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Economic Impacts of Greenhouse Gas Emission Mitigation Policies
- Analysis by AIM Model -

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ABSTRACT

This paper attempts to evaluate the economic impacts of the Kyoto Protocol by using AIM model. It is estimated that the GDP losses to Japan, US, EU, and Russia would be 0.42%, 0.56%, 0.44%, and 0.25%, respectively in case the Annex B countries ratify the Kyoto Protocol and reduce their emissions without emissions trading and without accounting carbon sink. On the other hand, the GDP losses to Japan and EU would grow when the United States would not ratify the Kyoto Protocol, and it is estimated to fall by 0.48% and 0.47% relative to the base case scenario, respectively. The GDP loss of Russia would be 0.17%. The GDP of US would increase by 0.01%.

These losses would be recovered if Kyoto mechanisms were adopted. When the emissions trading would be introduced, the GDP losses to Japan, US, and EU would be 0.14%, 0.33% and 0.19%, respectively and Russia would gain GDP by 3.5%. When carbon sink is accounted, the economic impacts can be reduced further. Even when the amount of tradable carbon is restricted, the impacts will become much less. In addition to emission trading, effects of CDM, price induced technical change, and boycott movement are examined.

The paper also analyzed the climatic impacts of the mitigation scenarios. Three scenarios are examined. First scenario assumes a goal of the Kyoto Protocol will be achieved in 2010. The second assumes that USA will not ratify the Kyoto Protocol. The third scenario assumes that the emission is reduced at the rate of 5% per decade after 2020. It is found that the temperature will increase to 2.15 ºC by the year 2100 even if the Annex B countries follow the Kyoto protocol and other appropriate countermeasures are taken. If we postpone the reduction policies, climate impacts will become worse. The implementation of the Kyoto Protocol is necessary to keep the temperature increase in 2100 below 2 ºC.

1. Introduction

The Kyoto Protocol was adopted in 1997 to take a step toward stabilizing atmospheric concentration of greenhouse gas emissions. As of 19 March 2002, 50 countries have ratified the Kyoto Protocol. With the formal decision of the EU on 4 March that 15 Member States will ratify the Protocol by 1 June, the first criterion for the treaty to become international law, ratification by a minimum of 55 countries, is set to be achieved. The second criterion is ratification by the industrialized nations that accounted for at least 55 per cent of the industrialized world's CO2 emissions in 1990 (WWF, 200).

In March 2001, President Bush announced that the United States would not ratify the Kyoto Protocol. Since the United States emits the largest amount of CO2 in the world, the influence of this decision on other industrialized nations might be quite big.

This paper analyzes the influence of the decision of President Bush as well as other important factors to reduce GHG emissions. Several cases are studied. One case is that the Protocol will be ratified including the United States. The other case is that it will become international law without the ratification by the United States. The price induced technical change and boycott movement of non-ratification country's goods are also analyzed.

The climatic impacts of the reduction policies are analyzed with the AIM/climate model. Three scenarios are used to estimate future temperature increase as well as climatic impacts. These scenarios are different according to when each country participates in reduction measures.

2. Structure of AIM

The AIM model is a recursive dynamic equilibrium model of the world economy used to analyze the effects of climate stabilization policies (Kainuma et al, 1999). The model divides the world into 21 geopolitical regions. To analyze the impacts of Kyoto Protocol, Annex B is divided into the following regions: Japan, Australia, New Zealand, the United States of America (USA), Canada, the European Union (EU), and Eastern Europe and the Former Soviet Union (FSU). The AIM model focuses in detail on the

Asia-Pacific region, which is divided into 10 regions: China, Taiwan, the Republic of Korea, Hong Kong, Singapore, India, Indonesia, Malaysia, the Philippines, and Thailand. Other regions are Latin America (L-America), Middle East Asia and North Africa (ME-Asia), Sub-Saharan Africa (SS-Africa), and Rest of World (ROW).

Goods are aggregated into seven energy goods and four non-energy goods. Energy goods are coal, crude oil, petroleum and coal products, natural gas, nuclear energy, renewable energy, and electricity. Non-energy goods are aggregated into four categories. The first is energy-intensive products; the second is agriculture, other manufactures and services; the third is transport industries; and the last is savings.

