Macro-quantitative Analysis of Kyoto Mechanism

-- Estimating Marginal Cost for CO_2 Emission Reduction through Japan's CDM Cooperation with China and Other Asian Nations --

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Summary

The Kyoto Protocol, as adopted at the Third Conference of the Parties to the U.N. Framework Convention on Climate Change known as COP3, has introduced the Kyoto Mechanism (including the Emissions Trading (ET), Joint Implementation (JI) and Clean Development Mechanism systems (CDM)) to promote the efficient achievement of greenhouse gas emission reduction targets. Calls have grown for global efforts to enhance the Kyoto Mechanism. This study represents a quantitative analysis of the Kyoto Mechanism (including the ET, JI and CDM systems) taking advantage of a world economy and energy model under a hypothetical situation where no problem exists with the actual implementation of the Kyoto Mechanism. Specifically, the author has estimated global CO_2 emissions, energy investment and the marginal cost for CO_2 emission reduction based on shadow price concept.

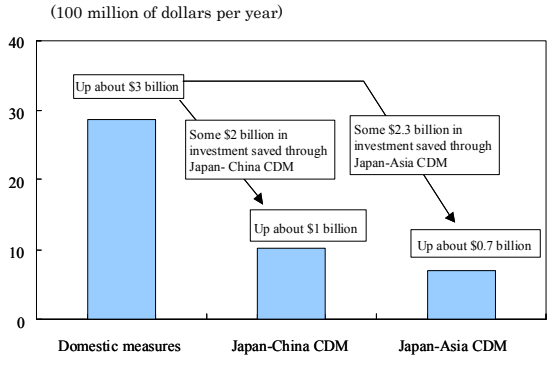
Estimating Marginal Cost for CO_2 Emission Reduction through Japan's CDM Cooperation with China and Other Asian Nations

The author has conducted a macro-quantitative analysis of Japan's possible CDM cooperation with China and other Asian developing nations. If Japan were to take only domestic measures to achieve its CO_2 emission reduction target under the Kyoto Protocol, it would have to invest some additional $3 billion per year more than in a reference case. Japan's CDM cooperation with China, including energy conservation projects, would work to cut the additional annual investment to some $1 billion. If Japan implements CDM cooperation with China and other Asian developing countries, the additional annual investment would be limited to some $0.7 billion (see Figure 1). Japan would thus take advantage of the CDM system to save additional annual investment by $2 billion to $2.3 billion while achieving the Kyoto Protocol target. The marginal cost for CO_2 reduction is estimated to total about $300 per ton of carbon-equivalent (t-C) if Japan depends only on domestic measures. The cost is expected to fall to about $50/t-C or one-sixth through Japan's CDM cooperation with China and to about $30/t-C through such cooperation with China and other Asian developing nations (see Figure 2). In this way, the introduction of the CDM under the Kyoto Protocol is expected to bring about substantial economic benefit for Japan.

Figure 3 shows a breakdown of the CO_2 emission reductions for the case in which Japan achieves its Kyoto Protocol emission target through its CDM cooperation with China. The

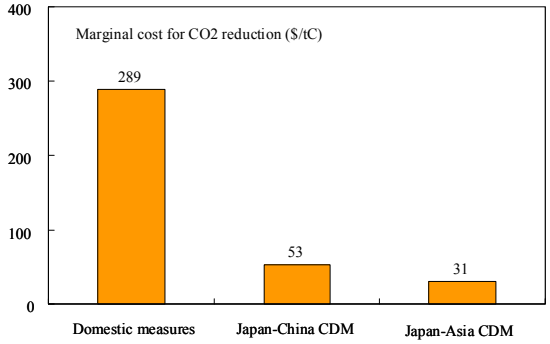
Japan-China CDM cooperation is estimated to work to reduce China's CO_2 emissions in 2010 by the equivalent of 123 million tons of carbon from 1,140 Mt-C to 1,017 Mt-C. The reduction includes 113 Mt-C through energy conservation, indicating Japan's transfer of energy conservation technologies to China would greatly contribute to reducing China's CO_2 emissions.

