Analysis of Economic and Environmental Impacts of CO_2 Abatement in Japan Applying a CGE Model with Knowledge Investment

Ken'ichi MATSUMOTO[1*] and Azusa OKAGAWA[2]

[1]Center for Global Environmental Research, National Institute for Environmental Studies
[2]Social & Environmental Systems Division, National Institute for Environmental Studies

Abstract:
Technology progress plays an important role to efficiently abate CO_2 emissions and contributes to climate change mitigation as a result. Although a lot of computable general equilibrium (CGE) models considering technological change have been developed to analyze climate change issues and policies, most of them incorporate the effect exogenously. However, considering endogenous technological change in CGE models is significant, since direction and magnitude of the change can differ according to taken policies and measures. Recently, some CGE models incorporating endogenous technological change have been developed in US and China, but such examples are still rare.
This paper has two purposes. First is to develop a country-based CGE model based on the Japanese economy considering endogenous technological change. Second is to analyze the effect of subsidies on knowledge investment, or R&D investment, on economy and environment in Japan using the model.

We developed a single-country CGE model with environmental and energy components. It is a recursive dynamic model based on the 2005 Input-Output Table for Japan and industrial sectors are aggregated into 33 sectors. The data on CO_2 emissions are based on the Energy Balance Table for Japan (2005). The model uses nested constant elasticity of substitution structure for production function and final demand.
In the model, endogenous technological change is expressed by knowledge capital and R&D investment. However, they are not separated in the social accounting matrix (SAM) developed based on the above data. Therefore, they are disaggregated from the intermediate input matrix of SAM based on the R&D data in Japan. In the model, knowledge capital has a substitution relationship with the aggregation of the other inputs. The dynamic process of knowledge capital is similar to that of physical capital.
The simulation period of this study is from 2005 to 2030.

The analyzed cases are the combination of CO_2 emissions abatement (0-50% for each year from the baseline) and subsidies on R&D investment (0-50% for each year), a total of 36 cases.
The main results can be summarized as follows.
(1) Carbon price: carbon prices increase as the emissions abatement rate becomes higher and decrease over time in all the cases. Lower carbon prices are observed as subsidies on R&D investment become higher with the exception of a few cases (smaller abatement amount in the earlier years).
(2) Knowledge capital: R&D investment decreases when CO_2 emissions are abated. However, it increases as the subsidies become higher and knowledge capital is accumulated more as a result.
(3) Physical capital: physical capital investment decreases when CO_2 emissions are abated. In addition, it decreases by introducing the subsidies, namely crowding-out, contrary to R&D investment.
(4) GDP and consumption: GDP and household consumption decrease as the emissions abatement rate becomes higher, while they increase as the subsidies become higher. If the abatement amount is not large, the decreases due to the emissions abatement can be offset by the subsidies. Increases in GDP achieved by the subsidies mainly stem from increases in household consumption.

[*] Corresponding author: Address: 16-2, Onogawa, Tsukuba, Ibaraki, 305-8506, Japan
E:mail: matsumoto.kenichi@nies.go.jp

(5) CO_2 emissions: By breaking down CO_2 emissions into GDP, energy intensity and emissions intensity, energy intensity and emissions intensity are the main factors to contribute to the compatibility of CO_2 emissions abatement and increases in GDP. Improvement of CO_2 emissions per unit of GDP is stimulated by the subsidies.

Key words:
Recursive dynamic CGE model; Endogenous technological change; Knowledge capital, R&D investment; Climate change policy; Economic impact

1. Introduction

Climate change is one of the most significant global environmental issues for the present society and policy discussions from mid- to long-term perspectives are continuing all over the world including in Japan and the international arena such as in UNFCCC. Although the expected new protocol for the Post Kyoto Protocol beyond 2013 was not established at COP15 held in Copenhagen in December, 2009, the Copenhagen Accord was made. Based on the accord, the Annex I countries of UNFCCC and some major non-Annex I countries (55 countries and 78% of the world emissions in total) submitted their pledge on GHG emissions abatement by the end of January, 2010 (UNFCCC, 2010). As Prime Minister Hatoyama stated at the United Nations Summit on Climate Change on September 22nd, 2009, the target Japanese government submitted was a 25% abatement compared to the 1990 level. The Hatoyama cabinet also plans to submit the Global Warming Basic Act (tentative title) to the coming ordinary diet session. Promotion of innovative technological development is considered to be one of the fundamental measures and policies in it (MOE, 2010). In addition, the cabinet established a target to raise the research and development (R&D) investment of the total of private and governmental sectors to 4% of GDP by 2020FY following the new growth strategy (basic policies) determined at the extraordinary cabinet meeting on December 30th, 2009 (Hatoyama Cabinet, 2009).

International actions considering the relationships between climate change measures, R&D investment, technological development, and economy preceded such movements. On July 21st, 2008, The Green New Deal Group published “A Green New Deal” (Green New Deal Group, 2008) and UNEP put out a press release on “Global Green New Deal” on October 22nd, 2008 (UNEP, 2008). Along with the speech on such topics given by US President Obama, similar movements have spread to many countries.

