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Economic impacts to avoid dangerous climate change using the AIM/CGE model

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Abstract

This study purposes to analyze economic aspects of defined climate policies applying the AIM/CGE[Global] model to understand the economic consequences of abating a large amount of greenhouse gas emissions to avoid dangerous climate change. As a result, higher carbon prices and larger decreases in GDP are observed when emissions are abated more deeply. However, such GDP losses are rather small and insignificant compared to the GDP growth throughout this century. These results suggest that although it is challenging to abate emissions until the level to avoid dangerous climate change, there is a sufficient possibility to achieve it from economic perspectives.

Keywords: Economic impact; Dynamic CGE model; Dangerous climate change; 2°C target; Greenhouse gas emission abatement; AVOID

1. Introduction

According to the Objective (Article 2) of UNFCCC (United Nations Framework Convention on Climate Change), "the ultimate objective of this Convention … is to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system…" With this statement in mind, limiting global warming below 2°C has been considered to be a target of climate change policies globally. For example, the European Union has released a statement [1] indicating its aim to achieve the target. In the G8 Summit in 2009, the G8

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Leaders Declaration expressed that global average temperature should not exceed 2°C above the pre-industrial levels [2]. Furthermore, significance of this target to achieve the ultimate objective of UNFCCC is emphasized in the Copenhagen Accord [3].

Considering this perspective, the AVOID Programme was launched in UK in 2009 [4, 5]. The purposes of this project are (1) to promote understanding of dangerous climate change and its implications including impacts, economic, and social consequences and responses, (2) to further encourage the integration and communication of scientific and socioeconomic research on climate, and (3) to accumulate policy-relevant evidence to achieve international agreement on GHG (greenhouse gas) emission abatement. In order to achieve these purposes, AVOID addresses the following key questions [5]: (1) how much climate change is too much?; (2) what level of global climate change should be avoided?; (3) what does the world need to avoid such levels of climate change?; and (4) what is considered as an acceptable risk of climate change impacts for different regions and communities?

More than 150 emission scenarios have been developed [6, 7] and five scenarios out of them are selected for economic and impact assessment, which is a study involved in the Work Stream 1 of AVOID [7, 8]. In the Work Stream 1, (1) the climatic consequences of defined climate policies, (2) damages and impacts under these policies and targets and damages avoided by them, and (3) the economic characteristics of the inferred mitigation strategies and their economic consequences are mainly estimated.

The purpose of this paper is to show the results and implications from economic analysis implemented for the Work Stream 1 of AVOID using the AIM/CGE [Global] model. In this study, the analysis is implemented until 2100 and the results on carbon prices and GDP on a global basis are shown. These results are finally compared with those of the E3MG model [9, 10], which is also one of the economic models involved in the project.

2. Methods

2.1 Model

The AIM/CGE [Global] model is used for the analysis [11, 12]. This model is a recursive dynamic CGE (computable general equilibrium) model on a global scale. The model consists of 21 industrial sectors (Table 1) and 24 world regions (Table 2). These definitions are based on the GTAP6 database [13, 14], which is also used for the economic data. In addition to it, the Energy Balances is used for the energy data [15], the EDGAR 3.2 Fast Track 2000 is used for the emission data [16], and the FAOSTAT is used for the land-use data [17] for the base year data.

The basic mechanism of this model is similar to the GTAP model [18] and the GTAP-E model [19]. However, the structure is different from them. Some significant differences can be summarized as follows: dynamic structure is considered; not only CO_2 emissions but also other GHG, aerosol, and chemical emissions are incorporated; power generation by various resources such as fossil fuels, nuclear, water, and other renewables (e.g. geothermal, solar, wind, and biomass), and also that with CCS (carbon capture and storage) technology are considered. Concerning the dynamics in the model, the acceleration principle is applied to determine the investment and autonomous energy efficiency improvement is adopted for the technological change.

In this study, the base year is 2001 and a simulation analysis is implemented until 2100 with 10-year time steps.