Figure 1 Japan's Additional Energy Investment Required to Achieve Kyoto Protocol Target (2010)



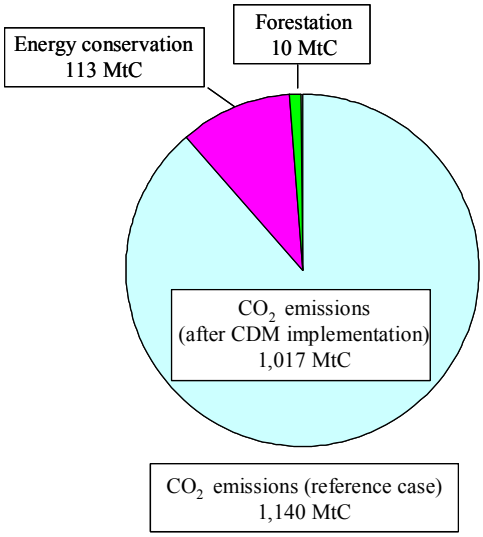
Source: Author's model calculation

Figure 2 Japan's Marginal CO_2 Reduction Cost (CO_2 Shadow Price) (2010)



Source: Author's model calculation

Figure 3 Breakdown of CO_2 Emission Reduction through Japan's CDM Cooperation with China (2010)



Source: Author's model calculation

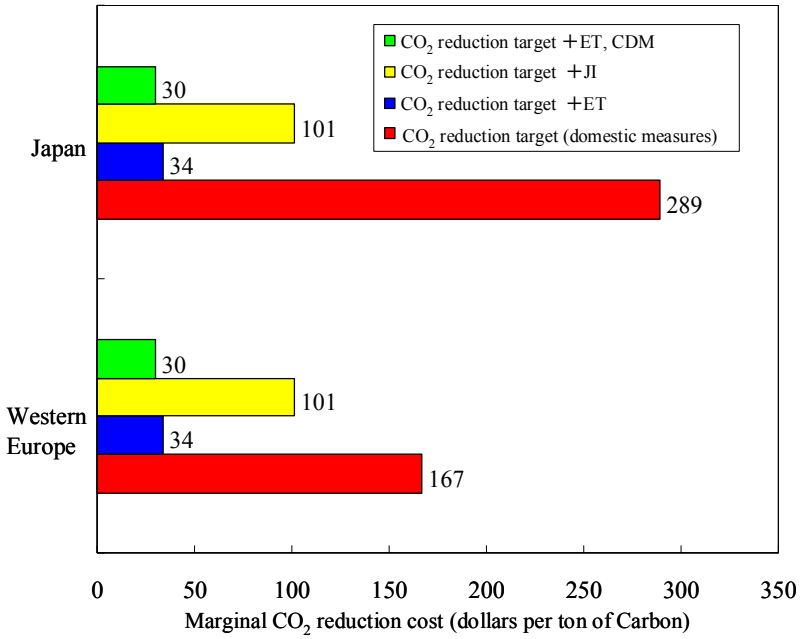
Industrial countries' CO_2 emission reduction alone cannot be used to deal with global warming. In the future, they will have to cooperate with others including Asian developing countries

where CO_2 emissions are expected to increase rapidly. There may be many inexpensive CO_2 reduction measures in Asian developing countries. Industrial nations' smooth transfers of energy conservation and other technologies to reduce the burden on the environment would be more cost effective for the whole of Asia. In this sense, Asia should take maximum advantage of the CDM. International energy cooperation including technology transfers under the CDM would grow more important. An important challenge for industrial countries, including Japan, would be to further enhance technology transfers and financial assistance to and human resources development in Asian developing countries.

Estimating Marginal Cost for CO_2 Emission Reduction through Kyoto Mechanism Exploitation

If global ET and JI systems are implemented within the Kyoto Protocol framework, marginal emission reduction costs in Annex I countries may be equalized and reduced to \$34/t-C for the ET implementation case and \$101/t-C for the JI implementation case. If the CDM is implemented in addition to the ET and JI systems, the marginal costs may be equalized and cut to \$30/t-C. In particular, Japan can be expected to substantially reduce the marginal cost for its achievement of the emission reduction target by exploiting the Kyoto Mechanism.

Figure 4 Marginal CO_2 Reduction Cost (2010)



Source: Author's model calculation

1. Introduction

The Kyoto Protocol was adopted at the Third Conference of the Parties to the U.N. Framework Convention on Climate Change, known as COP3, in 1997. The protocol set numerical targets for greenhouse gas emissions in Annex I countries (industrial nations, the countries of the former Soviet Union and Eastern Europe). These targets are ceilings on average emissions in the first commitment period (2008-2012). The numerical targets for Annex I countries, including Japan, the United States, Western Europe, Oceania, countries of the former Soviet Union and Eastern Europe, are an average 5.2% less than in 1990.