In order to address the additional costs and economic impacts that accompany climate change mitigation measures, importance of technological development and its diffusion is being particularly emphasized globally in recent years. Technological change can be understood as the increase in outputs possible from a given level of inputs through the processes of invention, innovation, and diffusion (Gillingham, et al., 2008). That is to say, fewer inputs are required to produce the same amount of outputs if technological change is realized. Especially, a decrease in inputs from fossil fuels can be connected directly to mitigation in climate change. Handling endogenous technological change in economic models will be significant to analyze such relationships between climate change and its measures, technology, and economy. This is because endogenous technological change implies incorporating a feedback mechanism by which policy can direct technological change toward carbon-saving technology (Gillingham, et al., 2008). Under an exogenous technological change assumption, technological change occurs independently of the impacts of policies and measures. However, computable general equilibrium (CGE) models, which have been frequently used for economic analysis of climate change issues and measures, in previous studies have treated technological change exogenously (Babiker, et al., 2001; Nijkamp, et al., 2005; Matsumoto and Masui, 2009) and those with endogenous technological change are rare (Goulder and Schneider, 1999; Sue Wing, 2006; Wang, et al., 2009). There have been no such models targeting the Japanese economy. In addition, the methodology of modeling endogenous technological change has not yet been consolidated and several methods have been proposed. When modeling endogenous technology, mainly two methods can be considered, namely knowledge capital accumulation through R&D investment and technology learning. The latter is generally used in bottom-up models such as energy system models and the former is more appropriate for CGE models considering structure (Wang, et al, 2009).

Based on the above background, this study proposes to develop a CGE model targeting the Japanese economy and to introduce endogenous technological change in it. Economic and environmental impacts of a climate change measure are then analyzed considering technological change.

2. Model

In order to analyze the economic impacts when CO_2 emissions are abated and technology is changed, a recursive dynamic CGE model installing R&D investment and knowledge capital has been developed. The model is a single-country model focusing on Japan and consisting of 33 industrial sectors (Table 1). Also, energy and environmental modules have been combined in the economic model. Knowledge capital appears in the production, consumption, and dynamics as shown below.

Table 1 Classification of Industrial Sectors

	Abbreviation	Classification	Industry
1	AGR	Agriculture	Agriculture, forestry, fishery
2	MIN	Mining	Metallic and non-metallic ores
3	COA	Coal	Coal
4	OIL	Crude oil	Crude oil
5	GAS	Natural gas	Natural gas
6	FOD	Foods	Foods, beverage, etc.
7	TEX	Textile	Textile, wearing apparel, etc.
8	PPP	Pulp, paper, wood	Pulp, paper, wood, furniture, etc.
9	CHE	Chemical	Chemical products, medicaments, etc.
10	PPR	Petroleum products	Gasoline, kerosene, etc.
11	CPR	Coal products	Coal products, coke, etc.
12	CLY	Ceramic, stone, clay	Glass, cement, pottery, etc.
13	STL	Ferrous metal	Iron, steel, etc.
14	NFE	Non-ferrous metal	Copper, aluminum, etc.
15	MET	Metal products	Metal appliances, bolts, etc.
16	MCH	General machinery	Boilers, conveyors, etc.
17	ELQ	Electric machinery	Generators, air conditioners, etc.
18	ITQ	Information equipment	Cellular phone, PC, etc.
19	ECM	Electronic components	Semiconductor, IC, etc.
20	TRQ	Transportation equipment	Motor vehicle, ship, etc.
21	PRQ	Precision Instruments	Camera, watches, etc.
22	OMF	Other manufacturing	Plastic, toys, etc.
23	CNT	Construction	Building, repair, etc.
24	ELE	Electricity	Electricity
25	GSH	Gas and heat supply	Gas, heat
26	WTR	Water supply	Water, sewage disposal
27	WST	Waste management	Waste management services
28	COM	Commerce	Wholesale, retail
29	FIN	Finance	Finance, insurance, etc.
30	EST	Real estate	Real estate, house rent, etc.
31	TRN	Transportation	Railway, air transportation, etc.
32	ICT	Communication	Postal, telecommunication, etc.
33	OSV	Other services	Education, health, etc.

2.1 Economic entities

Industry (industrial sectors), and households, government, and abroad (final consumption sectors) are considered as economic entities in the model. In this study, only one sector exists for households, government, and abroad, respectively.

The household sector possesses labor and capital (both knowledge capital and physical capital) and obtains income by supplying them to the industrial sectors. Taxes are imposed on the income and the remainder is used for consumption and saving. This household saving is distributed to investment (both R&D investment and physical capital investment).

Industrial sectors produce goods using domestic and imported intermediate goods and production factors owned by households such as labor and capital. The produced goods are distributed to those for domestic consumption and export. They pay production tax to government.

Government uses the tax revenue, tariffs, and revenue from emissions permits (in this study it is assumed that government allocates emissions permits by auction when implementing CO_2 emissions abatement) for its consumption. It is assumed that budget deficits and current account surplus are imposed on the household sector.

2.2 Data

The social accounting matrix (SAM) is the most frequently used data form for CGE models. In this study, SAM is developed based on the 2005 Input-Output Table for Japan. As described above, the industrial sectors are aggregated into 33 sectors, but the energy sectors are described in detail with seven sectors (i.e. COA, OIL, GAS, CPR, PPR, GSH, and ELE) to analyze a climate change measure. Since the data on labor and capital taxes are not represented in the Input-Output table, they are based on the National Accounts of Japan. In addition, the data on knowledge capital and R&D investment are also not represented in the Input-Output Table. This estimation method is described in 2.5.

For the data on CO_2 emissions, they are based on the Energy Balance Table for Japan (2005FY). Since emissions data by energy and sector (including households) are shown in the Carbon Balance Statistics Table, the data are aggregated into the energy and sectors of this study. Since direct CO_2 emissions are taken into account, CO_2 is taken as emitted in all energy sectors except ELE.

2.3 Production structure

Each industrial sector performs production activities using production factors and intermediate inputs. Although each sector produces single goods, export-manufacturing industries produce goods for domestic use and export as joint goods. The intermediate inputs are input as Armington aggregations of domestic and imported goods. When consuming energy goods, CO_2 emissions permits corresponding to the amount of emissions from the energy use are required. The model uses nested CES (constant elasticity of substitution) production functions, which are often used in CGE models. The substitution relationship of knowledge capital is considered at the top level of the functions as in Wang, et al. (2009) and the same value is used for the elasticity (Figure 1).