Table 1 – Structure of industrial sectors

Code	Including sectors	Code	Including sectors
COA	Coal	EIS	Energy intensive industries
OIL	Crude oil	OMN	Other mineral mining
GAS	Natural gas	M_M	Metals & manufacture
P_C	Petroleum & coal products	FOD	Food processing
GDT	Gas manufacture & distribution	OMF	Other manufacture
ELY	Electricity	CNS	Construction
AGR	Agriculture	TRT	Transportation
LVK	Livestock	CMN	Communication
FRS	Forestry	WTR	Water
FSH	Fishery	OSG	Governmental services
		SER	Other services

Table 2 – Structure of world regions

Code	Including countries	Code	Including countries
AUS	Australia	IDN	Indonesia
NZL	New Zealand	THA	Thailand
JPN	Japan	XSE	Rest of Southeast Asia
CAN	Canada	IND	India
USA	United States of America	XSA	Rest of South Asia
XE15	15 Western EU countries	ARG	Argentina
RUS	Russia	BRA	Brazil
XE10	10 Eastern EU countries	MEX	Mexico
XRE	Rest of Europe	XLM	Rest of Latin America
CHN	China & Hong Kong	XME	Rest of Middle East
KOR	Korea	ZAF	South Africa
XRA	Rest of Asia-Pacific	XAF	Rest of Africa

2.2 Baseline scenario

The IPCC (Intergovernmental Panel on Climate Change) SRES (Special Report on Emissions Scenarios) A1B scenario is adopted for the baseline scenario as the basic assumption of AVOID. We use population and potential GDP growth projections of the A1B scenario for the drivers toward the future. Since parameters and some other assumptions such as the rates of technological change are based on the original settings as used in the previous studies [11, 12], however, it is not possible to duplicate the original A1B emissions by the model calculation. Thus, the calculated results are considered to be the baseline and policy scenarios, explained in the next section, are structured based on it. In the scenario, CO_2, CH_4, N_2O, NO_X, NMVOC, CO, SO_2, and fluorinated gases in the Kyoto Protocol are covered. Since the AIM/CGE [Global] model cannot handle the fluorinated gases inside the model, these gas emissions are exogenously given. However, this influence is negligible considering the importance of the other gases especially CO_2. The model is run using the above assumptions without any emission constraints for the baseline scenario.

2.3 Policy scenario

In this study, five policy scenarios are prepared based on the following three parameters: (1) the year in which emissions peak globally; (2) the rate of emission abatement after the peak year (R); and (3) the minimum level to which emissions are eventually abated (H: High or L: Low). These scenarios are named 2016R2H, 2016R4L, 2016R5L, 2030R2H, and 2030R5H. For example, 2016R4L means that the peak year is 2016, the rate of emission abatement is 4%, and the eventually achieved (long-run) minimum emission level is low. CO_2 emission pathways of these scenarios are shown in Figure 1. The details of the process to develop the emission scenarios are explained in Gohar and Lowe [20-22]. The probabilities of the global mean temperature rise below 2°C under these scenarios are expected to be 7-45% (Table 3).

As mentioned in the previous section, the calculated baseline emission pathways are different from the original A1B emission pathways. Thus, the relationships between the original baseline and policy scenarios are not kept at all. However, it is significant to maintain the percentage differences among the scenarios, since one of the parameters of the policy scenarios is the rate of emission abatement. Hence, the percentage abatement in emissions that occurs between the original baseline scenario and the particular policy scenario, for each gas in each period, is first calculated, and then these percentages are applied to the calculated baseline scenario to derive the constraints for each gas over the century. For each policy scenario, the model is run under the corresponding emission constraints.

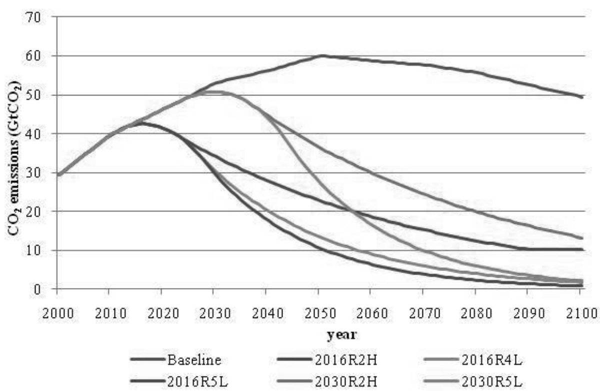

Figure 1 – CO_2 emission pathways of baseline and policy scenarios

Table 3 – Global mean temperature rise in 2100 (central estimate)

	Baseline	2016R2H	2016R4L	2016R5L	2030R2H	2030R5L
Probability of remaining below 2°C	1%	30%	43%	45%	7%	17%
Probability of remaining below 3°C	7%	87%	91%	91%	63%	76%
Probability of remaining below 4°C	46%	98%	99%	99%	93%	96%

Source: Revised version of Table A in Warren et al. [8]

3. Results and discussion

Since five policy scenarios are calculated in this study, we focus on the results on a global scale here.