The model has three sectors - production, household, and government sectors- in each region. CO2 and other greenhouse gases are emitted by each of these sectors. The production of electricity and of non-energy goods uses fossil fuels and emits CO2 in the production sector. Besides the use of automobiles and other direct uses of fossil fuels emit CO2 in the household and government sectors. It is assumed that the household sector has carbon emission rights and distributes them to the other sectors and within the household sector itself. Fossil fuels cannot be used without carbon rights. The price of carbon rights depends on several factors such as emission targets and the method of emission trading. The household sector also supplies primary factors to the production and government sectors. An agent in the household sector determines consumption and saving. The marginal propensity to save is a calibrated function of a weighted aggregate of regional and global rates of return on fixed capital. A regional investment is calculated with the GDP growth rate, regional and global rates of return. Investment is balanced with saving on a global scale. The model allows for trade in intermediate goods. AIM assumes identical preferences in all countries for foreign versus domestic goods; i.e., the elasticity of substitution is the same for all regions. Domestic and import goods are not perfect substitutes.

3. Economic Impacts of the Kyoto Protocol

3.1 Targets

The emission reduction target adopted at COP3, held in Kyoto, is analyzed with the AIM model. The reduction target of each country compared to the 1990 emission level is as follows: Austria; 0.8%, New Zealand; 0%, FSU; 0%, Japan; -6%, Canada; -6%,

USA; -7%, and EU; -8%. It is assumed that several policy measures such as carbon tax and Kyoto mechanisms are used to meet this target.

3.2 Scenario assumptions

Three sets of scenarios are examined. In the first set, we assume no restriction on trading amount of carbon. In the second set, it is assumed that tradable carbon is less than one third of committed reduction. In the third set, carbon sink is accounted. In each set, the impacts of USA participation/non-participation of the Kyoto Protocol are examined.

In the first two sets, in addition to emissions trading, other factors such as CDM, price induced technical change, boycott movement of goods exported by non-ratification countries are examined. In the price induced technical change scenario, it is assumed that technologies shift to energy saving ones as energy price goes up. In the boycott movement scenario, it is assumed that the price of exported goods by non-ratification countries is 10% higher than the price of the base scenario.

In the third set, effects of carbon sink are analyzed. The amount of sink is assumed as follows: EU, 9.84 MtC/year; FSU, 19.46 MtC/year; Australia, 0 MtC/year; Canada, 12.0 MtC/year; Japan, 13.0 MtC/year, New Zealand, 0.2 MtC/year, and USA, 28.MtC/year. The scenario numbers and corresponding assumptions of each set are listed in Table 1-3.

[Insert Table 1, Table 2, and Table 3]

3.3 Simulation

Table 4 shows the percent reduction in GDP compared with the base scenario (Scenario 21) in the set 1, where trading amount of carbon is not restricted. Figure 1 shows the percent change in GDP in 2010 in the case of no emission trading. Six scenarios are compared. They are categorized into two types of scenarios - ratification and non-ratification of USA. Other three axes are scenarios without Kyoto mechanism, scenarios with price induced technical change, and boycott movement scenarios. Figure 2 shows percent change in GDP in 2010 with emission trading and no restriction on trading amount of carbon. Figure 3 shows percent change in GDP in 2010 with emission trading and CDM with no restriction.

The GDP loss of USA is the highest in the ‘Kyoto Protocol including USA’ scenario even though the carbon price is the lowest among Japan, USA and EU. The GDP gain of China is the highest in ‘CDM case including USA’ (Scenario 24). This gain is lowered in the case excluding USA (Scenario 54).

[Insert Table 4, Figure 1, Figure 2 and Figure 3]

Table 5 shows the corresponding carbon price in the set 1. The carbon price of Japan is the highest in all scenarios. If CDM is assumed in addition to emission trading, the carbon price would become very low. It becomes especially true in the case when the United States would not ratify the Kyoto Protocol. If price induced technical change will occur, the price will become much cheaper.

[Insert Table 5]

Table 6 shows the percent reduction in GDP compared with the base scenario in the set 2, where trading amount of carbon is less than one third of the committed reduction. The impact is higher in the emission trading case with the restriction scenarios than the no restriction scenarios except the carbon induced technological change scenarios. Figure 4 shows percent reduction in GDP in 2010 with restricted emission trading scenarios. Figure 5 shows percent change in GDP in 2010 with restricted scenarios of emission trading and CDM.

[Insert Table 6, Figure 4 and Figure 5]

Table 7 shows the carbon price in the set 2. The carbon price is higher than the corresponding price without restriction scenario.

