifiable, as mentioned by Zvi Griliches (1979). A number of authors, most recently Jones and Williams (1998), Park (2004), and Alvarez-Pelaez and Groth (2005), find that R&D investment has strong social returns that also create stronger economic growth. Engelbrecht (1996) emphasized that the country’s total factor productivity (TFP), an element of measurement for economic growth, rises due to the cumulative R&D effort. Frantzen (2000) focused on measuring R&D intensity by stocks of foreign and domestic capital for analyzing long-run TFP growth, finding positive impacts to economic growth of OECD countries.

According to a number of previous studies, two forms of capital, R&D and human, must be considered in measurement of economic growth; moreover, Lucas (1988) and Romer (1990) used those capitals in their endogenous growth theory, focused on long-run growth, which has received broad acceptance in Neo-classical economics. Romer (1990) and Grossman and Helpman (1991) support the endogenous growth model, finding that the stock of R&D facilitates technical progress and increased productivity.

Unlike R&D capital, there are no precise methodologies for measuring human capital stock, even though it is the important factor of economic growth, as emphasized by Aghion and Howitt (1998). To measure and analyze human capital stock, Lucas (1988) provides two elements: education and learning by doing, which were also expressed by Romer (1990). For explaining the insight of two elements endogenously, they use the concept of stock suggested by Nelson and Phelps (1966), recently discussed due to Schumpeterian growth literature, explaining advanced countries' innovative abilities by stock of human capital. As Aghion and Howitt (1998) emphasized, accumulation and division of human capital, as labor and education, must be defined. This is connected to the work of Becker (1964), who found more positive effects when people invest in specialized human capital, by division of labor and of education, which also increases returns. In fact, it is mandatory to classify level of labor and of education depending on conditions.

As accumulation of capital stock requires longer term observation, the present study uses the Computable General Equilibrium (CGE) model. The CGE model, rooted in the general equilibrium concept by Leontief (1936; 1937; 1941), developed in its present form by Johansen (1960), analyzes ripple effect on multi-sectors when there is a shock in a part of the system. The previous studies, Diao et al. (1999), Ghosh (2007), Lecca (2008), Bye et al. (2009), and Bor et al. (2010) employed an R&D-focused CGE model based on Romer’s endogenous theory for analyzing macroeconomic effect; however, none of the above research has considered human capital stock endogenously. Verbic (2009), Jung and Thorbecke (2001), and Gibson (2004) have observed that expenditure on human capital has positive effects on economic growth under a CGE model including various scenarios but considering R&D stock. Rojas-Romagosa (2010) expands the CPB multicountry CGE model, focused on R&D, by revising the human capital satellite model developed by Jacobs (2005) to identify policy implications; nevertheless, the scenario sets are based on the Lisbon Agenda, considering the European Union (EU), although it does apply both of R&D and human capital stock.

1.2 Research objective

In this study, the authors establish dynamic CGE model, considering both R&D and human capital in detail, for analyzing the ripple effect of these factors on industry in the Republic of

Korea. Specifically, for observing investment efficiency of R&D and Labor, the proposed model exploits the endogenous model, which produces stocks that affect value added. The labor sector is segmented into two parts, skilled and unskilled, based on education level in a Social Accounting Matrix (SAM), for in-depth analysis of consequences of investment on education.

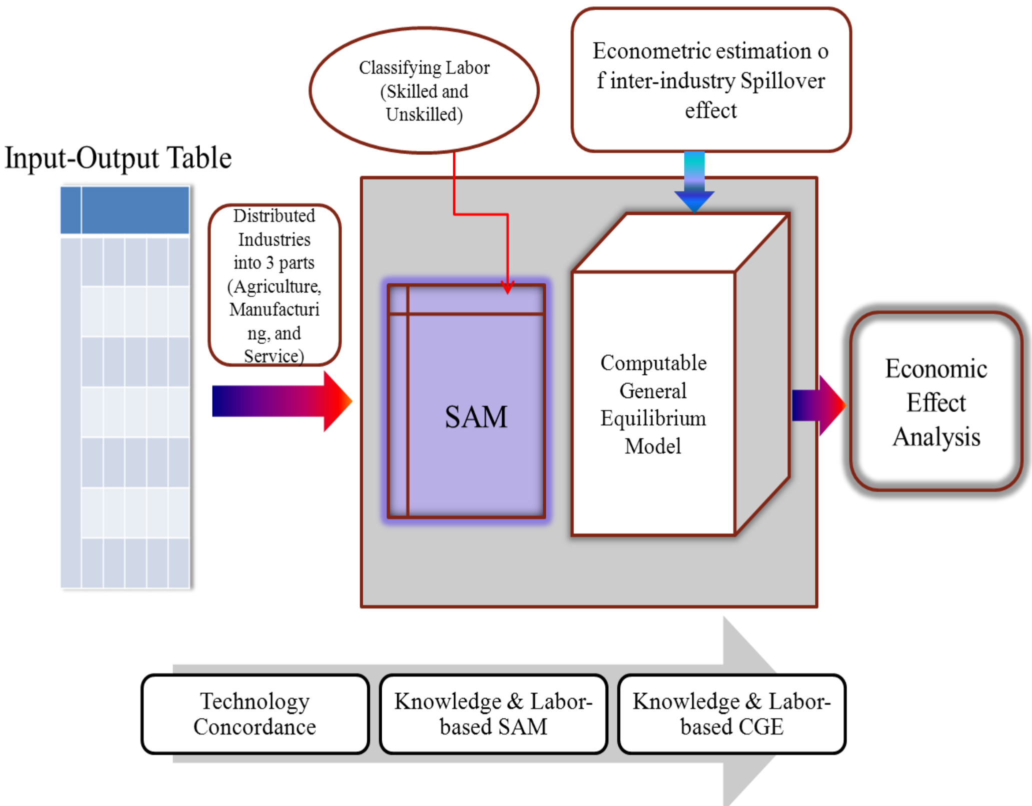

Figure 1. Conceptual outline of study

1.3 Structure of the study

The paper is organized as follows: In Section II, literature related to R&D and human capital with various methodologies is reviewed, mainly focused on CGE. In Section III, the present model, using CGE and SAM, is presented and distinguished from existing models. Section IV develops the scenario based on conditions of South Korea for the purposes of the simulation. Finally, results are discussed, along with the study limitations and opportunities for future research.

Chapter 2. Theoretical background

2.1 The Computable General Equilibrium (CGE) Model

2.1.1 Background

To understand the complex national system and to determine the impact from economic elements, an equation encompassing all economic principles needs to be built; the General Equilibrium (GE) model supposes that there is a value suitable as the beginning equilibrium point for analyzing effect of policies, despite having limitations in reflecting reality. For solving that limitation, the Computable General Equilibrium (CGE) model has been introduced. The CGE model is a useful tool that includes specific assumptions, manufacturing technology, economic factors, government and public activity, and various other elements, to analyze economic effect according to different policy simulations, as expressed by Choi (2002).

Quensnay (1758) first introduced GE in his economic theory, Tableau Econimique, for examining trades among industries. Wallas (1984) defined the GE model by equations, and Wald (1936) determined unique values existing under certain assumptions by using simultaneous equation systems. Arrow and Debreu (1954) emphasized that competition balance exists under the GE when applying fixed point theorem. Leontief (1936; 1937; 1941) exploited the Input-Output (IO) table for reflecting reality in his studies. Johansen (1960) develops the CGE model, the first model to consider the whole national economy, which applies a new method for calculating approximated value made by linearization in the inverse matrix. Scarf (1967; 1973) advanced GE to the CGE model for affording various arithmetic operations, which is presently widely used. Since policy has focused on tax and tariff in the past, GE or CGE models have been applied to those problems; however, these models are now affected to other economic issues, environment and energy, with development of systems, as emphasized by Kim (2005).

2.1.2 Components

For structuring a CGE model, there are three steps: 1) establishing SAM, 2) calibration, and 3) setting equation systems. SAM is the matrix shape that shows the target country's economy, showing relationships among economic units of income and expense. Each unit has transaction relationships among other units, which becomes the critical element of deciding parameter values. When SAM is completed, calibration needs to be operated for the parameters. These parameters, with various elasticity, determine the degree of changes occurred by transition of policy or institution from the baseline. When there are sufficient time series data, using the econometric method would show the most precise outcome, however, since it is hard to collect constant data, many studies extract data from previous studies, which can be a limitation. To avoid this problem, the CGE model mostly restrains the number of parameters. Lastly, due to the functions creating the CGE model, many equations must be built to show manufacturing technology, supply-demand relations, transaction system, and other economic relationships already set in SAM, as demonstrated by Park (2001).

The basic structure of the CGE model is classified in five steps (Choi, 2002). First, setting economic units in detail, which has supply and demand sides. Second, applying the motive of individual units to the code of behavior, assuming that every individual produces products for profit maximization. Third, price is the key factor in the rationalization method for decision-making. Fourth, setting interaction game theory; most of CGE model are under the condition of perfect competition and a small open economy. Finally, the equilibrium conditions needs to solve discordance between supply and demand. When each economic unit spends all their income on consumption, total income and total expense must be equal; however, a gap always occurs because of saving and investment. For creating equilibrium, the macro closure has been commonly adopted in neo-classic economics, with Johansen, Keisian, and Fisherian. For creating market clearing condition, supply and demand are made the same and consistency among selections from economic units is applied.

2.1.3 Comparison with other models

The Input-output (IO) table is a statistical chart that shows trade connections among industries involved in the national economy during a given period. IO analysis adopts an input coefficient, the manufacturing technology, to demonstrate changes of endogenous economic factors econometrically when providing final demand and value-added. IO analysis has the strength of comprehending economic ripple effect by changes of policy or institution in the short-run as the connections of industries are linked based on technological relationships. Despite connection among economic units, IO analysis assumes a linear relationship in those units with a static method; thus, it has limitations in reflecting reality.

The Macroeconomic model, the neoclassical economic method, applies reflection of consumption and production according to price change, analyzing relationships between negative shocks and economic changes with econometric methodologies. The model optimizes function of demand and supply under certain constraint conditions for analyzing changes of policy. With modeling of relationships of variables and setting regulation variables exogenously, it is possible to determine various policy implications. The model shows dynamic changes with a simple structuring method even though abundant time series data are required for estimating precise parameters; it is hard to analyze the ripple effect of industries in conditions of changing institutions.

The CGE model includes the elements of manufacturing technology, preference relation, production factors, economic policy of government, and many other elements requisite in analyzing economic effect by institutional changes. Compare to the above methodologies, the CGE model was the first to consider all effects of economic shocks because it as it considers both activities of and interactions of economic units. Second, with its detailed data analysis, it reflects reality closely. Third, unlike other models, the CGE model gives explicit conditions: profit and utility maximization. Last, it is feasible to observe changes in each industry and executable considering relative price and effect, as expressed by Park (2007).

Nevertheless, as various modes of effect emerge, the elaborated route cannot be analyzed; especially when the effects overlap, the relationships among economic units are hard to define. Second, various assumptions on variations and models are required, which is detrimental to reflecting reality. Third, in spite of difficulty of structuring, the CGE model is only used ofr particular purposes. Fourth, the model requires continuous upgrades to reflect dynamic systems. Last, the model is strongly affected by baseline year.

2.2 Literature reviews

2.1.1 R&D focused CGE

Diao et al. (1999), using computable general equilibrium model for policy simulations, econometrically investigate the importance of policy alternatives and mechanism which affect to long-run economic growth of country based on endogenous growth theory. Their study follows Coe and Helpman (1995), found mechanism of government policy that influenced long-run economic growth; moreover, two critical points have focused. First, cognizing research and development as the main growth point of national growth. In this point, the government provides incentives to the markets which create new technology knowledge, patent, and invest R&D in commercialization for long-run national economic growth. Second, treating the country as an entity decided degree of R&D stock of the whole world. According to the second point, the open trade policy not only encourages international commerce but also imports technologies and knowledge to domestic market which impact to economic growth of country.