Figure 2 shows global carbon prices. Since international emissions trading is assumed in the model, these prices hold true for all regions. Carbon prices represent the cost of abating GHG emissions under a certain policy. As it shows, higher carbon prices are required to cause emissions to peak in 2016 compared to 2030 and also required to abate emissions more significantly. That is to say, the larger the amount of emission abatement, the higher the prices will be. In the figure, it is also shown that the carbon prices tend to fall in the end of the century for all the scenarios. This reason is considered that although the percentage abatement in emissions required is increasing throughout the century for the policy scenarios, the absolute emission abatement amounts decrease due to decreases in the emissions seen in the latter half of the century for the baseline scenario (Figure 1).

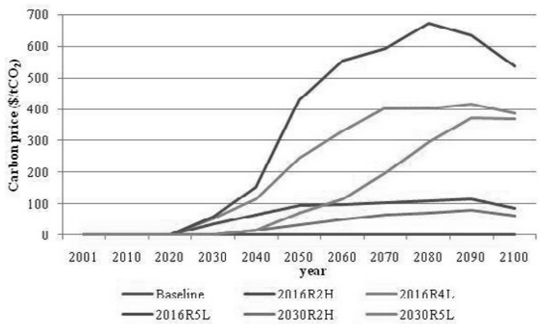

Figure 2 – Global carbon prices for baseline and policy scenarios

Figure 3 shows global total GDP. As it shows, GDP decreases for all policy scenarios compared to the baseline scenario. The rates of the decrease in 2100 are 2.9% for 2016R2H, 6.1% for 2016R4L, 7.0% for 2016R5L, 2.0% for 2030R2H, and 5.0% for 2030R5L. However, the rates are not so large and GDP is still increasing over time. Furthermore, the differences between the policy scenarios are rather small. As well as the carbon prices shown above, the larger decreases are observed from the 2016-peak cases compared to the 2030-peak cases and also when the emissions are abated more deeply. In other words, the larger the amount of emission abatement, the higher the rates of the decreases will be.

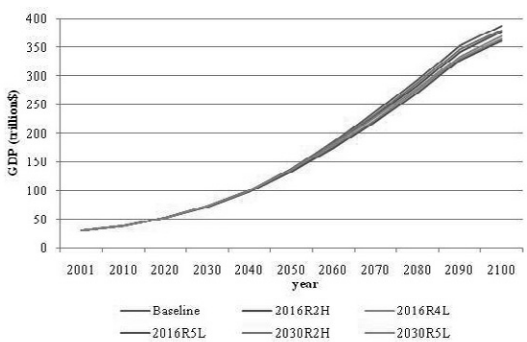

Figure 3 – Global total GDP for baseline and policy scenarios

4. Conclusion

In this study, we analyzed economic impacts of abating GHG emissions relative to the baseline applying the AIM/CGE [Global] model. One baseline scenario based on the IPCC SRES A1B scenario and five policy scenarios were considered. The results we focused on in this paper were carbon prices and GDP, which can represent the economic costs to realize the policy scenarios. As a result, higher carbon prices and larger decreases in GDP were observed as the peak year of global emissions came earlier and emissions were abated more deeply, while the probability to achieve the 2°C target became higher under such scenarios. On the other hand, the decreases in GDP were relatively small and insignificant even for the most severe policy case (i.e. 2016R5L) compared to the increases in global GDP by the end of the century. It was also indicated that the carbon prices and the changes in GDP increased over time. These results therefore suggest that while significant emission abatement is indispensable to aim to avoid dangerous climate change and it seems a challenging issue, the economic damage to achieve the level is rather small and there is still a possibility to achieve it.

In the AVOID Programme, our results are compared with those of the E3MG model as mentioned above. The notable results from the E3MG model can be summarized as follows [8]: (1) carbon prices in the E3MG model are constant in real terms from 2020 to 2100, and they are higher than those of the AIM/CGE [Global] model until around 2050 and becomes lower in the latter half of the century; and (2) the E3MG model shows increases in GDP for the policy scenarios relative to the baseline scenario (about 2 to 5%). These results are economically more positive for abating GHG emissions than our results. Economic models showing such results are few so far in the literature [23, 24]. Such significant differences in the results between the two models are caused by the following reasons: (1) technological change (exogenous technological change in AIM, but endogenous and induced technological change in E3MG); (2) revenue recycling (a lump-sum payment of revenues from emissions trading to consumers in AIM, whereas lowering indirect taxes and providing incentives to invest additionally in low-carbon technology in E3MG); (3) timing of emission abatement (later in AIM than in E3MG); and (4) modeling approach (a first-best world in AIM , while a second-best world in E3MG).

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