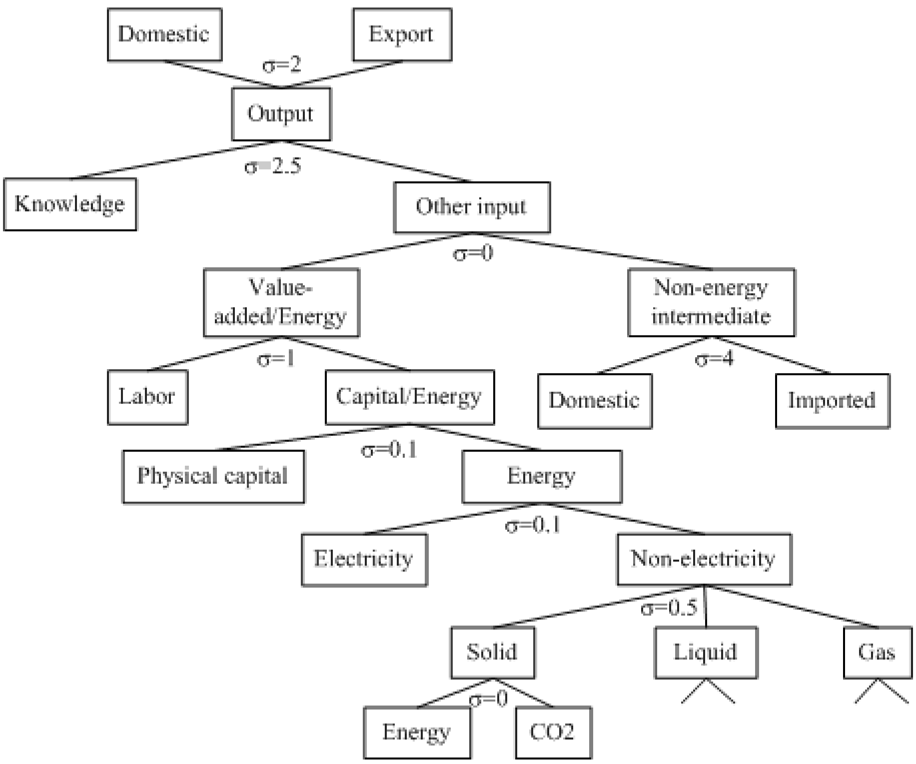


Figure 1 Production Structure of Industrial Sectors

2.4 Consumption structure of household and government

The household sector determines its consumption to maximize its utility based on consumption. It earns its income from labor and capital supply, and consumes goods as Armington aggregations subject to its budget. It also is required to hold emissions permits for energy use just as the industrial sectors are. The household utility function is also a nested CES function (Figure 2).

On the other hand, government determines its consumption (of Armington aggregations) and saving levels subject to the budget obtained from labor income tax, capital income tax, production tax, tariffs, and revenue from emissions permits. The government utility function is also a nested CES function (Figure 3).

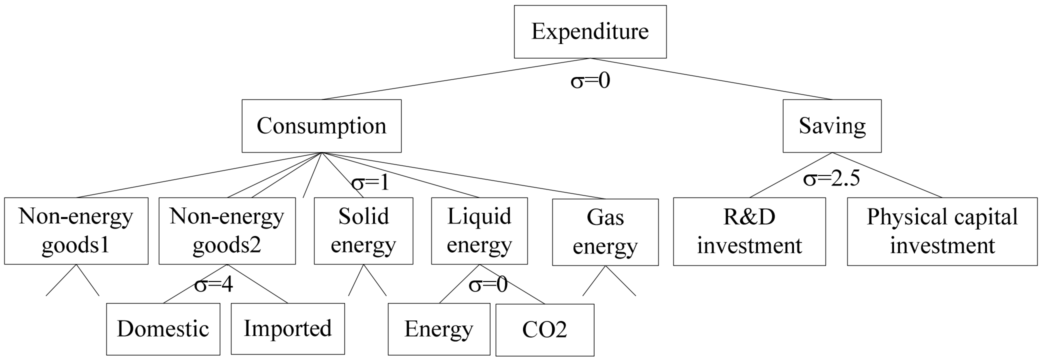


Figure 2 Consumption Structure of Household Sector

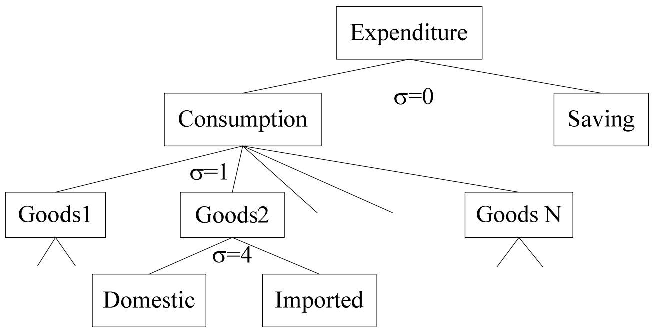


Figure 3 Consumption Structure of Government

2.5 Endogenous technological change

One characteristic of this model is to handle knowledge capital as one type of capital. Knowledge capital is used as a production factor, as described above, and modeled to demonstrate the link between the knowledge capital accumulation in the economy and technological change (Sue Wing, 2006). It is accumulated due to R&D investment, the scale of which is determined endogenously. Knowledge capital is assumed to be distributed throughout the economy as well as physical capital.