Based on the targets, the Kyoto Mechanism (called flexibility measures) was introduced to help these countries attain their numerical targets efficiently. The Kyoto Mechanism consists of three systems -- Emissions Trading (ET), Joint Implementation (JI) and the Clean Development Mechanism (CDM).

The three Kyoto Mechanism systems are divided by trading type into two -- the ET system for trading in emissions and the JI and CDM systems for trading in credits. Under the ET system, specific emission quotas fixed for Annex I countries under the Kyoto Protocol are subject to trading. Under the CDM and JI systems, however, trading can be done in credits given for emission reductions for each project. Under the JI system for emission trading among industrial nations, the unit for trading is called an Emissions Reduction Unit, or ERU. For the CDM, the unit is called a Certified Emissions Reduction Unit, or CER. Trading targets are limited to emission quotas for the ET system. Under the JI and CDM systems, procedures are required to fix a baseline emission for each project, identify a reduction through the implementation of the project and subject the reduction to trading. For trading in emission reduction credits under the JI and CDM systems, it is important to address problems including the transparency and approval of projects.

In this study, the author has estimated global CO_2 emissions in 2010 and the marginal CO_2 reduction cost under the shadow price concept, using the world economy and energy model for an ideal case where problems or obstacles do not exist regarding the implementation of the Kyoto Mechanism. The author has attempted to produce quantitative estimates for Japan's CDM cooperation with Asian developing countries including China that has led growth in global energy demand and CO_2 emission. The author has also tried to estimate CO_2 emissions and the marginal CO_2 reduction cost for an ideal situation where the Kyoto Mechanism can work for all the Annex I countries and others, although the United States and Australia among the Annex I countries have not ratified the Kyoto Protocol. Based on estimates for each Kyoto Mechanism system, the author would like to provide basic data for designing systems for future greenhouse gas emission reductions.

2. Outline of World Economy and Energy Model (WING-LDNE Model)

In this study, the author uses a world economy and energy model to make estimates for the

world economy, population, energy supply and demand, and CO_2 emissions through 2010. Here is an outline of the model. The model, called WING-LDNE, consists of two modules -- the WING module[1] to endogenously estimate economic growth, population and final energy demand through 2010 and the LDNE module[2] to determine energy supply on the precondition of the final energy demand estimate and on a cost minimization basis. For this study, the author divides the world into 10 regions -- (1) North America, (2) Western Europe, (3) Japan, (4) Oceania, (5) China, (6) other Asian nations, (7) the Middle East and North Africa, (8) other African nations, (9) Central and South America, and (10) the countries of the former Soviet Union and Eastern Europe. Annex I countries are (1) North America, (2) Western European countries, (3) Japan, (4) Oceania, and (10) the countries of the former Soviet Union and Eastern Europe. (Although the United States and Australia have yet to ratify the Kyoto Protocol, this study considers an ideal situation where these countries also take part in the Kyoto Mechanism.)

Modeling of the Kyoto Mechanism is formulated as mathematical programming problems. Specifically, in a bid to assess the Kyoto Mechanism, the author incorporates ET, JI and CDM concepts into the constraint equation for CO_2 emissions in the LDNE module described as mathematical optimization problems.

3. Modeling Kyoto Mechanism

This chapter explains about modeling of the Kyoto Mechanism. Specifically, the Kyoto Mechanism systems are reflected in the CO_2 emission constraint equation used for the LDNE module as described in the previous chapter, after problems with the real implementation are considerably simplified. In this analysis, calculations regarding banking, borrowing and other intertemporal transactions are not taken into account. The analysis target is limited to CO_2, although the Kyoto Protocol covers methane (CH_4), dinitrogen monoxide (N_2O), hydrofluorocarbon (HFC), perfluorocarbon (PFC) and sulfur hexafluoride (SF_6) in addition to CO_2 as greenhouse gases.

3.1 Reference Case

Estimates are made for the reference case in which no measures are taken to comply with greenhouse gas emission targets for Annex I countries under the Kyoto Protocol. This is a baseline case in which energy demand and CO_2 emissions increase at the present pace[3].

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[1] The WING module is the economy and energy model that the Energy Data and Modeling Center of the Institute for Energy Economics, Japan, has developed for making estimates for the very long term through 2100.

[2] The LDNE model, the linearized version of nonlinear functions (energy conservation and renewable energy supply functions) of the DNE21 (Dynamic New Earth21) model handling engineering technologies, is adopted as a technology assessment model. See Yamaji, K.et al., Global energy system to maintain atmospheric CO_2 concentration at 550 ppm, Environmental Economics and Policy Studies, 3, 159, 2000.