[Insert Table 7]

Table 8 shows the percent reduction in GDP compared with the base scenario in the set 3 where carbon sink is accounted. In case Russia will bank half of the tradable emissions, the GDP gains will increase. The impact is not so large for other countries. Figure 6 shows percent change in GDP in 2010 where carbon sink is accounted.

[Insert Table 8 and Figure 6]

Table 9 shows the carbon price. The carbon price becomes low when carbon sink is accounted and the GDP loss is also curved down. When Russia undertakes banking, the carbon price will increase.

[Insert Table 9]

3.4 Discussions

The change in GDP in 2010 to achieve the target of the Kyoto Protocol is less than 0.3% in any region if we assume emissions trading. It can be said that it will not exert a big influence on any single economy. If we assume boycott movement of goods of non-ratification country, its GDP loss will grow further. On the other hand, there is a possibility to reduce the economic loss or even to increase it by promoting introduction of the energy conservation technology.

No ratification by the United States lowers the carbon price, and decreases the CDM incentive. In that case the total greenhouse gases will increase compared to the base case scenario.

4. Climatic Impacts of the Kyoto Protocol

4.1 Long-term emission scenarios

Long-term emission scenarios are examined to estimate the climatic impacts. Three scenarios are examined. Scenario B1 assumes the accomplishment of the goal of the Kyoto Protocol in 2010. Scenario B2 assumes that USA will not ratify the Kyoto Protocol. Scenario B3 assumes that the emission is reduced at the rate of 5% per decade after 2020. Other assumptions are listed in Table 10.

[Insert Table 10]

4.2 Simulation

CO2 emissions, CO2 concentrations in the atmosphere, temperature increase and global

warming damage are estimated by the AIM/climate model. They are listed in Table 11. When all the developed countries follow the Kyoto protocol and other appropriate countermeasures are taken (scenario B1), the CO2 emission would be 7.41 GtC, atmospheric CO2 concentration would be 557 ppm, and the temperature increase would be 2.15ºC compared with the current temperature by the year 2100.

On the other hand, if the United States would not ratify the Kyoto Protocol, and the countermeasure by the developing countries would be delayed (scenario B2), the CO2 emission would be 8.82 GTC (19.0% increase from B1), atmospheric CO2 concentration would be 590 ppm (5.9% increase from B1), and the temperature increase would be 2.29ºC (6.5% increase from B1) by the year 2100.

When the Kyoto Protocol would not be ratified and the effective countermeasures would sbe delayed (scenario B3), the CO2 emission would be 9.42 GTC (27.1% increase from B1), atmospheric CO2 concentration would be 603 ppm (8.8% increase from B1), and the temperature increase would be 2.34ºC (8.8% increase from B1) by the year 2100.

[Insert Table 11]

4.3 Discussions

Even if the Kyoto Protocol comes into effect according to schedule, and a severe target is introduced afterwards, the temperature rise of 2ºC or more is estimated in 2100. The temperature would increase further if there is a delay of the countermeasures by the United States (scenario B2) and a delay of the Kyoto Protocol's ratification (scenario B3).

If the goal of the Kyoto Protocol is achieved by 2010 and the emissions of developing countries will be stabilized by 2020-2040, global warming damage will be 5.5 trillion US dollars, whereas if countermeasures will be delayed 10 years, more damage, 6.0 trillion US dollars in 2100, is estimated.

5. Concluding Remarks

It is at least important to keep the increase of the world temperature below 2℃ in 2100 considering the historical data. A downward revision of the target for temperature increase might be required in future as severe damage will be observed by climate change.

Without the Kyoto target, the world temperature will increase more than 2°C in 2100. It is predicted that the ratification may cause economic impacts. However there are several ways to mitigate the economic impacts and a possibility to fuel the growth of economies. For example, if investments are shifted to energy saving technologies, there are good chances to improve the economy. It is found that GDP will increase if price inducing mechanism is enhanced and CDM is introduced.

References

Kainuma, M. Matsuoka, Y. and Morita, T (1999), “Analysis of Post-Kyoto Scenarios: The Asian-Pacific Integrated Model”, Special Issue “The Cost of the Kyoto Protocol”, The Energy Journal, 207-220.

WWF (2002), “Ratification of the Kyoto Climate Treaty - the progress so far”, http://www.panda.org/news/press/news.cfm?id=2835.