Their model has structured based on endogenous growth theory expressed by Romer (1990) and Grossman and Helpman (1991). Production sector is distributed into two parts: R&D and final goods. R&D sector is divided producing knowledge, patent, and capital goods itself. They set one patent creates one capital goods which are same amount. The spillover effect is occurred from foreign leading and increasing productivity of R&D companies. The economy in the model has built by level of endogenous R&D activities.

Diao et al. (1999), consequently, focus on policies that promote R&D activity in domestic with direct supports of funds and legal aids. They also set the environment for adapting foreign knowledge or technologies from the spillover effect. This study utilizes economy of Japan with 1992 GTAP (Global Trade Analysis Project) and various data relate to Japan. Japan, one of the advanced countries, is the appropriate example because of using both of R&D stocks from the foreign, spillover, and domestic, R&D investment.

Although the domestic R&D activity through trade liberalization policy has minimal effects to resource reallocation, it increases productivity of companies and spillover effect occurred by foreign trade. In terms of equivalent variation index, it rises in the first period but gradually decreases after the certain time when trade liberalization policy, no tariff protection in every economic sector, has applied. However, non-neutral trade policy, supply strategic market incentives on investment goods, shows positive effect of creating higher economic growth.

The policy promoting R&D evaluates in two ways: 1) supporting R&D funds directly and 2) providing indirect benefits to producers. Although there is not much influence from both ways, the R&D stock has increased because they induce many effects to domestic R&D activity. It leads increasing of R&D activity and induction of importing goods which promote the country utilizes foreign R&D factors. This study implies the policy of direct support to

R&D can be the supplementary of trade liberalization policy when it is hard to maintain higher tariff rate under the liberalized commerce in the real world.

Ghosh (1999) applies endogenous model to small open economy of Canada for analyzing effect of alternative policies on productivity and economic growth. It shows government policies affect long-run economy by promoting public R&D activity through the market incentives.

The model divides production sector into two, R&D and capital goods. R&D sector is classified again by two sections: producing new knowledge or technologies, patent, the R&D companies, and capital variety for R&D.

The R&D companies produce new knowledge or technologies, patent, under the monopolistic environment. Their products are measured by the number of new patents. In the process of creating patent, each labor, capital, and commitment elements have shown the law of diminishing marginal utility limitation production effect; however, this effect of factor of production is relived because the number of produced patents are Constant Returns to Scale (CRS), which affects production of companies. According to the model process, each company has benefit from domestic R&D stock. The knowledge spillover, occurred by imports from foreign companies, is raised productivity of R&D companies; in addition, knowledge spillover increase when imports rise.

Product sectors, distributed into three sections (Agriculture, Manufacturing, and Service), are under the condition of perfect competition. These products are finally produced with Cobb-Douglas function, included composite intermediate goods and value-added, when the CES nested structure creates capital goods. Ghosh (1999) used Leontief function for composite intermediate goods and CES function for value-added including labor, capital, and R&D as commitment elements. Each of these elements has the law of diminishing marginal utility; however, when the number of R&D, patent, increase production of value-added simultaneously under the CES function which become the source of economic growth. Following to the model provided, individual R&D activities increase the productivity of both sides companies, producing patent and capital goods and spillover from the foreign only affects to productivity of R&D companies.

This study has statistical limitation because the model assumes the expense of R&D spend the same ratio of physical capital expenditure because there are no precise data of R&D expenditure to each product sectors. Besides that he uses GTAP DB version 5 (1997) as the main data. There are three policy simulations: 1) subsidy on R&D activity directly, 2) subsidy on product sectors that invest in R&D, and 3) trade liberalization. These simulations execute with decreasing related tax rate. Supporting R&D activity directly shows positive effects when other two simulations have minimal effects. In detail, the productivity percentage increases 0.70% from the baseline in the first year and 0.86% after two year in the first simulation. It rises up to 0.89% after ten years and 0.71% after one hundred fifty years.

Meaning that the growth rate of productivity gradually slows down despite of higher than baseline because the number of companies supported keep increasing under the fixed subsidy. The social utility has increased 2.79% in the whole simulation analyzed by Hicksian equivalent variation. In the second simulation, the productivity has increased 0.70% in the first year, 0.82% in the second year, and 0.78% after ten years; however, it has marked 0.69% after one hundred fifty years. There is 0.86% of improvement in social utility. As the numerical values, the effect of subsidy on product sectors has lower impact than direct supports because increasing productivity created by R&D investment has Decreasing Returns to Scale (DRS) when increasing physical capital has opposite condition, CRS. In the last simulation, the productivity has increased 0.700% in the first year, 0.701% in the second year, 0.703% after ten years, and 0.702% after one hundred fifty years. The social utility has decreased 0.179%.

Lecca (2008) structures R&D CGE model for analyzing ripple effect of R&D subsidy in Sardinia region, Italy. In his study, product sector has divided into four sections (light industry, heavy industry, energy, and service) and factors has classified by three sections (R&D, labor, and capital) as SNA 2008 put R&D into the value-added. In this model, tangible assets, labor and capital, and intangible asset, R&D, are interchangeable with different scale, decided by transition cost of product factors and degree of substitutability. Non-excludable elements knowledge reflected by knowledge spillover occurred by domestic and foreign trade activities are treating as one of the factors with the excludable element knowledge. This spillover knowledge finally affect to productivity through the change of Total Factor Productivity (TFP). It supposes that increasing foreign transaction and domestic R&D stock affect spillover from the foreign positively.

In this study, he uses 2005 System of National Account (SNA) of Italy with R&D stock data; employing Yale technology matrix to gain information of R&D expenditure with assumption of knowledge transfer simultaneously occurred by trade. Moreover, he presumes that the value-added occurred by intangible capital is already applied in Social Accounting Matrix (SAM); meaning that no consideration of new creation of value-added created by R&D capital. He also includes R&D into the physical capital so that deducting physical capital investment from R&D investment with separated sector. Nevertheless, different from his assumption, the expenditure of R&D has consumed as the intermediate consumption during the process and not applied to saving sector due to excluding R&D from the investment element in SNA.

Through the study, he finds that government policy encourages companies to invest in R&D which positively leads economic growth. The model has processed under two conditions: 1) National wage Bargaining regime (NB) and 2) Regional wage Bargaining regime (RB). NB supposes nominal wages of baseline are fixed as the value under the national bargaining system. In RB condition, the wage curve (Blanchflower and Oswald, 1994) defines labor market applied unemployment rate in negative correlation. With observation, subsidy on R&D need to be increased 4.49% in NB and 2.22% in RB for raising 1.44% of regional economic growth.

With applying spillover effect of knowledge, the growth rate of labor market has increased 0.1056% in NB and 0.0153% in RB which means the endogenous productivity growth affected by foreign has not heavily impacted. He concludes that the policy of increasing regional R&D stock is not showing large differences for long-run economic growth and expanding foreign knowledge and technologies. However, regions have benefits from the open economy or trade when domestic industries have abilities to accumulate foreign knowledge. Moreover, the expenditure of R&D policy is changing depend on condition of regions' labor market.

Bye et al. (2009) select small open economy of Norway as a simulation target for improving social utility and structuring preference differences system of innovation.

Although Diao et al. (1999) already analyze similar situation, Japan is not heavily influenced by external economics other than Norway. Different from previous study, Bye et al. (2009) suppose that the spillover from the foreign is the most influenced element to economic growth; he sets 95% of the technological change due to the foreign spillover in Norway. Under his hypothesis, the R&D activity from domestic companies has showed low knowledge spillover changes.

The model follows Romer (1990) organizing three product sectors: 1) industry developing R&D, 2) industry producing capital goods using patents, 3) rest of industries. As Romer (1990) and Jones and Williams (2000) emphasize technology improvement create profit maximization and become outputs in closed economy. Distinct from past studies, Bye et al. (2009) find implication in the small open economy that international market price influence both domestic market and amount of import and export.

There are one industry in two product sectors and sixteen industries in the last product sector. The industry, producing capital goods used patents, purchases one patent from the R&D company for investing as a sunk cost. Supposing all of the markets is under the perfect competition except R&D companies that control the market monopolistically. The economic growth has been built endogenously by preference effect, which is decided by productivity and variation of companies. The productivity of R&D companies is increasing due to the ripple effect from the R&D stock, which positively affect to other industries due to love-of-variety effects. In addition, knowledge spillover from foreign also raises factor productivity when every company has the same amount of factor productivity exogenously.

Set three simulations for having policy implications with support of lump sum taxes. First, support subsidies on R&D producing sector. Second, support subsidies on capital goods industries. Third, support indirect subsidies on final goods industries.

In the first simulation, in spite of increasing productivity, the growth of final goods industries has decreased in seventy years periods. However, in long-run, GDP has increased up to 1.9% with 0.7% of growth rate. Due to the subsidy on capital goods industries, the productivity cost has decreased in second simulation. In the same period, the number of patents increases even though it is about 60% of the effect from the first simulation. There is 1.2% rising of GDP and 0.33% increasing of social utility. There are minimal changes in the last simulation. In conclusion, the direct subsidies on R&D or related industries show positive effect on both of economic growth and social utility which also appear in econometric analysis; however, those of two elements are not co-related.

Bor et al. (2010) simulate the effect of public R&D investment with recursive dynamic CGE. Their Social Accounting Matrix has set with 2001 data of Taiwan. It allows one industry produces various products during the process meaning that there are sixteen industries with twenty seven commodities. Labor sector has distributed into eight sections.

There are three productivity factors (land, labor, and capital) which use again for producing final goods. Two investment types, physical and R&D, has set; R&D section has distributed into two parts: public and private.

The simulation shows positive effect on the economic growth with increasing 1% of R&D investment by the government. There are 0.02% rising of GDP in short-run; moreover, 0.04% increasing of GDP in middle-run with three or four years of time lag. Nevertheless, due to the crowding-out effect among domestic market, the growth rate of GDP decreases in the long-run even though the rate of export, growth of high-tech industry, and rise of wages gradually increase. This study shows that technology development by R&D investment is increasing human capital or labor productivity in long-run but different in short and middle-run. It means there need to be other policy correspondence for those of periods.

The study also recommends that primary industries require developing as the complex industries to avoid crowding-out effect made by public R&D investment because of having decreased effect in spite of showing positive effect in short term. Following to the previous studies, the precise Social Accounting Matrix must be structured in detail for appearing precise simulations and results realizing by Computable General Equilibrium model.

2.1.2 Human capital focused CGE

Verbic et al. (2009) focus on economy of Slovenia with CGE model based on endogenous growth theory that human capital and R&D interact as an element for economic growth. There are twenty product sectors, five households distributed by income level, government, investment, and foreign parts in the model. Each product sector produces one commodity. Each company in the product sectors produce one commodity under Cobb-Douglas production function included human capital stock, composed by three education levels, sector specialized human capital stock, physical capital, and R&D stock. For profit maximization, the basic economic theory, the companies select labor, physical capital, human capital, and R&D. Saving from households and government, producer's surplus, and foreign saving decide investment.

Under the budget constraints, households have decision making for utility maximization. Their decision considers certain time and cost for investing on human capital in every period and regards expenditure of time and cost are independent.

The model shows economic development with not only growth of TFP but also development of endogenous elements, households' human capital stock and sector specialized human capital stock and R&D stock. TFP proportionally increases depend on R&D products and services production rate per GDP and degree of trade openness. As TFP influences every production sector, companies' investment on R&D affect to the whole economy.

There are five simulations: 1) decreasing 10% personal income tax (SC1), 2) increasing share of households' investment in education that is deductible from the 25% of personal income tax (SC2), 3) decreasing 25% of corporate tax (SC3), 4) increasing the share of sectoral investment in human capital stock that is deductible from the 25% of corporate tax (SC4), and 5) increasing 10% of government expenditure on education (SC5). The SC4 has the most positive effect, increasing R&D expenditure 6.2~7.4%, while other simulations show minimal changes. R&D expenditure accompanies education investment in this model. Education, the tool of boosting R&D efficiency, becomes a role of supplement of R&D service, one of the product sectors. In the simulation, the education expenditure increase up to 0.3% in SC3, 1.4% in SC4, and 1.3% in SC5 when there are no changes in SC1 and SC2.