As mentioned in the previous section, both R&D investment and knowledge capital are not disaggregated in the Input-Output Table for Japan. Therefore, they are estimated using the method of Terleckyj (1974, 1980), also used in Zuern, et al. (2007) and Wang, et al. (2009). First, the amount of R&D investment by sector is estimated based on the total expenditure on R&D of the Survey of Research and Development for Japan (2005). Knowledge factors are then separated from the intermediate input matrix of SAM using the data. The row sum and column sum correspond to R&D investment and knowledge capital, respectively. This method can be summarized in the following equations (1)-(4).

$$KC_{i,j} = \frac{INP_{i,j}}{\sum_j INP_{i,j}} RDV_i \tag{1}$$

$$RD_i = \sum_j KC_{i,j} \tag{2}$$

$$KN_j = \sum_i KC_{i,j} \quad (3)$$

$$INPX_{i,j} = INPX_{i,j} - KC_{i,j} \quad (4)$$

$INP_{i,j}$: original intermediate input matrix by sector, $INPX_{i,j}$: modified intermediate input matrix by sector, $RDV_{i,j}$: R&D investment by sector, $KC_{i,j}$: knowledge factors in intermediate input, RD_i: row sum of knowledge factors (R&D investment by sector), $KN_{,j}$: column sum of knowledge factors (knowledge capital by sector)

2.6 Dynamic structure

Consideration of the temporal aspect is indispensable for analyzing the changes in environment and economy as in this study. Thus, a recursive dynamic mechanism is applied in the model. In the dynamic process, the economic growth is based on the change in labor supply and capital accumulation. The growth of labor supply is determined by the increase rate of labor in efficiency units while physical capital and knowledge capital are determined through investment on each and the depreciation rates.

3. Baseline and Scenarios

3.1 Baseline settings

SAM shown in the previous chapter is used for the base year data, 2005, and then dynamic analysis is implemented from that year to 2030 with 5-year time steps based on labor increase and capital accumulation. The depreciation rates of physical capital and knowledge capital are assumed to be 5% and 15% per annum, respectively.

3.2 Scenario cases

In order to analyze the influence on CO_2 emissions and economy when considering endogenous technological change, scenario cases against the baseline are set. One is for the amount of CO_2 emissions abatement. In this study, six cases from 0% (no abatement) to 50% compared to the baseline are prepared and the same rate is abated every year for each. The other is subsidies on R&D investment. It is expected that R&D investment is promoted due to the subsidies and technological change occurs as a result. The subsidy rates from 0% (no subsidies) to 50% compared to the baseline are prepared and the rates are constant every year.

In 36 cases, the combination of the above two settings, are analyzed using the recursive dynamic CGE model, and then each scenario is compared with the baseline.

4. Results

4.1 Marginal abatement costs

Marginal abatement cost (MAC) of CO_2 emissions represents the cost to abate one unit of CO_2 emission incrementally and is frequently used to show the economic severity of the abatement. Figure 4 shows MAC curves for each year when only CO_2 emissions abatement is implemented. As it shows, MAC increases with the abatement rate and the curves can be approximated by quadratic functions (e.g. MAC = 192849 × (abatement rate)^2 – 7379.8 × (abatement rate) with R^2 = 0.997 in 2020). Also, it tends to decrease over time compared within the same abatement rate. In addition, it is indicated that MAC in each year except for 2005 declines with subsidies on R&D investment (Figure 5). This means that, the economic burdens from abating CO_2 emissions are reduced by introducing subsidies.

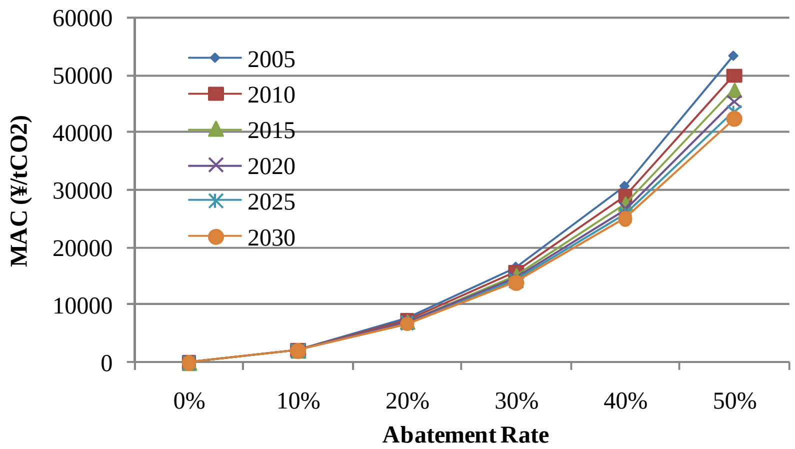


Figure 4 MAC Curves

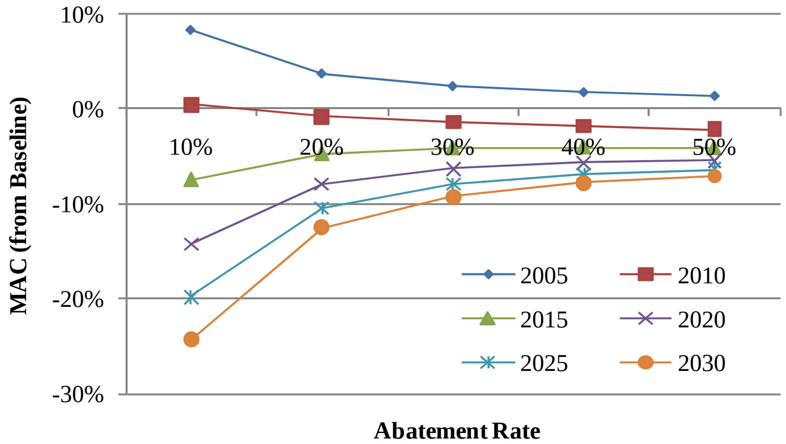


Figure 5 Change in MAC with Subsidies (20% Subsidies Cases)

4.2 Impacts on investments

Figure 6 shows the influence of CO_2 emissions abatement on R&D investment. As this figure shows the changes compared to the baseline, the higher the emissions abatement rate, the lower the R&D investment will be. The changes are smaller in the earlier years than in the later years.