Figure 1 Percent change in GDP in 2010 in case of no emission trading

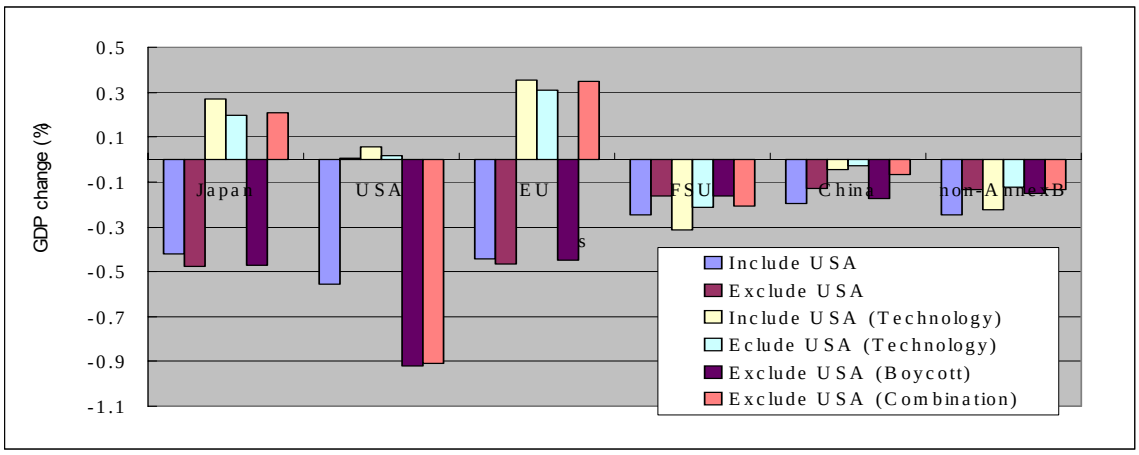

Figure 2 Percent change in GDP in 2010 with emission trading of no restriction

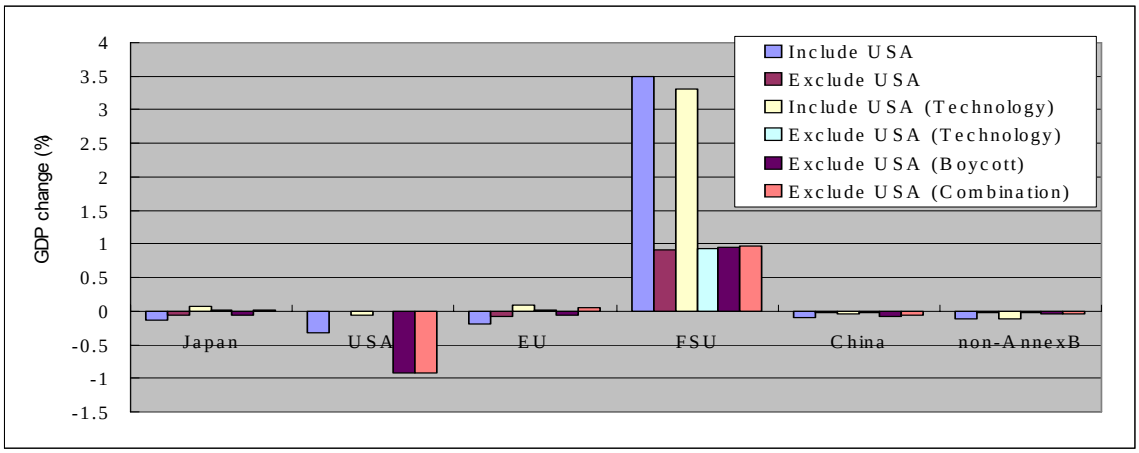

Figure 3 Percent change in GDP in 2010 with emission trading and CDM of no restriction