When observing GDP alteration in long-run, it raises until 1.4% in SC4 and SC5, meaning that when the government directly intervenes on the policy, the economic growth begin to vitalize. With the social utility view, there are 1.6% of rise in SC5 during 0.5~0.6% changes in other simulations.

Jung and Thorbecke (2001) apply two Heavily Indebted Poor Countries (HIPCs), Tanzania and Zambia), with expenditure on public education, human capital. For modeling CGE, they are utilizing the Tanzanian 1992 SAM and the Zambian 1995 SAM. To measure the affect of education expenditure, the model has four types of institution, households, firms, the government, and the rest of world. There are four sections, urban poor, urban nonpoor, rural poor, and rural nonpoor, distributed in households by region and income. The three factors, agriculture, industry (including mining, manufacturing, and construction), and services has placed in the model.

In this study, the amount of labor capital delegation has fixed during the simulating period despite of fluid across the sectors. Firms are having profits from the production and households are consuming for their utility due to each economic unit maximizing their profit. Each factor provides income to households, consuming or saving those of profits. The saving decides the amount of investment; government accumulates taxes, income, domestic indirect, and tariff, for supporting subsidies to other sectors. In the rest of the world, there are firms, households, and the government existing which also have economic activities.

To compose labor sector, two types have adapted in two different levels. As the model focuses on HIPCs countries, most of nation is noneducated or primary-educated. These two types are becoming composite of unskilled with Cobb-Douglas function. In this stage, the higher-educated part combines with composite of unskilled with CES function to finally have composite labor sector. The model put physical capital endogenously by investment, the saving from domestic and foreign, and human capital exogenously by population growth and the pattern of education expenditure. The model supposes thirty years of working life with 2.5% of fixed population growth rate.

The model simulated 3 scenarios: 1) fixed total labor supply, 2) excess supply of unskilled (Noneducated), and 3) targeted education expenditure. They spend two different amount of education spending, 15% and 30%, in each simulation. In first simulation, only Tanzania has positive effects especially on noneducated (6.2%) with increasing 15% when Zambia mostly has negative effects. With same conditions, in second simulation, supply of noneducated workers increases more than previous scenario while educated workers increases in same rate. The wage level and house income are not different from second scenario in the last simulation.

Bill Gibson (2005) structures dynamic CGE model focused on human capital accumulation for simulating two policy sides, green and red path. The green path, steady per capital income growth, reflects economic informality in reduction level and human capital accumulation with rapid rate. The red path, lower growth rate, has insufficient rate of human capital formation with expanding informal sector. Their SAM based on Paraguay 1998 IO table has two sectors, Formal (agriculture, manufacturing, utilities, construction, commerce, transportation, finance, and service) and Informal (agriculture, manufacturing, commerce, and service), two types of labor sector, skilled and unskilled, two types of capital, formal and informal, and four classes (rural Guarani and Spanish and urban Guarani and Spanish).

The model simulates two policy trajectories within a period of twenty years with critical parameters; then undertakes sensitivity analysis for checking robustness of those of parameters. Six parameters (real exchange rate, real interest rate, government investment/GDP, educational cost, direct tax rate, and transfer to households) reflect on the model with two policy ways. The organized chart is shown as below.

Table 1. Parameter Settings[a] in Gibson (2005)

Policy response	Instrument	Green	Red
Investment climate	Real exchange rate	Constant	Appreciation
	Real interest rate	Decreases	Constant
Fiscal discipline	Govt. invest/GDP	Constant	Decrease
	Educational cost	Constant	Increase
	Direct tax rate	Increase	Larger Increase
	Transfers to households	Increase	Constant

a = All others held constant

As comparing two simulations, educational effect gradually increases in the green trajectory but in red side. Especially, it shows rapid differences after five years; meaning that the effect of education is occurring when expense increases but need certain time for accumulating human capital. However, it causes job inflation when rapid growth occurs. Openness has showed positive effect on both simulations. With excess supply of skilled labor, skilled employment increases 13% in the green trajectory. Lastly, the green trajectory shows slower wage differential between skilled and unskilled.

Rojas-Romagosa (2010) models recursive dynamic CGE model of EU countries applied human capital and education formation based on human capital satellite model by Jacobs (2005). The study actually adds human capital equations to existed CGE model, focused on R&D. For building precise model, Rojas-Romagosa (2010) takes the new human capital accumulation, including three different skill types (low, medium, and high) composed of education levels; then adjusting key parameters exogenously. The model cares twenty eight EU countries including the rest of world.

As Romer (1990) introduces, two elements, education and learning-by-doing, establish human capital stock in this study. Two parts organize education: educational attainment (schooling years) and quality of schooling. Inflow and outflow of educational attainment composed of skill, region, and year, used OECD’s Education Database, affect to human capital accumulation. Quality of schooling is classified by years of schooling as mentioned above. An assumption that the wages of labor is not decreasing with increasing the career enables including learning by doing to human capital accumulation. As two key parameters are changing endogenously, the human capital stock dynamically shifting.

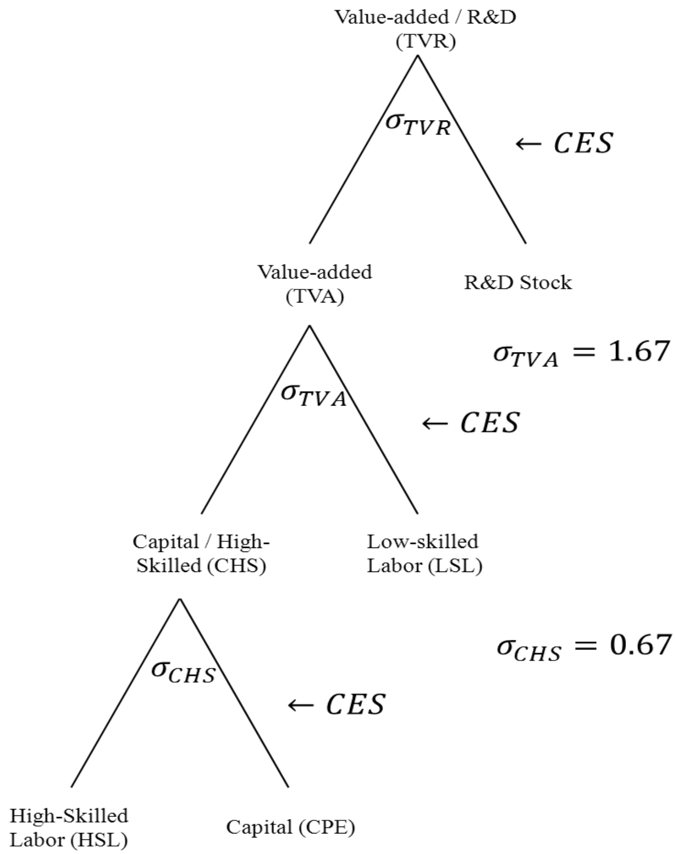

Figure 2. WorldScan's aggregation of labor and R&D[1]

[1] Expressed by Rojas-Romagosa (2010)

For composing with previous R&D focused CGE model, the model changed aggregation function from Cobb-Douglas to CES because the elasticity of high skilled labor is higher than low skilled labor. The step of aggregations is as follows: 1) High skilled and capital aggregate. 2) This aggregation combines with low skilled labor for creating value added. 3) Finally, R&D stock adds to value added, which structure total stock of R&D and human capital. All of aggregation use CES function.

The model simulates Lisbon Agenda published in 2010 with five targets: early school leavers, secondary school completion, achievement in literacy, lifelong learning, and engineering students. However, the study is not (or cannot) applying detail policy instruments because model focuses comparison of countries; it finally fails to create linkage between human capital outcomes and those of tools.

Chapter 3. Structure of the model[2]

3.1 Structure of human capital and R&D focused SAM

As shown in Table 4, three differences are added to the basic SAM. First, the model combines interior goods and imported goods occurring in the activity sector due to focusing on observing exogenous elements, labor and R&D, though with segmented industries.[3] The model compresses industries into three types: Agriculture, Manufacturing, and Services.[4]

Second, as the assumption of the capital of R&D, knowledge, interacting to production factors, three sections were created. The present model included the knowledge section under the sector of factors that have occurred due to R&D capital. Moreover, R&D investment is separated from the physical investment due the assumption that R&D activity has been processed when there is R&D investment. Following to basic rule of SAM, R&D investment in columns (E and F) refers to expense for activity sector and R&D investment, respectively, in rows (A, B, C, and D) save for the institution sector. For a precise outcome, the model distributes R&D investment into two parts: Public (government) and Private (household).

[2] In this study, we use the structure of basic SAM established by Lee (2012). Unlike previous studies, we classified the labor sector specifically with creation of human capital stock. The basic SAM is placed in Appendix 1.

[3] Depended on the purpose of research, the structure of SAM can be changed or reorganized, as emphasized by Park (2009).

[4] Following the Bank of Korea (2011), South Korea's industries are distributed into 403 industries, which are classified by 168 sectors in the small class level, 78 sectors in the middle class level, and 28 sectors in the big class level. In terms of big class level, our model combines two industries to Agriculture, 3-18 industries to Manufacturing, and 19-28 industries to Services.

Third, the Labor sector is distributed into two parts, Skilled S(5.3.1) and Unskilled S(5.3.2), for reflecting expenditures on each education level. Skilled labor is composed of people who graduated college or beyond, while the remaining education levels comprise unskilled labor (elementary, middle school, high school, and community college). For assembling the SAM, the amount of labor is given by total wages times number of workers. The ratio of skilled labor in each industry sector is found for classifying the differences in wages of the two labor parts[5].

Table 2. Total wages of skilled and unskilled labor in three sectors

	Agriculture & Mining	Manufacturing	Service
Unskilled Labor	108,099,483	54,717,257	48,713,179
Skilled Labor	131,840,396	43,051,108	93,458,309

Notes: Ministry of Employment and Labor (2009), Units: Millions KRW

[5] Ratio of skilled labor is 0.5495.

Table 3. Labor and R&D based SAM

Classification			ACTIVITY		FACTOR				INSTITUTION		INVESTMENT			TAX				FOREIGN		Total
			Interior	Imported	Labor		Capital	Knowledge	Household	Gov.	Physical Investment	R&D Investment		Indirect	Corporate	Income	Tariff	Export	Import	
			Goods	Goods	Skilled	Unskilled						Private	Public							
ACTIVITY	Interior Goods		S(1,1)						S(1,5)	S(1,6)	S(1,7)	E	F					S(1,12)		S1
	Imported Goods		S(2,1)																	S2
FACTOR	Labor	Skilled	S(3,1,1)																	L1
		Unkilled	S(3,1,2)																	L2
	Capital		S(4,1)																	S4
	Knowledge		E1																	K1
INSTITUTION	Houshold				S(5,3,1)	S(5,3,2)	S(5,4)	E2		S(5,6)										S5
	Government										S(6,7)			S(6,8)	S(6,9)	S(6,10)	S(6,11)			S6
INVESTMENT	Physical Investment								S(7,5)	S(7,6)									S(7,13)	S7
	R&D Investment	Private							A	C										K2
		Public							B	D										K3
TAX	Indirect		S(8,1)																	S8
	Corporate		S(9,1)																	S9
	Income		S(10,1)																	S10
	Tariff			S(11,2)																S11
FOREIGN	Export																		S(12,13)	S12
	Import			S(13,2)																S13
Total			S1	S2	L1	L2	S4	K1	S5	S6	S7	K2	K3	S8	S9	S10	S11	S12	S13	

3.1.1 Formation of value-added

Formatting the uniformed SAM, firstly, current expenditures to knowledge capital are changed. These current expenditure is shown in S(1,1), originally placed in intermediate goods in the IO table; however, there are already R&D industries, research institutions (No. 148), and private research and development (No.149), existing in the small-sized distribution. This means that the total sum of expenditure from each ‘j’ industry has the same amount of those of two R&D industries.