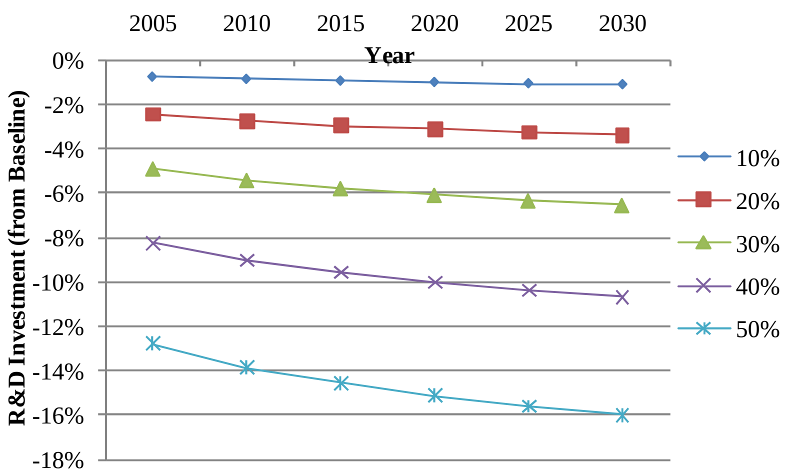


Figure 6 Changes in R&D Investment by Emissions Abatement Rate

Observing the changes in physical capital investment, the higher the emissions abatement rate, the lower the investment will be as well as R&D investment (Figure 7). The changes are also smaller in the earlier years than in the later years.

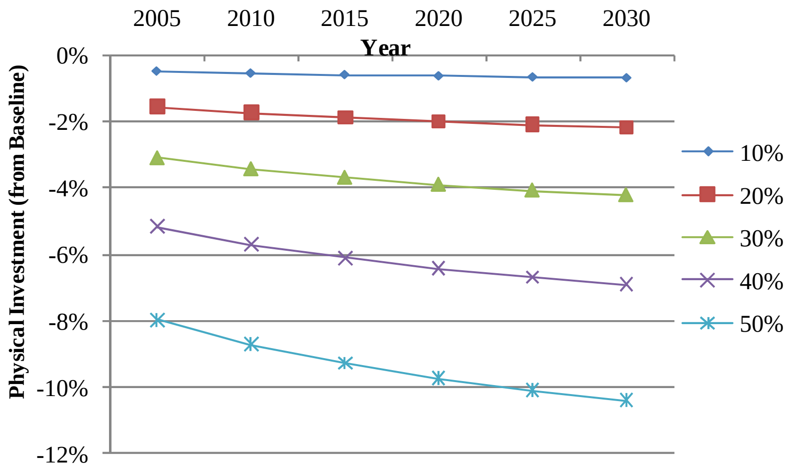


Figure 7 Changes in Physical Capital Investment by Emissions Abatement Rate

Next, Figure 8 shows the influence of subsidies on R&D investment compared to the no subsidies case. R&D investment increases by introducing the subsidies and the amount of increase is almost the same throughout the simulation periods. On the other hand, physical capital investment decreases by introducing the subsidies and the amount of decrease is almost the same throughout the simulation periods (Figure 9). The total of them slightly increases by subsidizing R&D investment.

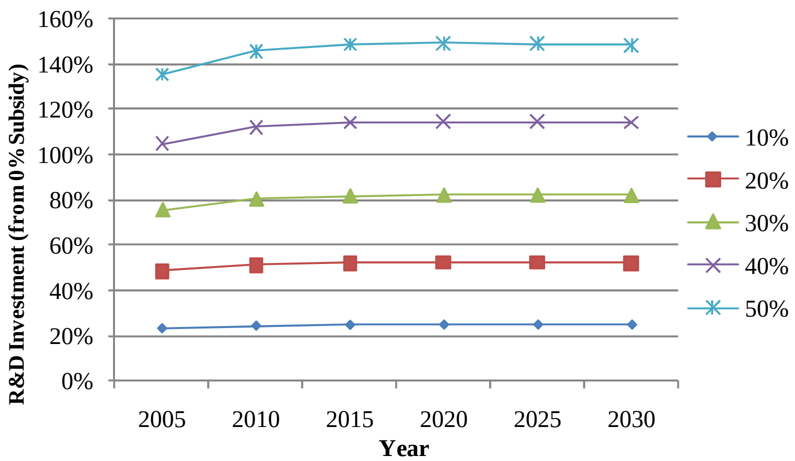


Figure 8 Changes in R&D Investment with Subsidies (10% Abatement Cases)

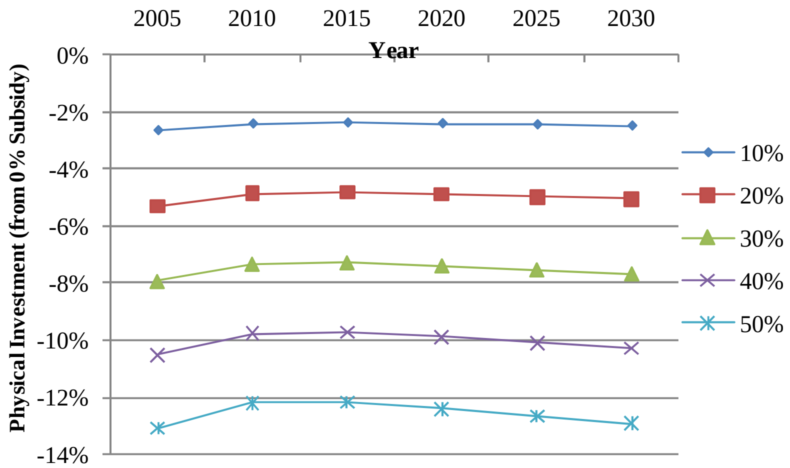


Figure 9 Changes in Physical Capital Investment with Subsidies (10% Abatement Cases)

4.3 Economic impacts

Observing the economic impacts other than investment, GDP decreases compared to the baseline when emissions are abated (Figure 8). The reduction rates are from about 0.1 – 0.3% for the 10% abatement case to about 2.3 – 5.5% for the 50% case, and the rates tend to be larger over time for all the cases. Decreases in household consumption are the most significant factor both in the amount and rate for decreases in GDP (Figure 11). As the figure shows, the decrease rates are from about 0.5 – 0.8% for the 10% abatement case to about 8.6 – 11.1% for the 50% case, and the rates also tend to be larger over time for all the cases.