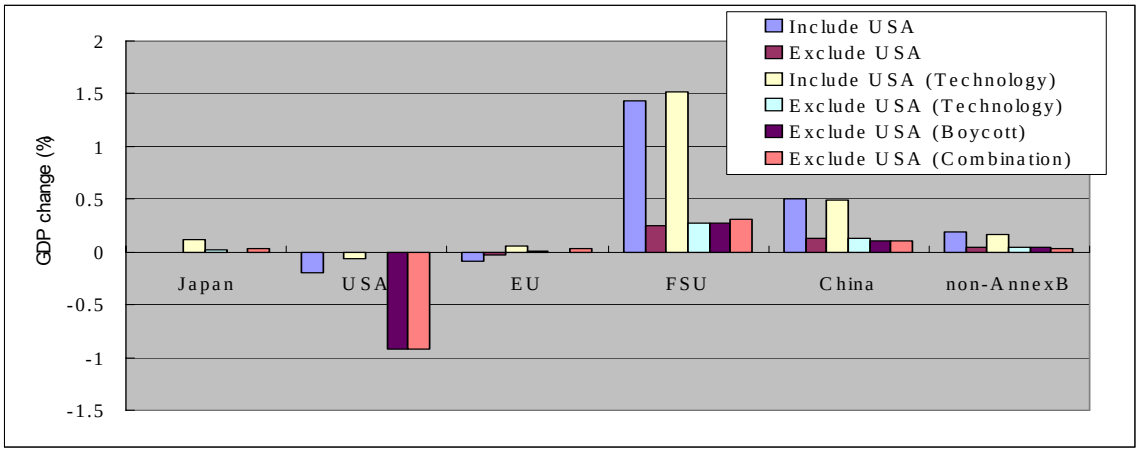

Figure 4 Percent change in GDP in 2010 with emission trading of 1/3rd restriction

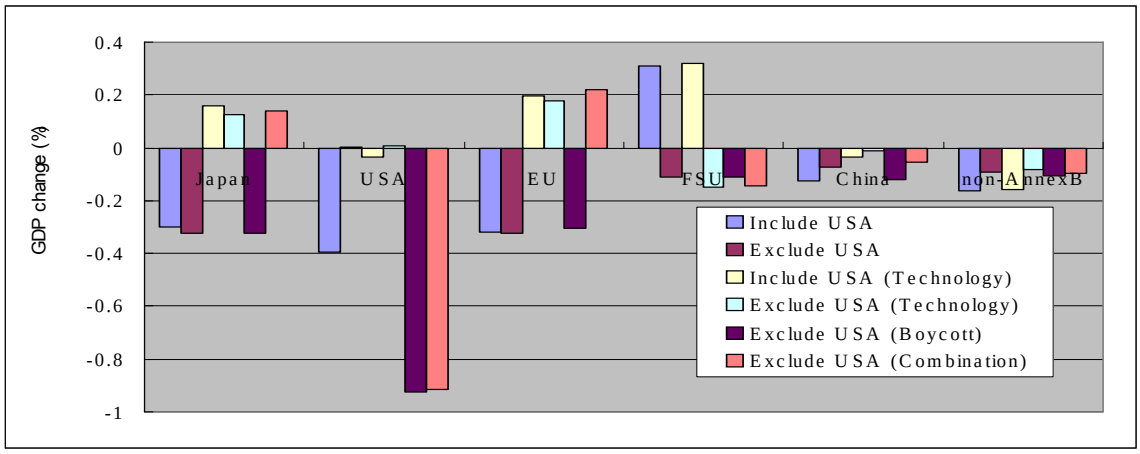

Figure 5 Percent change in GDP in 2010 with emission trading and CDM of 1/3rd restriction