Table 4. Creating knowledge value-added

Classification		Activity		
		Agriculture	Manufacturing	Service
Activity	No. 148	A	C	E
	No.149	B	D	F
Factor	Knowledge	0	0	0

(Before the Process)

Classification		Activity		
		Agriculture	Manufacturing	Service
Activity	No. 148	0	0	0
	No.149	0	0	0
Factor	Knowledge	A + B	C + D	e + f

(After the Process)

According to fact, the value-added in SAM (1x28 column vector) has capitalized and is, thus, not intermediate consumption anymore. There are two types, market producers and non-market producers, in produced value-added due to the principle of expenditure. When the addition of consuming knowledge capital and consumer surplus composes the market producer, the non-market producer only takes consuming-knowledge capital.[6]

3.1.2 Formation of knowledge capital

The accounts in the row column show the expenditure on R&D provided by households and government. As explained in the previous chapter, there are only two R&D industries

[6] The non-market producer has no operating surplus, as assumed by South Korea's System of National Account (SNA).

defined, which the present SAM reflects in the R&D investment sector, becoming knowledge capital, after being removed from intermediate transactions.

There are three R&D expenditure provisions, mechanics, premises, and computer software, taking 9.5% of total capital expenditures. In the IO table, mechanics and premises are tangible fixed assets while computer software is an intangible fixed asset. To avoid overlapping, the amount of R&D expenditure is subtracted from the total capital expenditure in the investment sector; then, the same values are transposed into the R&D investment sector.

As mechanics industry expense for five items (KCi), the detail equations are shown as below:

KCi = R&D expenditure to ‘i’ industry

FCi = Investment of ‘i' industry

KCi = ‘Items related to mechanics’ x {FCi / (FC12 + FC13 + FC14 + FC15 + FC16)}

$I \in \{12, 13, 14, 15, 16\}$

With the assumption above, model also considers public (CKCi) and private (GKCi) parts that have a constant ratio (CRD and GRD).

CKCi = KCi x CRD

GKCi = KCi x GRD   when CRD + GRD = 1

Table 5. Knowledge capitalization from mechanic industries

Classification		Investment		
		Physical Investment	R&D Investment	
			Private	Public
Activity	General mechanics	A	0	0
	Electronics	B	0	0
	Precision mechanics	C	0	0
	Transportation	D	0	0
	Other manufacturing	E	0	0

(Before the Process)

Classification		Investment		
		Physical Investment	R&D Investment	
			Private	Public
Activity	General mechanics	A-KC12	KC12*CRD	KC12*GRD
	Electronics	B-KC13	KC13*CRD	KC13*GRD
	Precision mechanics	C-KC14	KC14*CRD	KC14*GRD
	Transportation	D-KC15	KC15*CRD	KC15*GRD
	Other manufacturing	E-KC16	KC16*CRD	KC16*GRD

(After the Process)

For the creating knowledge capital from premises part, R&D expenditure is subtracted from the capital expenditure of industries related to construction (KC18). For the computer software part (KC24), 14.4% is taken from the ‘real estate and service’ industry (No. 24 in the big class level in IO table), as done by Park (2003).

Table 6. Knowledge capitalization from construction and service industries

Classification		Investment		
		Physical Investment	R&D Investment	
			Private	Public
Activity	Construction	A	0	0
	Real Estate and Service	B	0	0

(Before the Process)

Classification		Investment		
		Physical Investment	R&D Investment	
			Private	Public
Activity	Construction	A-KC18	KC18*CRD	KC18*GRD
	Real Estate and Service	B-KC24	KC24*CRD	KC24*GRD

(After the Process)

3.1.3 Saving and R&D investment distribution

Investment or saving activities appear in both household and government sectors for R&D capitalization. These values are shown in A, B, C and D in our SAM, which uses the Survey of Research and Development in Korea, published by the National Science & Technology Commission and KISTEP[7] (2009).[8]

A = Household's investment to private R&D research

B = Household's investment to public R&D research

C = Government's investment to private R&D research

D = Government's investment to public R&D research

As the government's knowledge stock, the public goods is a non-exclusive asset, and 'E2' is set directly to the total sum.

E2 = K1

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[7] The Korea Institution of S&T Evaluation and Planning

[8] National Science & Technology Commission and KISTEP publish the Survey of Research and Development in Korea every year.

3.1.4 Macro clauses

Transfer to household, S(5,6), government debt, S(6,7), and trade balance, S(7,13) play the role of balanced clauses under the double entry system:

S(7,13) = S13 – S12

S(6,7) = S7 – S(1,7)

S(5,6) = S6 – S(1,6) – S(7,6) – D – E.

Finally, cross-entropy method is applied for completing the matrix, the same total sum of row and column.

3.2 Stocks

3.2.1 Capital stock

The difference in amount of cost between baseline year and expected year becomes the total fixed capital stock, also called net capital stock, which includes owned, leased, and idle capitals (Pyo, 2007). The present study utilizes ‘National Wealth Statistics’ for translating value of capital stocks. Since there is no data from the National Wealth Statistics after 1997, total fixed capital formation deflator is changed from the 1997 data onward to a constant price of 2000, reflecting depreciation since 1998.

3.2.2 Human capital stock

Ahn (2011) adopts the model of Jorgenson and Fraumeni (1989, 1992), which compared human capital to physical capital with an income-based approach for calculating economic growth in the U.S. market.[9] However, his method is based on the income and wage, which does not match with the present model.

As our study focusses on education, the human capital stock is also estimated with education expenditure. Following Ahn (2013), Shaw (2013), Annabi (2007) and Lee (1998), education stock, A, has been calculated as:

$$A_t = A_{t-1}(1-\delta) + I(t) \quad \text{Eq. (1)}$$

Annabi (2007) found the sensitivity of elasticity in public spending, with ζ , 0.18, including this in the investment of education.[10] As the preset model considers two different types of labor, those are counted separately; moreover, the stock of education is accumulated

[9] Jorgenson and Fraumeni (1989, 1992) assume that the price of labor services is decided by wage in the labor market, meaning that the scale of human capital stock is equal to the current value of a person's lifelong labor income.

[10] Heckman et al. (1998) have introduced human capital depreciation (0.04); however, the importance of investment on human capital has changed the depreciation rate recently. Groot (1998) and Hong (2003) estimate depreciation of education from England at 0.11 and the Netherlands at 0.17.

every four years, at the time of average grade change.[11] The stock of skilled labor (ASL) and stock of unskilled labor (AUL) are estimated by the previous human capital stock times considering depreciation, δ = 0.07 with the summation of education investment[12]:

$$ASL_{(t+4)} = ASL_t(1-\delta_s) + IAS^{\zeta_s} \quad \text{Eq. (2)}$$

$$AUL_{(t+4)} = AUL_t(1-\delta_u) + IAU^{\zeta_u} \quad \text{Eq. (3)}$$

For the initial value, the equation can be expressed as Eq. (4) and Eq. (5), with growth rate of human capital, g = 0.029, provided by Bank of Korea (2009):

$$ASL(0) = \frac{1}{g_s + \delta_s} \cdot IAS(0) \quad \text{Eq. (4)}$$

$$AUL(0) = \frac{1}{g_u + \delta_u} \cdot IAU(0) \quad \text{Eq. (5)}$$

[11] Rojas-Romagosa (2010) set each education level with a gap of 3 to 4 years, depending on the levels.
[12] Korea Institute of Public Finance (2007) shows human capital depreciation according to the finance activities.

3.2.3 Knowledge stock

R&D investment and outcomes produce knowledge stock, which is hard to show quantitatively. According to the assumption of knowledge capitalization expressed in the previous chapters, with the depreciation rate, the equation of knowledge stock can be expressed as in Eq. (6), as emphasized by Shin (2004).

$$RDS_t = (1-\delta)RDS_{t-1} + RDI_{t-i} \quad \text{Eq. (6)}$$

RDS_t = Knowledge stock of ‘t'

RDI_t = R&D investment in ‘t’ period

δ = Depreciation rate

The knowledge stock of base year must be defined, since it accumulates every year from the baseline, as per Eq. (7) below:

$$RDS_{t0} = \sum_{j=0}^{\infty} RDI_{t_0-j}(1-\delta)^{j} \quad \text{Eq. (7)}$$

When the past years’ increasing rate of knowledge is the same as after the base year, the Eq.(2) can be transformed into Eq. (8)):

$$RDS_{t_0} = RDI_{t_0}\left[\frac{1+g}{g+\delta}\right] \quad \text{Eq. (8)}$$

In this study, we suppose one year of time series of R&D and 0.15 of knowledge depreciation with two different sectors, public and private. With the base year from 1991, knowledge stock has been estimated, determined by the National Science & Technology Commission and KISTEP (2009). Due to the private knowledge stock not having been calculated in the previous data, we structure the present SAM with the base year from 2005 including the knowledge sector.

Table 7. Each activity's private and public knowledge stock in 2009

Activity	Knowledge Stock
Agriculture	0.08
Manufacturing	105
Service	20
Sum of private knowledge stock	125
Sum of public knowledge stock	41

Units: Millions KRW

3.3 Structure of the human capital- and R&D-focused CGE

3.3.1 The dynamic CGE model

The CGE model is the most useful methodology for analyzing multisectoral economic effects of R&D, as demonstrated by Im (2011). As R&D effect has economic externality, it is hard to achieve a precise analysis with econometric methodology, which considers partial equilibrium; furthermore, the effect of R&D gradually emerges in the long-term. Thus, to determine the effects of R&D investment, a dynamic CGE model that observes more than ten years must be applied.

Unfortunately, there are, not many previous studies using a dynamic CGE model due to several reasons. First, it takes too much time to structure the model starting from building a SAM. For the first step, the data—at least, the IO table, System of National Account (SNA), and other public information—need to be considered with economic backgrounds, micro, macro, and endogenous theories; then, the programming, named GAMS, is necessary to operate for realizing the CGE model, which is time consuming. Second, as the CGE model has used many parameters found in previous literatures or novel studies, the reliability problem occurs. Despite using a sensitivity test for improving precision of outcome, there are still limitations in reflecting reality.

Hudson and Jorgenson (1974) have adapted a dynamic CGE model for having precise results, which steadily develop with adding endogenic elements and various policy inputs.

Unlike the static CGE model, which only considered changes of policies, the dynamic CGE model considers time series with stocks and population growth.