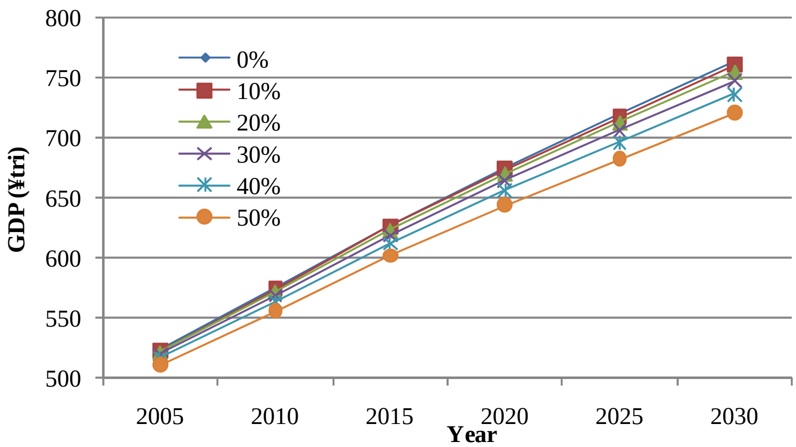


Figure 10 Changes in GDP by Emissions Abatement Rate

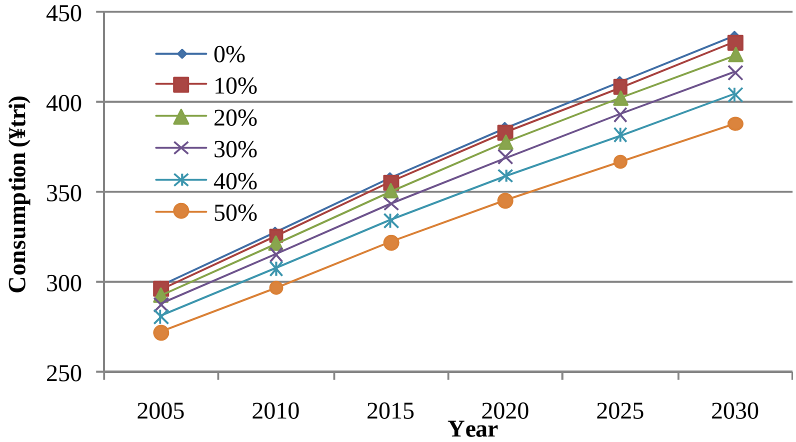


Figure 11 Changes in Household Consumption by Emissions Abatement Rate

What will happen if R&D investment is subsidized? Figure 12 shows some results on the changes in GDP for scenarios compared to the baseline. As the figure shows, there is a possibility of increasing GDP, except for the base year, by introducing subsidies on R&D investment even if CO_2 emissions are abated. According to the analysis, such a tendency is observed when the combinations of abatement-subsidies are 10-10%, 20-30%, and higher subsidies cases than these (in cumulative GDP). Among these cases, government consumption also increases for some cases, which means that increase in GDP is achieved through the subsidies without sacrifice of government consumption. In addition, household consumption increases compared to the baseline (in cumulative amount) when the combinations of abatement-subsides are 10-10%, 20-30%, and higher subsidies cases than these (Figure 13).

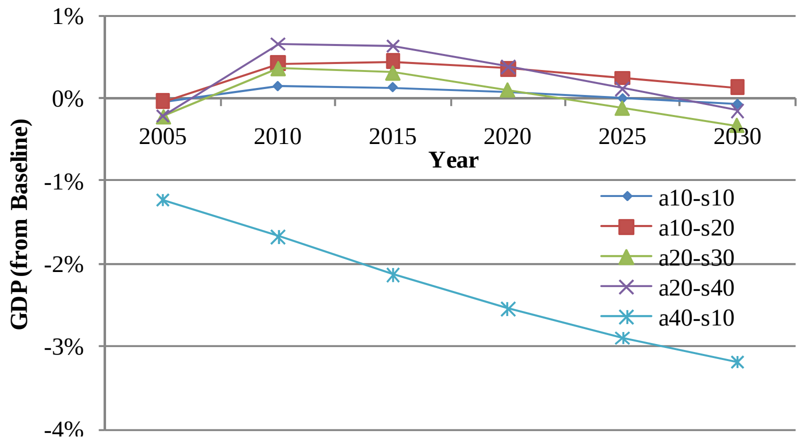


Figure 12 Changes in GDP due to Combination of Emissions Abatement Rate and Subsidies

*"a" indicates emissions abatement and "s" indicates subsidies in the figure.