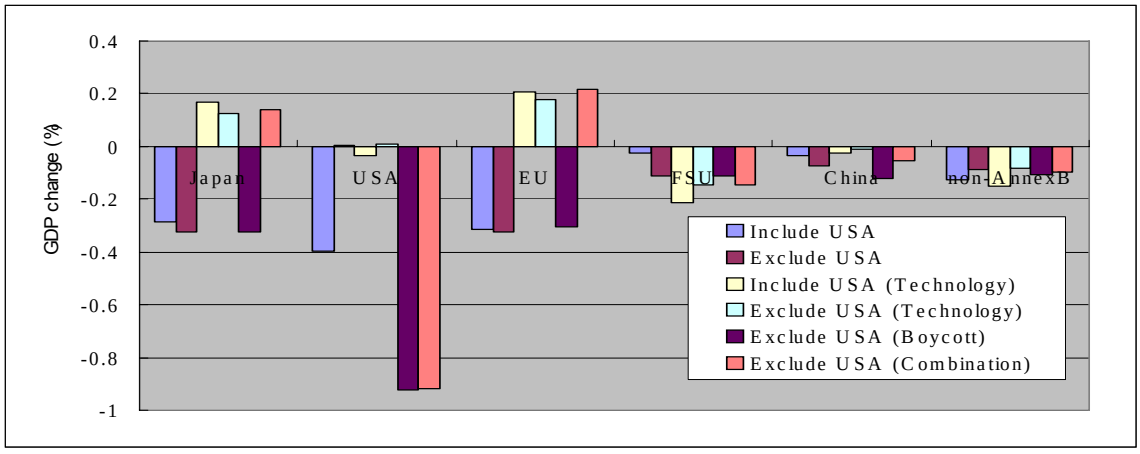

Figure 6 Percent change in GDP in 2010 with carbon sink accounting

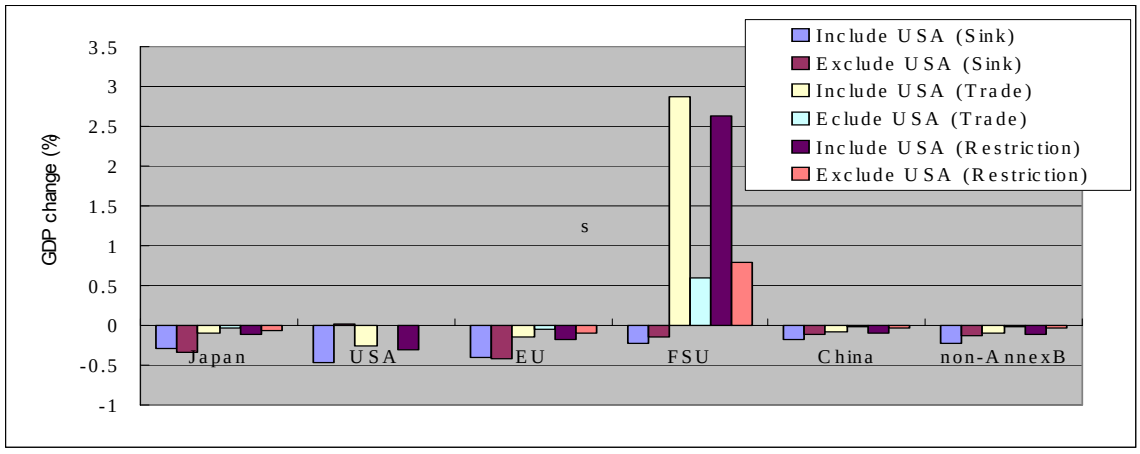

Table 1 Categorization of scenario set 1: no restriction on trading amount of carbon

Scenario	Kyoto Protocol including /excluding USA	Emission trade	CDM	Price Induced technical Change	Boycott movement
	Business as Usual				
21	Base case scenario				
	Kyoto protocol including USA				
22	include				
23	include	✓			
24	include	✓	✓		
	Kyoto protocol excluding USA				
52	exclude				
53	exclude	✓			
54	exclude	✓	✓		
	Kyoto protocol including USA, price induced technical change				
92	include			✓	
93	include	✓		✓	
94	include	✓	✓	✓	
	Kyoto protocol excluding USA, price induced technical change				
62	exclude			✓	
63	exclude	✓		✓	
64	exclude	✓	✓	✓	
	Kyoto protocol excluding USA, boycotte movement				
72	exclude				✓
73	exclude	✓			✓
74	exclude	✓	✓		✓
	Kyoto protocol excluding USA, price induced technical change, boycotte movement				
82	exclude			✓	✓
83	exclude	✓		✓	✓
84	exclude	✓	✓	✓	✓

Table 2 Categorization of scenario set 2: 1/3rd restriction of tradable carbon

Scenario	Kyoto Protocol including /excluding USA	Emission trade	CDM	Price Induced technical Change	Boycott movement
	Business as Usual				
21	Base case scenario				
	Kyoto protocol including USA				
22	include				
123	include	✓			
124	include	✓	✓		
	Kyoto protocol excluding USA				
52	exclude				
163	exclude	✓			
154	exclude	✓	✓		
	Kyoto protocol including USA, price induced technical change				
92	include			✓	
193	include	✓		✓	
194	include	✓	✓	✓	
	Kyoto protocol excluding USA, price induced technical change				
62	exclude			✓	
163	exclude	✓		✓	
164	exclude	✓	✓	✓	
	Kyoto protocol excluding USA, boycotte movement				
72	exclude				✓
173	exclude	✓			✓
174	exclude	✓	✓		✓
	Kyoto protocol excluding USA, price induced technical change, boycotte				
82	exclude			✓	✓
183	exclude	✓		✓	✓
184	exclude	✓	✓	✓	✓

Table 3 Categorization of scenario set 3: accounting carbon sink

Scenario	Kyoto Protocol including/excluding USA	Emission trade
	Kyoto protocol without emission trading	
322	include	
352	exclude	
	Kyoto protocol with no restriction emission trading	
323	include	no restriction
353	exclude	no restriction
	Kyoto protocol with restricted emission trading	
423	include	restriction*
453	exclude	restriction*