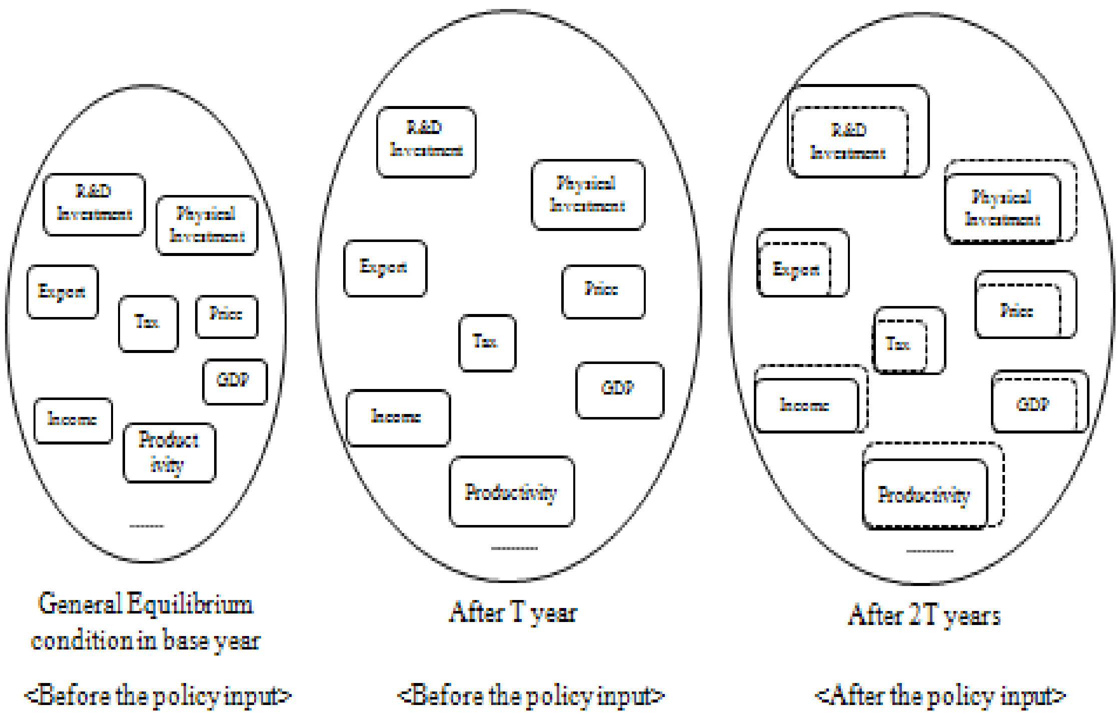

Figure 3. Forward-looking CGE model (dynamic CGE model)

There are two CGE model types: 1) time recursive model and 2) inter-temporal optimization or forward looking model.[13] The time recursive model finds static equilibrium in every period, which determines the dynamic equilibrium; moreover, present decision makings do not affect the future parameters, as shown by Shin (1999).[14]

The forward looking model assumes utility maximization such that each economic unit acquires complete knowledge of future behaviors. Since the model covers not only specific times but also a whole period, even a policy effect affects the past and the future. With the development of the computer, programming, GAMS for example, has been used to observe more detail processes.

For analyzing policy effects of the entire period, the forward looking model is utilized in this study. The essential point is that the investment in time ‘t’ becomes the stock in time ‘(t+1)’. The stocks are endogenously produced in the time ‘t’ passing to the next time (t+1) as the exogenous parameter.

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[13] Time recursive model is also called the sequential dynamic model, and the forward looking model is also called the truly dynamic model.
[14] This point of view is called myopic expectation.

3.3.2 Detailed equations

The present study assumes that each industry has the same production structure. With the Leontief function, every intermediate good is gathered with composite value-added productions, as below:

$$Z(i,t) = \min\left[\frac{X(1,i)}{ax(1,i)},\ldots,\frac{X(n,i)}{ax(n,i)},\frac{VA(i,t)}{ava(i,t)}\right] \cdots\cdots\cdots \text{Eq. (9)}$$

$Z(i,t)$ = Final product of industry

$X(j,i)$ = Intermediate goods

$VA(i,t)$ = Composite value-added productions

$ax(j,i)$ = Input coefficient of intermediate goods

$ava(j,i)$ = Input coefficient of composite value-added productions

The knowledge produced in the public R&D sector is one of the production input factor, and in the private R&D sector it is positively contributing to total factor productivity.

Stocks are creating a spillover effect. The model used in this study is not considering stocks occurred from foreign sources. These stocks affect every industry sector indirectly. Following to Teleckyi (1980), the model calculates each industry’s stock utilized to measure spillover effect by ratio of the amount of trade of intermediate goods, as shown in the IO table. Reflecting Leontief function for the coefficient of spillover effect is shown as below:

$$VA(i,t) = ava(i,t)Z(i,t) \qquad \text{Eq. (10)}$$

$$ava(i,t) = ava(i,0) / spl(t) \qquad \text{Eq. (11)}$$

$spl(t)$ is the coefficient that shows spillover effect produced by stocks. It also affects $ava(i,t)$, the coefficient of Total Factor Productivity (TFP) in production function.[15]

[15] Das et al. (2001) and Cian and Parrado (2012) combined spillover effect as per Eq. (11).

Chapter 4. Simulation

4.1 Scenario setting

As Lucas (1988) and Romer (1990) express that education and R&D should be considered in a long-term growth model with the critical factor, stock, the present simulation observes the scenarios until 2020 from the baseline of 2009 and adapting a dynamic CGE model. With the twenty years of probation, it is possible to show short- and long-term effects. As explained in Chapter 3, the dynamic model produces detailed information of growth rate for each year by considering stocks.

Scenarios are set based on the investment and comparison. As the model focuses on the education and R&D, comparing these elements is inevitable. With the classification of labor by education levels, the scenario shows the effect of investment in different levels of education.

According to the OECD (2012), the education investment ratio of the Republic of Korean government was 7.3% of total GDP in 2009, which means the effect of education investment depends heavily on the growth of GDP. The specific investment rates of skilled and unskilled labor are 2.6% and 4.7%. As the present model set two variables, education and R&D, those elements are compared. In the first two scenarios, the model fixed the government investment on R&D to observe the impact of education stock.

Table 8. Scenario setting

Classification	Explanation
Base Scenario (BAU)	Maintaining investment rate of education and R&D continuously
Scenario 1 (SC1)	Investing on skilled education up to 5.7% of GDP when investment in R&D by government is fixed
Scenario 2 (SC2)	Investing on unskilled education up to 3.6% of GDP when investment in R&D by government is fixed
Scenario 3 (SC3)	Government invests in R&D up to 1.8% when investment in education by government is fixed
Scenario 4 (SC4)	Increasing physical capital when investment in education and R&D by government is fixed

For comparing with scenarios, we set BAU[16] with the year, 2009. Since the investment in R&D is lower than that in education, the value is adjusted accordingly. Calculating 1.8% of R&D investment by the government by adding the calculated

[16] BAU = Business-As-Usual scenario, which is the reference scenario.

value to the initial value of human capital determines the growth rate of human capital.[17]

To observe the R&D effect on the economy other than from human capital, the present model sets the second scenario, which fixed human capital investment. Government invests 5% of GDP in R&D. For comparing scenarios with the original difference, we set business as usual (BAU), which denotes no shock.

To classify two education types, skilled and unskilled, it is assumed that the government invests one of those of types in SC1 and SC2. SC1 represents the investment in unskilled and when SC2 the investment in skilled labor. Physical investment was also used to observe the short-term effect.

4.2 Results

The results show the changes from 2009 to 2030 with various values. Most outcomes show a positive effect when investment in human capital has occurred. Due to the Republic of Korea having higher labor productivity, the effect of education, as seen with the labor sector in this study, impacts on economic growth. As shown in Figure

[17] The government of South Korea aims 5% of R&D investment; moreover, the ratio of R&D investment by household and government is 3:1 following to the BAU.

(5), the GDP growth has a higher rate in SC2, focused on unskilled education because of higher labor productivity. The rate of increase falls from 2016 due to the population growth decreasing. The main reason for the sudden change during 2013~2014 is time difference, which occurs after four years from the base year. As in the above, the value-added created by labor has the most positive effect compared to other factors, capital and knowledge. Although investment in physical capital shows changes compared to the base scenario, other investments have greater effects.

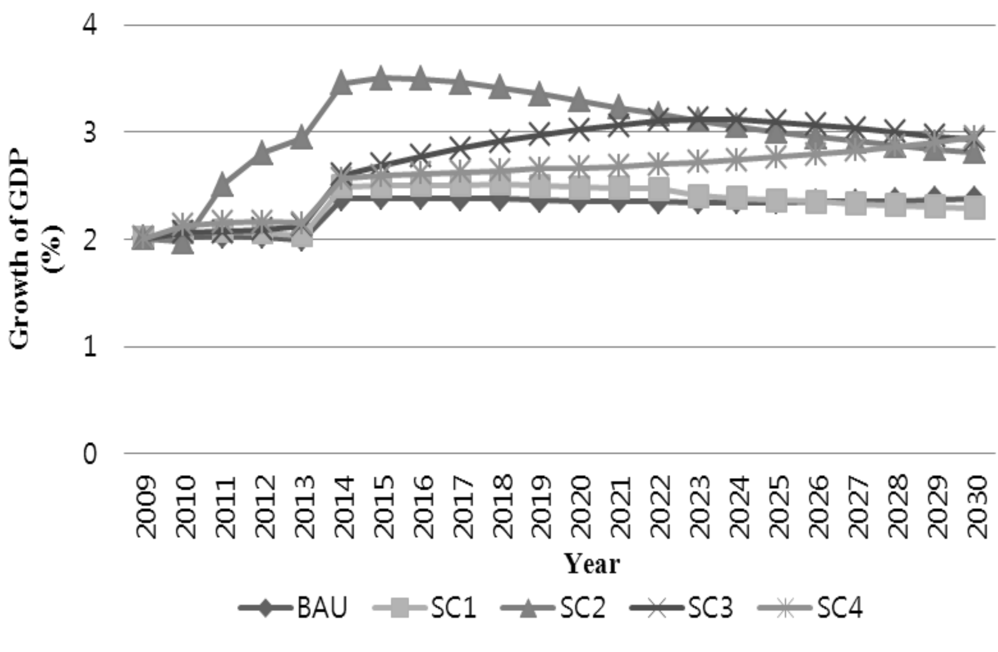

Figure 4. Growth of GDP

Since there were no actual investments of capital, the observation of changes in stocks need to be determined. As in Figure (6), the capital stock is mostly saved in SC2 when other scenarios also increased gradually. Even with the time difference, there were no rugged because of the concept of stock explained in Section III.

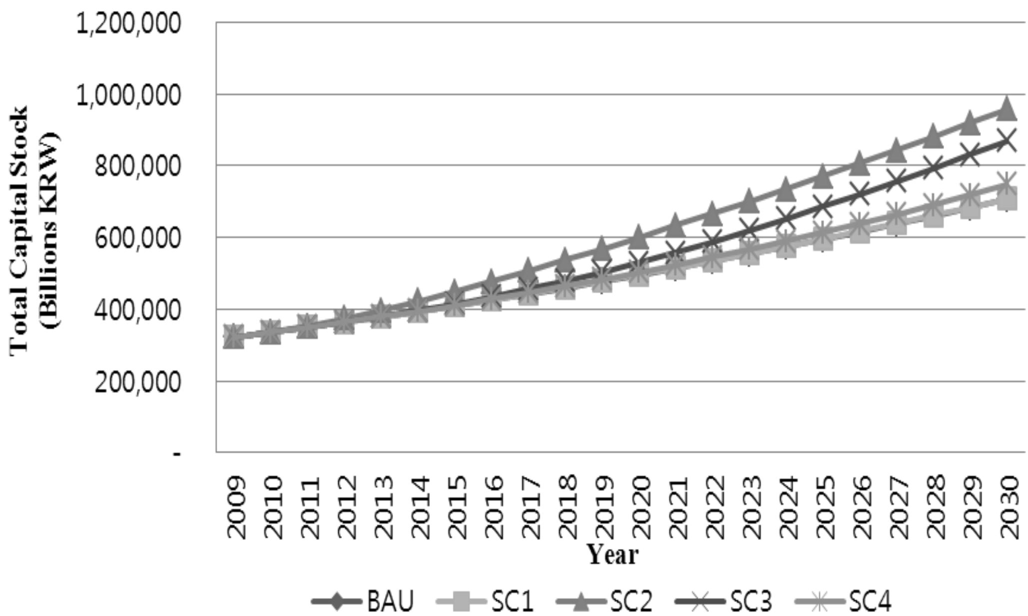

Figure 5. Capital stock

Following the importance of the labor productivity in South Korea, the labor force is estimated depending on the scenarios. When the labor is calculated together, the labor force has no difference from other scenarios, as shown in Figure (7). According to the fact, this is distributed into two types.