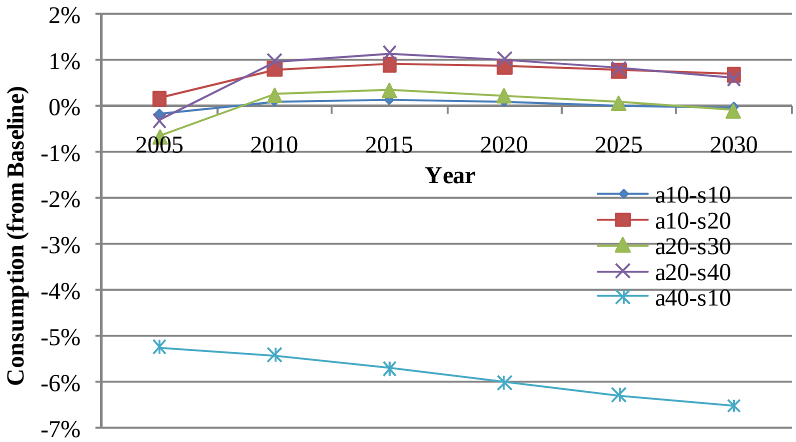


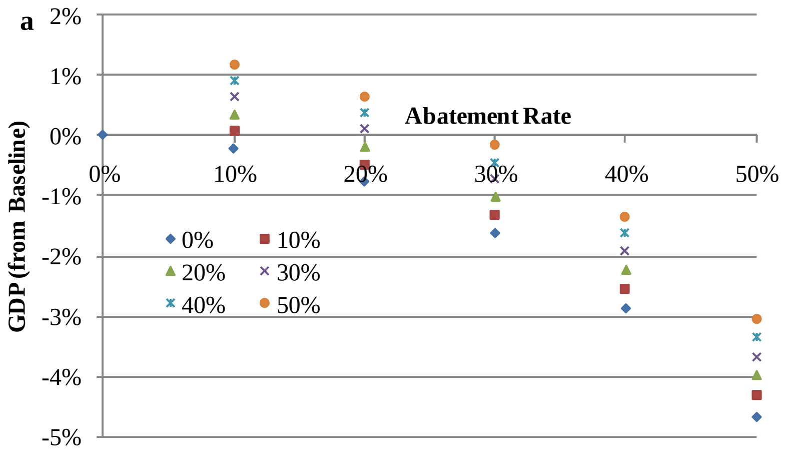
Figure 13 Changes in Household Consumption due to Combination of Emissions Abatement Rate and Subsidies

*"a" indicates emissions abatement and "s" indicates subsidies in the figure.

4.4 Breakdown of CO_2 emissions

Considering the situation that CO_2 emissions abatement and increases in GDP can be compatible, it is interesting to investigate what is happening by abating emissions and subsidizing R&D investment. CO_2 emissions can be expressed as the production of population, GDP per capita, energy use per unit of GDP (energy intensity), and CO_2 emissions per unit of energy use (emissions intensity), known as the Kaya identity. Since it is assumed that population is identical among the scenarios in this study, the other factors are investigated below.

Observing the results of 2020 as the representative example, the changes in GDP, energy use per unit of GDP, and CO_2 emissions per unit of energy use are summarized in Figure 14. As the figures show, energy intensity and emissions intensity are the influential factors to abate CO_2, and the former is more influential for higher abatement cases and the latter is more influential for lower abatement cases. Consequently, CO_2 emissions per unit of GDP decrease as the emissions abatement rate becomes higher and R&D investment promotes the effect (Figure 15).



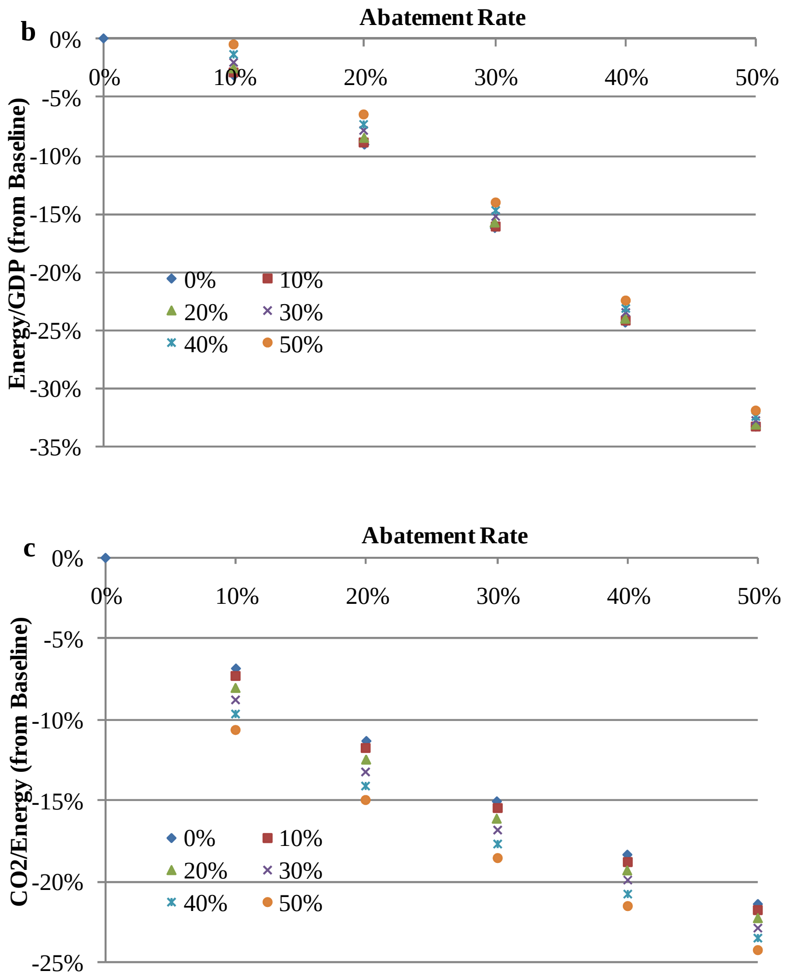


Figure 14 Breakdown of CO_2 Emissions in 2020 (a: GDP; b: Energy/GDP; c: CO_2/Energy)

*The tendencies of the results are same for the other years.