* restriction Tradable carbon is less than 1/2rd of committed reduction
Half of the tradable emission rights can be banked

Table 4 Percent reduction in GDP in the year 2010 compared to the base case scenario: no restriction on trading amount of carbon

Scenario	JPN	USA	EU	FSU	CHN	non-AnnexB
22	-0.423	-0.557	-0.443	-0.246	-0.198	-0.245
23	-0.137	-0.330	-0.185	3.499	-0.091	-0.113
24	-0.001	-0.201	-0.092	1.437	0.505	0.187
52	-0.476	0.007	-0.467	-0.164	-0.128	-0.136
53	-0.065	0.001	-0.085	0.922	-0.028	-0.024
54	-0.003	0.001	-0.029	0.244	0.124	0.049
92	0.270	0.058	0.352	-0.311	-0.047	-0.222
93	0.078	-0.069	0.084	3.317	-0.038	-0.113
94	0.115	-0.059	0.058	1.512	0.490	0.161
62	0.197	0.017	0.309	-0.213	-0.026	-0.121
63	0.014	0.003	0.015	0.938	-0.014	-0.025
64	0.026	0.001	0.009	0.274	0.124	0.046
72	-0.472	-0.920	-0.449	-0.162	-0.175	-0.150
73	-0.061	-0.922	-0.062	0.958	-0.074	-0.042
74	0.002	-0.922	-0.006	0.272	0.103	0.041
82	0.209	-0.911	0.350	-0.209	-0.069	-0.134
83	0.023	-0.920	0.044	0.972	-0.059	-0.042
84	0.035	-0.921	0.037	0.307	0.100	0.037

Table 5 Carbon price in the year 2010: no restriction on trading amount of carbon

					US$/tC
Scenario	JPN	USA	EU	FSU	CHN
21	0.0	0.0	0.0	0.0	0.0
22	343.0	176.9	255.9	0.0	0.0
23	69.3	69.3	69.3	69.3	0.0
24	37.7	37.7	37.7	37.7	37.7
52	336.9	0.0	249.6	0.0	0.0
53	25.3	0.0	25.3	25.3	0.0
54	9.6	0.0	9.6	9.6	9.6
92	251.7	145.3	195.0	0.0	0.0
93	60.8	60.8	60.8	60.8	0.0
94	35.5	35.5	35.5	35.5	35.5
62	247.0	0.0	190.5	0.0	0.0
63	23.2	0.0	23.2	23.2	0.0
64	9.3	0.0	9.3	9.3	9.3
72	355.3	0.0	264.2	0.0	0.0
73	27.1	0.0	27.1	27.1	0.0
74	11.0	0.0	11.0	11.0	11.0
82	260.0	0.0	200.3	0.0	0.0
83	24.8	0.0	24.8	24.8	0.0
84	10.6	0.0	10.6	10.6	10.6

Table 6 Percent reduction in GDP in the year 2010 compared with the base scenario: 1/3rd restriction of tradable carbon

Scenario	JPN	USA	EU	FSU	CHN	non-AnnexB
22	-0.423	-0.557	-0.443	-0.246	-0.198	-0.245
123	-0.301	-0.396	-0.317	0.309	-0.125	-0.164
124	-0.287	-0.395	-0.314	-0.024	-0.033	-0.126
52	-0.476	0.007	-0.467	-0.164	-0.128	-0.136
153	-0.325	0.003	-0.326	-0.112	-0.075	-0.090
154	-0.325	0.003	-0.326	-0.112	-0.075	-0.090
92	0.270	0.058	0.352	-0.311	-0.047	-0.222
193	0.161	-0.037	0.196	0.321	-0.034	-0.156
194	0.169	-0.035	0.207	-0.213	-0.024	-0.152
62	0.197	0.017	0.309	-0.213	-0.026	-0.121
163	0.125	0.010	0.179	-0.148	-0.011	-0.083
164	0.125	0.010	0.179	-0.148	-0.011	-0.083
72	-0.472	-0.920	-0.449	-0.162	-0.175	-0.150
173	-0.322	-0.922	-0.307	-0.110	-0.121	-0.106
174	-0.322	-0.922	-0.307	-0.110	-0.121	-0.106
82	0.209	-0.911	0.350	-0.209	-0.069	-0.134
183	0.141	-0.916	0.219	-0.146	-0.054	-0.098
184	0.141	-0.916	0.219	-0.146	-0.054	-0.098