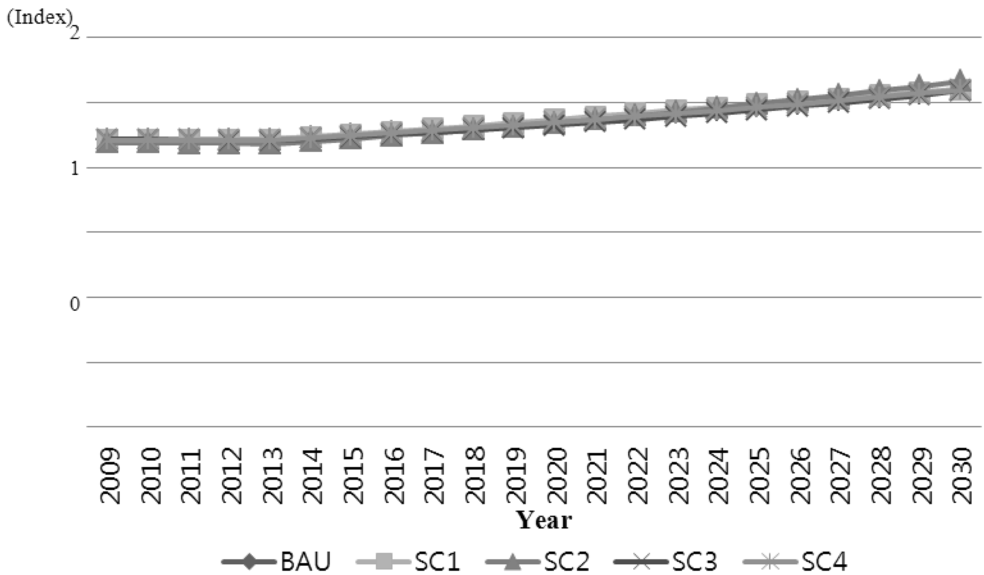

Figure 6. Labor force

Despite classification of the unskilled labor force having no changes as expected, there was an impact in skilled labor force. The rate of skilled labor force has a greater effect than other investments; particularly, with R&D which requires skilled labor force, SC1 has impressively increased. This means that investment on the skilled education has increased labor force more than other investment.

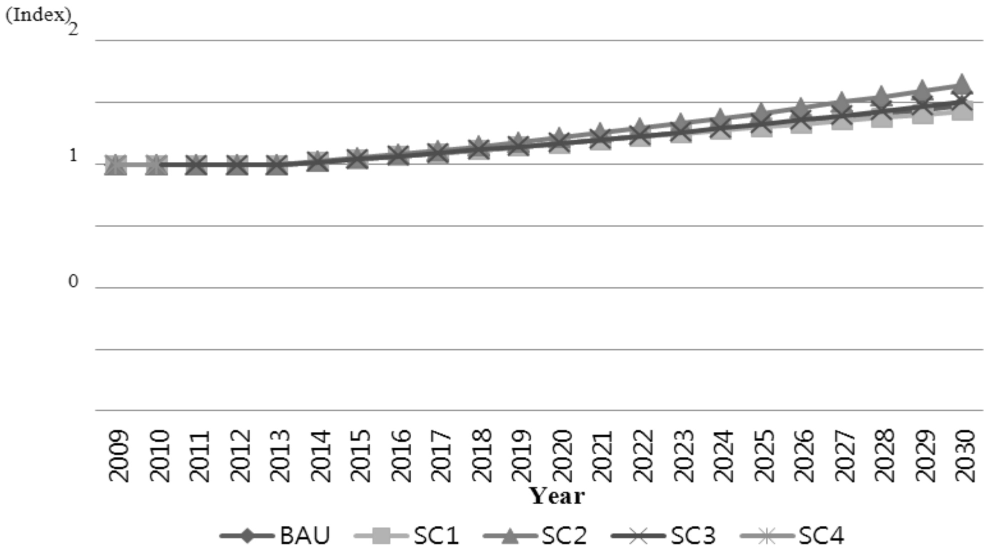

Figure 7. Unskilled labor force

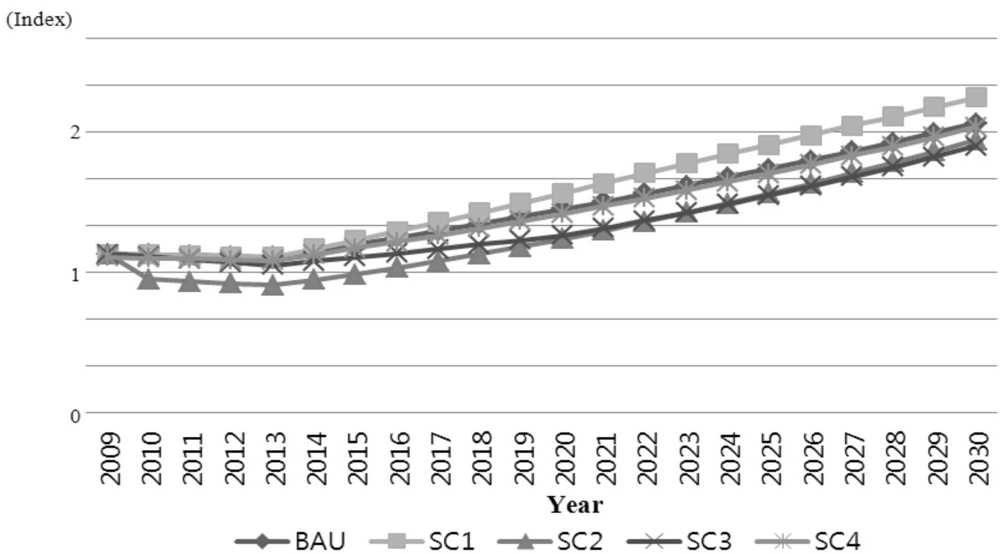

Figure 8. Skilled labor force

There was an interesting result in total output of whole industry. As shown in Figure (10), the total output of SC1 has no increase in rate from 2016. The reason of the decrease is that the unskilled labor does not affect R&D at all in the present model though skilled labor does. This means that no labor educated under the high school level is engaged in most of the manufacturing and service industry. Following to the fact, SC2 has the higher rate than other scenarios even more than SC3, the R&D focused scenario.

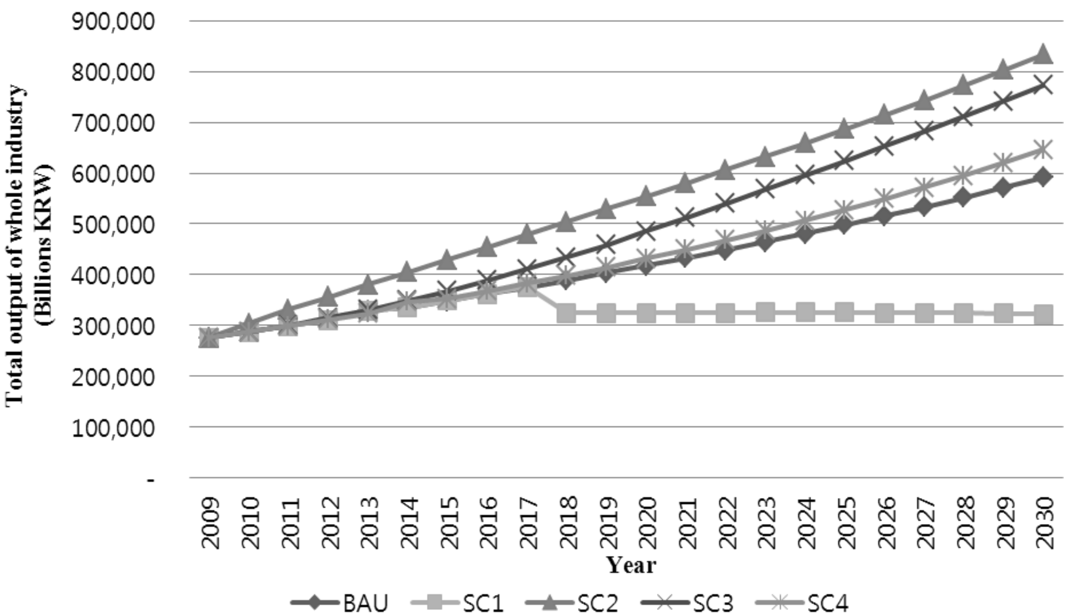

Figure 9. Total output of whole industry

To achieve detailed comparison of each industry, the histogram is created. As explained, SC1 has lower output than BAU scenario despite additional investment by the government. SC2 has the most positive impact among all industries, agriculture, manufacturing, and services.

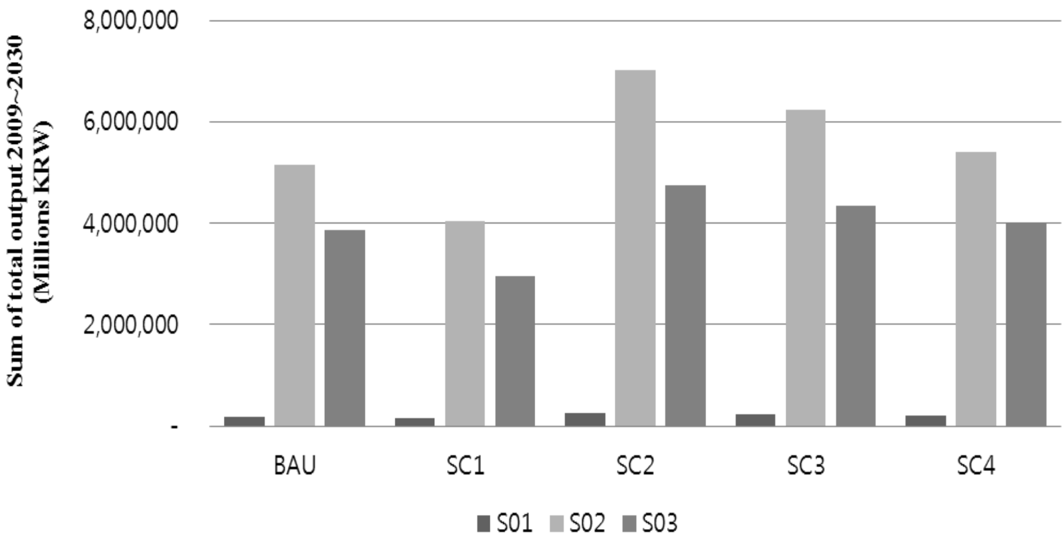

Figure 10. Comparison of total output from each industry (2009~2030)

Chapter 5. Conclusion

5.1 Summary

The study mainly focused on the human capital and R&D stocks produced by investment affect on economic growth of the Republic of Korea. To observe the ripple effect from specific parts, a dynamic CGE model was adopted.

For the first step, the basic SAM was structured based on the I-O table for the Republic of Korea. For focusing on the effect of education and R&D investment, the labor sector has classified into two parts, skilled and unskilled, by education levels; the R&D sector is newly added under the investment sector with two sections, private and public. These elements are used in creating stocks. In addition, industry sectors are condensed from twenty-eight to three.

The main reason of using the CGE model is observing the ripple effect. The model in this study, especially, adopts a forward looking dynamic model that considers investment in each year. Unlike in previous studies, we contemplate both human capital and knowledge stocks produced by education and R&D. For analyzing specific effect of stocks, our model set the simulations with a twenty-year period so that both short- and long-term growth rates can be compared.

5.2 Policy Implications

As seen in the previous chapter, the investment in education has deeply impacted economic growth. As the Republic of Korea has higher labor productivity, investment in labor, especially unskilled, raises the GDP rate. However, there were opposite results in output from industries. Unlike GDP rate, the total output of industries has not increased with investment in unskilled education. This is because the unskilled labor is not transferable into the most of the manufacturing or service sector.

Labor force, the critical factor in South Korea's economic growth, has increased in terms of skilled labor. There were minimal changes in investment in unskilled education due to the population who only graduated high school not directly affecting the industries. Unlike unskilled labor, skilled labor has increased gradually, more so than R&D investment, which means the investment in skilled education is mostly positive, resulting in more output from the industries.