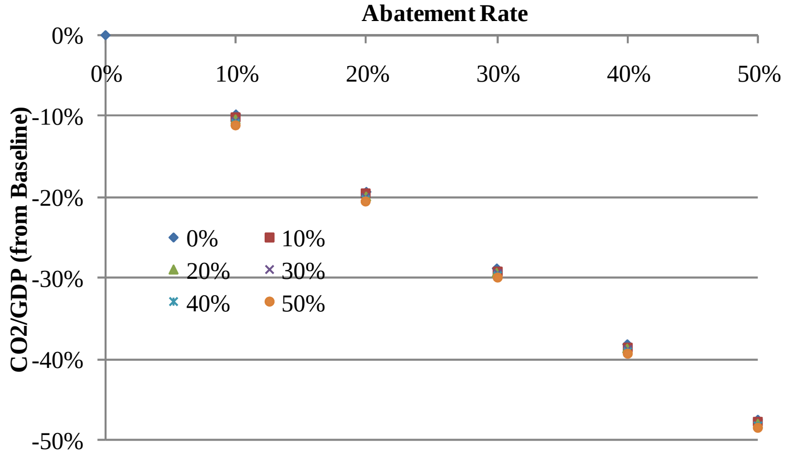


Figure 15 CO_2 Emissions per Unit of GDP in 2020

5. Concluding Remarks

In this study, a recursive dynamic CGE model that considers endogenous technological change was developed and the effects and influence of CO_2 emissions abatement and subsidies on R&D investment were analyzed using the model. Endogenous technological change was defined as the relationship with the accumulation of knowledge capital through R&D investment. As a result, negative economic impacts such as increases in MAC and decreases in household consumption and GDP were observed when CO_2 emissions were abated as in existing studies. However, even in such a situation, it was suggested that positive economic effects could occur due to acceleration in the accumulation of knowledge capital through R&D investment by introducing subsidies on it. It was shown that CO_2 emissions abatement was mostly brought by improvement of energy intensity and emissions intensity, and CO_2 emissions per unit of GDP were improved, the effect of which was stimulated by subsidies on R&D investment, as a result.

As mentioned in the previous chapters, most of the CGE models in existing studies considered technological change exogenously. Therefore, it was difficult to analyze the effects of technological change corresponding to policies and measures unlike this study. Even in such models, one possibility is to set parameters related to technological change in advance for each policy or measure, and use them accordingly. However, the relationship between policies and measures and technological change is assumed arbitrarily even though there is background information to some extent. Thus, the method used in this study, that is technological change is determined according to changes in policies and measures (CO_2 emissions abatement and subsidies for this study) endogenous in the dynamic structure while considering the relationships with other factors, is considered better than the above one.

In this study, revenue from emissions permits accompanied by CO_2 emissions constraints is considered as the general income of government, and the subsidy rates on R&D investment are set independently of it. Therefore, analysis taking account of the relationship between the revenue and subsidies, and also policy-oriented analysis considering more broadly about climate change measures and environmental investment will be implemented for the future works. Furthermore, studies on modeling methodology of knowledge capital such as the spill-over effects of knowledge and sector-specific knowledge (technology) will be implemented.

Acknowledgement

This study was supported by the Global Environmental Research Fund (Bc-088), the Ministry of the Environment, Japan.

References

Babiker, M.B., Reilly, J.M., Mayer, M. Eckaus, R.S., Sue Wing, I., and Hyman, R.C. (2001) The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Revisions, Sensitivities, and Comparisons of Results. MIT Joint Program on the Science and Policy of Global Change Report 71.

Gillingham, K.T., Newell, R.G., and Pizer, W.A. (2008) Modeling Endogenous Technological Change for Climate Policy Analysis. Energy Economics 30(6), pp.2734-2753.

Goulder, L. and Schneider, S. (1999) Induced Technological Change and the Attractiveness of CO_2 Abatement Policies. Energy Economics 21, pp.211-253.

Green New Deal Group (2008) A Green New Deal. New Economics Foundation.

Hatoyama Cabinet (2009) The New Growth Strategy (Basic Policies): Toward a Radiant Japan (December 30, 2009).

Matasumoto, K. and Masui, T. (2009) Mid-term Dynamic Effects of Carbon Tax Based on the Imputed Price of Carbon. Environmental Science 22(6), pp.391-400.

MOE [Ministry of Environment, Japan] (2010) Summary (Draft) of the Global Warming Basic Act (Tentative Title). 11^{th} Policy Council of Ministry of Environment (in Japanese).

Nijkamp, P., Wang, S., and Kremers, H. (2005) Modeling the Impacts of International Climate Change Policies in a CGE Context: The Use of the GTAP-E Model. Economic Modelling 22(6), pp.955-974.

Sue Wing, I. (2006) Representing Induced Technological Change in Models for Climate Policy Analysis. Energy Economics 28, pp.539–562.

Terleckyj, N.E. (1974) Effects of R&D on the Productivity Growth of Industries: An Exploratory Study. National Planning Association Report 140.

Terleckyj, N.E. (1980) Direct and Indirect Effects of Industrial Research and Development on the Productivity Growth of Industries. In: Kendrick, J.W. and Vaccara, B.N. (eds.), New Development in Productivity Measurement. University of Chicago Press, pp.359-386.

UNEP [United Nations Environmental Programme] (2008) Global Green New Deal.

UNFCCC [United Nations Framework Convention on Climate Change] (2010) UNFCCC receives list of government climate pledges. Press Release (1 Feb., 2010).

Wang, K., Wang, C., and Chen, J. (2009) Analysis of the Economic Impact of Different Chinese Climate Policy Options Based on a CGE Model Incorporating Endogenous Technological Change, Energy Policy 37(8), pp.2930-2940.

Zuern, M., Robert, K., Ellersdorfer, I., and Farhl, U. (2007) R&D Investment and Knowledge Input in a Technology Oriented CGE Model, Proceedings of EcoMod Conference on Energy and Environmental Modeling, CD-ROM.