Table 7 Carbon price in the year 2010: 1/3rd restriction of tradable carbon

					US$/tC
Scenario	JPN	USA	EU	FSU	CHN
21	0.0	0.0	0.0	0.0	0.0
22	343.0	176.9	255.9	0.0	0.0
123	195.0	97.0	152.7	15.2	0.0
124	198.2	97.2	155.2	6.2	6.2
52	336.9	0.0	249.6	0.0	0.0
153	192.9	0.0	151.3	0.0	0.0
154	192.9	0.0	151.3	0.0	0.0
92	251.7	145.3	195.0	0.0	0.0
193	146.9	83.9	120.2	14.6	0.0
194	147.3	83.9	121.1	0.0	0.0
62	247.0	0.0	190.5	0.0	0.0
163	145.0	0.0	119.1	0.0	0.0
164	145.0	0.0	119.1	0.0	0.0
72	355.3	0.0	264.2	0.0	0.0
173	204.5	0.0	161.1	0.0	0.0
174	204.5	0.0	161.1	0.0	0.0
82	260.0	0.0	200.3	0.0	0.0
183	152.9	0.0	125.9	0.0	0.0
184	152.9	0.0	125.9	0.0	0.0

Table 8 Percent reduction in GDP compared with the base scenario in the year 2010: accounting carbon sink

Scenario	JPN	USA	EU	FSU	CHN	non-AnnexB
322	-0.284	-0.474	-0.405	-0.229	-0.174	-0.226
352	-0.332	0.010	-0.427	-0.152	-0.112	-0.125
323	-0.101	-0.260	-0.151	2.866	-0.077	-0.095
353	-0.039	0.001	-0.056	0.599	-0.019	-0.016
423	-0.120	-0.307	-0.182	2.625	-0.098	-0.115
453	-0.072	0.002	-0.101	0.792	-0.036	-0.030

Table 9 Carbon price in the year 2010: accounting carbon sink.

					US$/tC
Scenario	Japan	USA	EU	FSU	China
322	266.7	157.9	238.4	0.0	0.0
352	261.9	0.0	233.0	0.0	0.0
323	56.3	56.3	56.3	56.3	0.0
353	16.6	0.0	16.6	16.6	0.0
423	70.4	70.4	70.4	70.4	0.0
453	31.6	0.0	31.6	31.6	0.0

Table 10 Long-term emission reduction scenarios

Scenario B1	Developed country	Goal of the Kyoto protocol is achieved by 2010. Thereafter, the emission reduction is continued by the rate of 5% per decade.
	Developing country	The emission will be stabilized by the year 2020-2040. Thereafter, the emission is reduced by the rate of 0.5% per decade.
Scenario B2	Developed country	Goal of the Kyoto protocol is achieved by 2010 except US. Thereafter, the emission reduction is continued by the rate of 5% per decade. US reduces emissions by the rate of 5% per decade after 2020.
	Developing country	The emission will be stabilized by the year 2030-2050. Thereafter, the emission is reduced by the rate of 0.5% per decade.
Scenario B3	Developed country	The emission is reduced by the rate of 5% per decade after 2020.
	Developing country	The emission will be stabilized by the year 2040-2060. Thereafter, the emission is reduced by the rate of 0.5% per decade.

Table 11 Climatic impacts of mitigation scenarios

(a) The year 2010

	Scenario B1	Scenario B2	Scenario B3
CO2 emission （GtC）	7.25	7.81	8.03
CO2 concentration（ppm）	394	395	396
Temperature rise（ºC）	0.353	0.355	0.355
Global warming damage (trillion US dollars)	0.108	0.108	0.108

(b) The year 2050

	Scenario B1	Scenario B2	Scenario B3
CO2 emission （GtC）	8.26	9.81	10.42
CO2 concentration（ppm）	480	494	498
Temperature rise（ºC）	1.19	1.23	1.25
Global warming damage (trillion US dollars)	1.04	1.04	1.08

(c) The year 2075

	Scenario B1	Scenario B2	Scenario B3
CO2 emission （GtC）	7.81	9.29	9.91
CO2 concentration（ppm）	522	547	556
Temperature rise（ºC）	1.70	1.79	1.82
Global warming damage (trillion US dollars)	2.58	2.72	2.76

(d) The year 2100

	Scenario B1	Scenario B2	Scenario B3

CO2 emission （GtC）	7.41	8.82	9.42
CO2 concentration（ppm）	557	590	603
Temperature rise（ºC）	2.15	2.29	2.34
Global warming damage (trillion US dollars)	5.50	5.87	6.00