Since Shultz (1964) and Becker (1961) proposed the human capital theory, investment in education is considered important in forecasting long-term economic performance. Although the terms of the period changed to the neoclassic with Lucas (1988) and Romer (1990), the perceived importance of labor has increased impressively. In particular, research focusing on skilled labor investment is found in many previous studies, even in the Republic of Korea.[18] As the environment of the Republic of Korea has higher labor productivity, investment in education must be prioritized.

5.3 Limitation

Education is basically invested in only by public sector in this study because there are no data or information for private investment in the education sector; this means that a cost gap likely occurred. In the data on education levels, there are only four different levels excluding graduate college. As high-skilled labor has more effect on each industry, specific data for the higher level of education must be considered. If the econometric method had been utilized in the critical parameters, like human capital stock, detailed numerical value of stock would have been found. Lastly, to show more detailed comparison between investments in education or R&D, the education part needs to be added under the investment sector in SAM as R&D investment.

[18] Park (2005), Ahn (2013), and Park (2007) express the impact of education investment, which shows higher GDP growth in the Republic of Korea.

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Appendix 1: The basic structure of Social Accounting Matrix (SAM)

For structuring R&D and human capital focused CGE, SAM need to be created first. Our model basically uses 2009 IO table prepared by Bank of Korea and follows previous literature written by Kim (1998) and Park (2005). As Table 1 shows, SAM is written in matrix-from. Each row defines expense and each column specifies income. Si means the total addition of each row and column; those of same ‘S’ accounts must have equal amount. Each element S(i, j) expresses expense from ‘j’ account to ‘i’ account; it also shows income from ‘i’ to ‘j’. When there are exact same amount of expense and import, it has followed Warlas’ law.

SAM presents a country’s economic flow, productivity, consumption, and saving activities in the certain period. For showing those of activities, the basic SAM includes six elements: Activity, Factor, Institution, Investment, Tax, and Foreign. The Activity section, in production side, has a structure that including productivity factors from both of interior and imported goods; then expense to a tax sector. In demand side, products produced by activity utilize to intermediate consumption, institution sector, and foreign sector.

There are two parts, Labor and Capital, in the factor sector. Produced value-added and relevant income, compensation of labor and capital, provide to institute sector, organized by household and government. Household has income from the activity sector by providing productivity factors, labor and capital; then, tax to government. Reminders are using in saving and consumption. Government, the main actor of economic flow, collects taxes for replenishing other sectors. Saving of household and government create physical investment sector. Each industries in activity sector imports or exports commodities which are shown in foreign sector.

Table 9. Basic SAM

Classification		ACTIVITY		FACTOR		INSTITUTION		INVESTMENT	TAX				FOREIGN		Total
		Interior Goods	Imported Goods	Labor	Capital	Household	Gov.	Physical Investment	Indirect	Corporate	Income	Tariff	Export	Import	
ACTIVITY	Interior Goods	S(1,1)				S(1,5)	S(1,6)	S(1,7)					S(1,12)		S1
	Imported Goods	S(2,1)				S(2,5)	S(2,6)	S(2,7)							S2
FACTOR	Labor	S(3.1)													S3
	Capital	S(4.1)													S4
INSTITUTION	Houshold			S(5,3)	S(5,4)		S(5,6)								S5
	Government							S(6,7)	S(6,8)	S(6,9)	S(6,10)	S(6,11)			S6
INVESTMENT	Physical Investment					S(7,5)	S(7,6)							S(7,13)	S7
TAX	Indirect	S(8,1)													S8
	Corporate	S(9,1)													S9
	Income	S(10,1)													S10
	Tariff		S(11,2)												S11
FOREIGN	Export													S(12,13)	S12
	Import		S(13,2)												S13
Total		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	

In activity sector, S(1,1) and S(1,2), input of intermediate commodities, show domestic breakdowns (D) in Transactions Table of Domestic and foreign breakdowns (M) in Transactions Tables of Foreign. Each S(1,1) and S(1,2) has 28x28 matrix based on the IO table 2009, provided by Bank of Korea. Employee income, S(3,1), is the compensation of labor input appeared 1x28 row vector ‘W’. In the same term, S(4,1), the compensation of capital input shows with operating surplus of each industries (E) and consumption of fixed capital (DE) in 1x28 row vector. There are two types of taxes collected by government. Indirect tax S(8,1) applies 1x28 column vector (PT) from product tax (subsidy deduction) in IO table 2009. For estimate precise Corporate tax, S(9,1), multiplying operating surplus of each industry with corporate income tax rate, found by Kim (2009); then, expressing in 1x28 column vector (CT).

Tariff, S(11,2), is shown as 1x28 column vector (T), which inversely changes from 28x1 row vector of adding each industries’ tariff with import tax. Other than those of data, R&D sector has added with knowledge stock and labor sector has distributed into two, organized by education levels, with human capital stock. Net income, S(13,2), also uses inverse matrix of income from each industry, shown as 1x28 column vector, ‘NM’. Complying to double-entry bookkeeping system, income distribution, S(5,3) and S(5,4), reflects S3 and S4.

Table 10. Main Factors in SAM

Main Factors of Basic SAM		
S(1,1) = D	S(5,3) = S3	S(1,7) = DFC
S(2,2) = M	S(5,4) = S4	S(2,7) = MFC
S(3,1) = W	S(1,5) = DPC	S(6,8) = S8
S(4,1) = E + DE	S(2,5) = MPC	S(6,9) = S9
S(8,1) = PT	S(7,5) = CS	S(6,10) = S10
S(9,1) = CT	S(1,6) = DGC	S(6,11) = S11
S(11,2) = T	S(2,6) = MGC	S(1,12) = X
S(13,2) = NM	S(7,6) = GS	S(12,13) = S12

S(1,5) uses 28x1 column vector (DPC) in domestic parts of IO table and S(2,5) utilizes 28x1 column vector (MPC) in foreign parts of IO table. Household saving, S(7,5), is the sum of household sector in SNA and net saving (CS). Consumption of interior goods, S(1,6), uses consumption of government to each industry in Transactions Table of Domestic (DGC), 28x1 column vector, and consumption of imported goods, S(2,6), utilizes Transactions Table of Foreign parts (MGC), 28x1 column vector. Government saving, S(7,6), uses net saving (GS) part in System of National Account (SNA). Physical investment, S(1,7), reflects the addition of public and private physical investment and inventory change in the domestic parts shown as 28x1 column vector (DFC). S(2,7) applies 28x1 column vector of foreign parts (MFC). Following to the double entry system, each tax sections, indirect, corporate, income, and tariff have shown as below. The export section, S(1,12), has literally shifted from the export part in IO table which is shown as the 28x1 column vector (X). S(12,13) is the total addition of exports. Finally, transfer to household, S(5,6), government debt, S(6,7), and trade balance, S(7,13) would be balancing at the last step for equilibrium.

Appendix 2: Model Variables and Parameters[19]

Sets	
$i, j \in INDUSTRY$	Element of Industries
$l, m \in INPUT\ FACTOR$	Input Factors
$com \in COMMODITY$	Commodities
$t \in TIME$	Base year of 2009
$rdt \in \{RDC, RDG\}$	R&D of private and public sector

Parameters			
$ax(i, j)$	Intermediate goods in 'i' industry for creating a commodity in 'j' industry	$\Gamma_{RD}(i)$	Coefficient of R&D function
$ava(i)$	Value-added for creating commodity in 'i' industry	$\rho_{RD}(i)$	Elasticity of R&D investment
$\mu(i)$	Consumer goods of government	$\omega(i)$	Price weighted value of private R&D investment
$\lambda(i)$	Each industry's investment goods	$\chi(i)$	Price weighted value of public R&D investment
$rdg(i)$	R&D investment goods of government	$\alpha(i)$	Consumer goods of household
$rdh(i)$	R&D investment goods of households	$cs(com, i)$	Production in 'i' industry composed a consumer good
$\nu(i)$	Armington composite goods	$\xi(i)$	CET fucntion

19 Appendix 2 and 3 are applied the study of Lee (2012)

$\eta(i)$	Armington composite elasticity of substitution	$\varphi(i)$	CET function elasticity of substitution
$\gamma(i)$	Armington composite coefficient	$\theta(i)$	CET function coefficient
Γ_K	Coefficient of investment function in physical capital	ρ_K	Elasticity of physical capital investment
$rs(rdt)$	Coefficient of value-added composite production function in R&D	$rn(rdt)$	value-added composite production function in Labor
$rm(rdt)$	Coefficient of intermediate composite production goods in R&D	$axrd(rdt,i)$	Intermediate composite goods in R&D
$rdi(rdt)$	R&D intensity of public or private sector	$ayrd(rdt,i)$	The ration of value-added composite production in R&D output
$shrd(rdt)$	Coefficient of R&D function	$rp(rdt)$	Household's saving in R&D investment
$\varsigma(com)$	Ration of consumer goods	$intw(i,j)$	Coefficient of spillover effect created by industries
$sf(i)$	Coefficient of spillover effect function		

Exogenous Variables			
$pwe(i,t)$	International price of exported goods ($)	ir	Interest rate
$pwm(i,t)$	International price of imported goods ($)	$hdep$	depreciation

$ti(i)$	Tariff	$kdep$	Depreciation of capital stock
$tl(i)$	Tax on labor income	gt	Government's transfer to household
$tk(i)$	Tax on capital income	$gl(t)$	Population growth
$th(i)$	Tax on knowledge income	$rdes(i)$	Elasticity of R&D stock in industries
$tz(i)$	Indirect tax	$grdes(i)$	Elasticity of public R&D stock
$trd(rdt)$	Tax on R&D		

Endogenous variables			
$ex(t)$	Exchange rate (dollar/Korean won)	$D(i,t)$	Domestic goods
$pe(i,t)$	Price of exported goods	$E(i,t)$	Exported goods
$pm(i,t)$	Price of imported goods	$M(i,t)$	Imported goods
$pva(i,t)$	Price of composite goods	$VA(i,t)$	Value-added composite goods
$rk(t)$	Rental price of capital stock	$K(i,t)$	Capital demand of each industry

$w(t)$	Wage	$L(i,t)$	Labor demand of each industry
$rh(i,t)$	Rental price of knowledge stock	$H(i,t)$	Knowledge stock
$pz(i,t)$	Price of production	$X(i,j,t)$	Intermediate goods in ‘i' used in ‘j’ industry
$pq(i,t)$	Price of Armington composite productions	$Z(i,t)$	Total production in ‘i’ industry
$prdz(rdt,t)$	Price of R&D output	$Q(i,t)$	Armington composite production
$TL(i,t)$	Tax on labor income	$LI(t)$	Labor income of household
$TK(i,t)$	Tax on capital income	$KI(t)$	Capital income of household
$TH(i,t)$	Tax on knowledge income	$RI(t)$	Knowledge income of household
$TZ(i,t)$	Indirect tax	$HI(t)$	Total income of household
$TM(i,t)$	Tariff	$INVRES(t)$	Resources of investment
$XG(i,t)$	Consumption of government	$SP(t)$	Saving of household
$GI(t)$	Government income	$XV(i,t)$	Commodities used in investment
$HG(t)$	Public knowledge stock	$pinvk(t)$	Price of capital investment goods

$SG(t)$	Government saving	$INVK(t)$	Capital investment
$XP(i,t)$	Consumption of household	$pinvrd(t)$	Price of R&D investment goods
$pcm(com)$	Price of households' consumer goods	$INVRD(i,t)$	Ration of R&D investment
$CM(com)$	Household commodities	$RDZ(rdt,t)$	R&D productions
$spl(t)$	Coefficient of spillover	$pd(i,t)$	Price of domestic goods
$U(t)$	Utility of consumer	$LS(t)$	Supply of total labor
$KS(t)$	Total capital stock	$RDind(i,t)$	R&D investment of each industry
$sg(t)$	Saving rate of government	$GDP(t)$	GDP
$sp(t)$	Saving rate of household	$SF(t)$	Foreign Saving (Trade balance)
$Kdep(t)$	Depreciation of capital stock	$TRD(rdt,t)$	Tax on R&D
$Hdep(t)$	Depreciation of knowledge stock	$RVA(rdt,t)$	Composite value-added in R&D sector
$BG(t)$	Debt of government	$RLS(rdt,t)$	Labor demand of R&D
$TSAV(t)$	Total saving	$RKS(rdt,t)$	Capital demand of R&D

$prva(rdt,t)$	Price of composite value-added in R&D	$RDM(rdt,t)$	Composite intermediate goods in R&D
$prdm(rdt,t)$	Price of composite intermediate goods in R&D	$XVRD(rdt,i,t)$	Intermediate goods used in R&D investment
$INTST(i,t)$	R&D stock in each industry		

Appendix 3: Equation

[Production]

Demand of intermediate goods for final production

$$X(i,j) = ax(i,t)Z(j,t)$$

Demand of composite value-added for final production

$$VA(i,t) = ava(i,t)Z(i,t)$$

Zero profit condition of final producer

$$pz(j,t) = ava(j,t)\,pva(j,t) + \sum_i ax(i,t)\,pq(i,t)$$

Spillover effect of knowledge stock

$$ava(i,t) = ava(i,0)/spl(t)$$

[Household]

Labor income

$$LI(t) = \sum_j w(t)SL(i,t) + \sum_j w(t)UL(i,t)$$

Capital income

$$KI(t) = \sum_j rk(t)KS(i,t)$$

R&D stock income

$$RI(t) = \sum_i rh(t)H(i,t)$$

Total income of household

$$HI(t) = KI(t) + LI(t) + RI(t) + TG(t)$$

Final consumption of household

$$XP(i,t) = \alpha(i)(1 - sp(t)) \left\{ HI(t) - \sum_{i} \left(TSL(i,t) + TUL(i,t) + TK(i,t) + TH(i,t) \right) \right\} / \; pq(i,t)$$

Consumer goods

$$CM(com,t) = \sum_{j} cs(com,i) XP(i,t)$$

Value of consumer goods

$$pcm(com) CM(com,t) = \sum_{j} cs(com,i) \, pq(i,t) XP(i,t)$$

Household utility

$$U(t) = \prod_{com} CM(com,t)^{\zeta(com)}$$

[Government]

Tax on skilled labor income

$$TSL(i,t) = tl(i) \, pl(t) SL(i,t)$$

Tax on unskilled labor income

$$TUL(i,t) = tl(i) \, pl(t) UL(i,t)$$

Tax on capital income

$$TK(i,t) = tk(i) rk(i) K(i,t)$$

Tax on knowledge value-added income

$$TH(i,t) = th(i)rh(i,t)H(i,t)$$

Indirect tax

$$TZ(i,t) = tz(i)pz(i,t)Z(i,t)$$

Tariff

$$TM(i,t) = ti(i)pm(i)M(i,t)$$

Tax on R&D

$$TRD(rdt,t) = trd(rdt)prdz(rdt)RDZ(rdt,t)$$

Final consumption of government

$$XG(i,t) = \mu(i)(1-sg(t))(1-gt)GI(t) / pq(i,t)$$

Government transfer

$$TG(t) = gtGI(t)$$

Government income

$$GI(t) = \sum_j \left\{TL(i,t) + TK(i,t) + TH(i,t) + TZ(i,t) + TM(i,t)\right\} + BG(t)$$

[Investment and saving]

Total investment

$$INVRES(t) = \sum_i XV(i,t)pq(i,t) + \sum_{rdt}(1+trd(rdt))prdz(rdt,t)RDZ(rdt,t)$$

Total saving

$$TSAV(t) = SP(t) + SG(t) + ex(t)SF(t)$$

Composition of capital investment

$$XV(i,t) = \lambda(i) INVK(t)$$

Demand of physical investment

$$INVK(t) / KS(t) = \Gamma_K \left(\frac{rk(t)}{pinvk(ir + kdep)} \right)^{\rho_K}$$

Price of physical investment goods

$$pinvk(t) = \sum_i \left\{ pq(i,t)\lambda(i) \right\}$$

Demand of R&D investment

$$\frac{INVRD(i,t)}{H(i,t)} = \Gamma(i) \left(\frac{rh(t)}{prdz(RDC)(1 + trd(RDC))(ir + hdep)} \right)^{\rho(i)}$$

Amount of R&D investment in each industry

$$RDind(i,t) = RDZ(i,t) invrd(i,t) / \sum_j invrd(j,t)$$

Composite value-added production function in R&D

$$RVA(rdt,t) = rs(rdt)(pl(t)RLS(rdt,t))^{rn(rdt)} (pk(t)RKS(rdt,t))^{(1-rn(rdt))}$$

Composite value-added production function in capital

$$RKS(rdt,t) = (1 - rn(rdt)) prva(rdt,t) RVA(rdt,t) / rk(t)$$

Intermediate goods used in R&D

$$XVRD(rdt,i,t) = axrd(rdt,i) prmd(rdt,t) RDM(rdt,t) / pq(i,t)$$

Ratio of intermediate goods in R&D

$$RDM(rdt,t) = (1 - ayrd(rdt)) RDZ(rdt,t)$$

Ratio of composite value-added in R&D

$$RVA(rdt,t) = ayrd(rdt)RDZ(rdt)$$

Zero profit condition of R&D

$$prdz(rdt,t) = ayrd(rdt)\,prva(rdt) + (1 - ayrd(rdt))\,prdm(rdt)$$

R&D intensity

$$(1 + trd(rdt))\,prdz(rdt,t)RDZ(rdt,t) = rdi(rdt)GDP(t)$$

Household saving

$$SP(t) = sp(t)\left(HI(t) - \sum_i TL(i,t) + TK(i,t) + TH(i,t)) \right)$$

Government saving

$$SG(t) = sg(t)(GI(t) - TG(t))$$

Government debt

$$BG(t) = TSAV(t) - INVRES(t)$$

Relationship between saving and R&D

$$(1 + trd(rdt))\,prdz(rdt,t)RDZ(rdt,t) = shrd(rdt)SP(t)^{rp(rdt)}\,SG(t)^{(1-rp(rdt))}$$

[Foreign]

Price of export

$$pe(i,t) = ex(t)\,pwe(i,t)$$

Price of import

$$pm(i,t) = (1 + ti(i))ex(t)\,pwn(i,t)$$

Trade balance

$$\sum_j pwe(i,t)E(i,t) + SF(t) = \sum_j pwm(i,t)M(i,t)$$

[Import and Export]

Armington composite goods

$$Q(i,t) = \gamma(i)\left[v(i)M(i,t)^{\eta(i)} + (1-v(i))D(i,t)^{\eta(i)}\right]^{\frac{1}{\eta}(i)}$$

Imported goods in Armington composite goods

$$M(i,t) = Q(i,t)\left[\frac{\gamma(i)v(i)\,pq(i,t)}{(1+tm(i))\,pm(i,t)}\right]^{\frac{1}{(1-\eta(i))}}$$

Domestic goods in Armington composite goods

$$D(i,t) = Q(i,t)\left[\frac{\gamma(i)(1-v(t))\,pq(i,t)}{pd(i,t)}\right]^{\frac{1}{(1-\eta(i))}}$$

Final production

$$Z(i,t) = \theta(i)\left[\xi E(i,t)^{\phi(i)} + (1-\xi)D(i,t)^{\phi(i)}\right]^{\frac{1}{\phi(i)}}$$

Final production in exported goods

$$E(i,t) = Z(i,t)\left[\frac{\theta(i)\xi\,pz(i,t)}{pe(i,t)}\right]^{\frac{1}{(1-\phi(i))}}$$

Final production in domestic goods

$$D(i,t) = Z(i,t)\left[\frac{\theta(i)(1-\xi)\,pz(i,t)}{pd(i,t)}\right]^{\frac{1}{(1-\phi(i))}}$$

[Market Clearing]

Supply and demand of production

$$Q(i,t) = XP(i,t) + XG(i,t) + XV(i,t) + \sum_j X(i,j) + XRP(i,t) + XRG(i,t)$$

Supply and demand of physical capital

$$\sum_i K(i,t) = KS(t)$$

Depreciation of capital stock

$$Kdep(t) = rkdepKS(t)rk(t)$$

Depreciation of R&D

$$Rdep(t) = \sum_i hdep(j)H(j,t)rh(j,t)$$

GDP (Composition of all value-added)

$$GDP(t) = rk(t)KS(t) + \omega(t)SL(t) + \omega(t)UL(t) + \sum_j H(j,t)rh(j,t)$$

Consumer price index (CPI)

$$pcon(t) = \prod_{com}\left(\frac{pc(com)}{\zeta(com)}\right)^{\zeta(com)}$$

[R&D Stock Spillover]

R&D stock in other industries

$$INTST(i,t) = \sum_{j,j\neq i} \mathrm{int}\,\omega(j,i)H(j,t)$$

Spillover coefficient

$$spl(i,t) = sf(i)(INTST(i,t))^{rdes(i)}(HG(t))^{grdes(i)}$$

[Dynamic Process]

Physical stock accumulation

$$KS(t) = (1 - kdep)KS(t-1) + \sum_i INVK(i, t-1)$$

R&D stock accumulation in each industry

$$H(i,t) = (1 - hdep)H(i, t-1) + INVRD(i, t-1)$$

Accumulation of pubic R&D stock

$$HG(t) = (1 - hdep)HG(i, t-1) + INVRD(i, t-1)$$

[Human Capital]

Investment of skilled human capital

$$IAS(t) = GDP(t) \cdot \omega_S$$

Investment of Unskilled human capital

$$IAU(t) = GDP(t) \cdot \omega_U$$

Skilled labor supply

$$SL(i,t) = SL(i,0)ASL(t)^{\vartheta}\left[1 + gl(t)\right]$$

Unskilled labor supply

$$UL(i,t) = UL(i,0)AUL(t)^{\vartheta}\left[1 + gl(t)\right]$$

Stock of skilled labor

$$ASL(t+4) = ASL(t)(1-\delta) + IAS(t)^{\zeta}$$

Stock of unskilled labor

$$AUL(t+4) = AUL(t)(1-\delta) + IAS(t)^{\mu}$$

초 록

연산일반균형모형을 통한 교육투자와 R&D 투자의 파급효과 분석

본 연구는 두 가지의 중요 요소인 인적자본과 연구개발이 산업 전반에 어떠한 파급효과를 미치는지에 대하여 살펴보았다. 특히, 교육 수준에 따라 노동을 숙련과 비숙련으로 구분하여, 노동 숙련도에 따른 경제적 파급효과의 차이를 살펴보았다.

내생적 성장이론에 따르면, 인적자본과 연구개발은 시간이 지날수록 스톡이 쌓이므로, 동태적 관점에서 그 효과를 판단해야 된다. 이를 위해 이번 연구에서는 동태적 연산일반균형 (Dynamic Computable General Equilibrium) 모형을 도입하여, 장기적인 관점에서 두 요소에 투자가 이루어질 때, 국내 산업 전체에 미치는 연관효과를 분석하였다. 모형의 구축을 위해서, 한국은행의 산업연관표를 기반으로 사회회계행렬 (Social Accounting Matrix)을 작성하였으며, 연구 목적에 따라 연구개발과 교육 수준에 따른 노동계정을 추가하였다. 또한 인적자본스톡과 지식자본스톡을 추계하였다. 인적자본스톡의 경우, 교육 수준에 따라 노동을 두

부문으로 구분하였으며, 고등학교 졸업까지를 비숙련, 초대졸 이상을 숙련으로 나누어 추계하였다. 그리고 지식자본스톡은 공공과 민간 부문으로 나누어 추계하였다.

R&D 와 교육부문을 비교하였을 때, 노동에 직접적인 영향을 주는 교육에 투자를 하였을 때 너 높은 수준의 GDP 성장률을 보였고, 고등 교육에 투자 할 때 더 높은 효과를 얻을 수 있었다.

주요어 : 인적자본, 연구개발, 교육, 연산일반균형

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