[3] The objective function and constraint condition equation of the LDNE for this case are as follows.

3-2 Emission Target-Setting Case (domestic measures)

In this case, Annex I regions (North America, Western Europe, Japan, Oceania, the countries of the former Soviet Union and Eastern Europe) comply with their respective emission targets set out in the Kyoto Protocol. The CO_2 emission ceiling for 2010 is set at 93% (down 7%) of the 1990 emission level for North America, 92% (down 8%) for Western Europe, 94% (down 6%) for Japan, 108% (up 8%) for Oceania and 100% (unchanged) for the countries of the former Soviet Union and Eastern Europe. In this case, the Annex I regions attain their emission targets only with domestic measures, without introducing the Kyoto Mechanism. Estimates for the countries of the former Soviet Union and Eastern Europe, and non-Annex I regions for this case may be used as baseline estimates for the JI and CDM systems[4].

3-3 Kyoto Mechanism

Estimates are made for the case where the Kyoto Mechanism (flexibility measures) is introduced for achieving emission targets.

(a) Emissions Trading (ET)

Emissions trading means transactions in part of the CO_2 and other greenhouse gas emissions that are allowed for industrial countries under the Kyoto Protocol. Total allowable emissions are set and allocated to countries as emission quotas (or rights). Depending on the difficulties in reducing emissions domestically, countries may trade in emission rights. In emissions

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Gross system costs are minimized for each kind of resources supply and technological constraint conditions.
Objective function:

$$min.\ \ TotalCost = \sum_{n=1}^{10} f_n(x_n) \qquad (1)$$

Constraint condition:

$$A_n x_n \geq b_n \qquad (2)$$

x_n : The variable for Region *n*. A_n : The coefficient matrix of the constraint condition equation for Region *n*. b_n : The right constant term of the constraint condition equation for Region *n*. f_n : The cost function for Region *n*.

[4] In the modeling of the Kyoto Mechanism, the following constraint equation regarding CO_2 emissions for each Annex I region is added to Equations (1) and (2) in the reference case.
Objective function:

$$min.\ \ TotalCost = \sum_{n=1}^{10} f_n(x_n) \qquad (1)$$

Constraint condition:

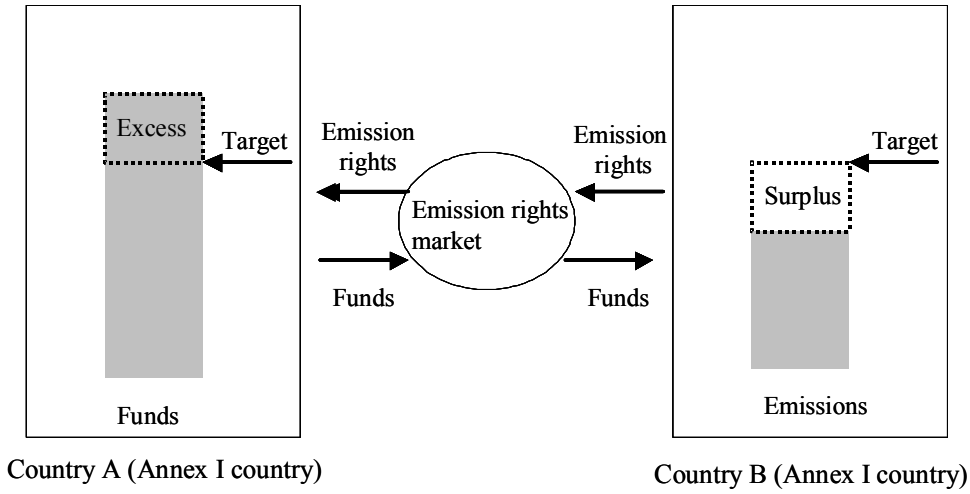
$$A_n x_n \geq b_n \qquad (2)$$

$$G_n x_n \leq e_n \quad for \quad n \in Annex\ \mathrm{I} \qquad (3)$$

G_n: The coefficient matrix of CO_2 emissions in Region *n*. e_n: The CO_2 emission target for Region *n* under the Kyoto Protocol

trading among industrial nations subject to numerical targets, one country that emits more greenhouse gases than its target may buy an amount equivalent to the excess from others to attain the target. A country that emits less than its target may sell the gap to others. The ET system has attracted attention as a globally efficient way for CO_2 reduction through international trading.

Figure 3-1 Concept of Emissions Trading (ET)



For this analysis, emissions trading is assumed to be implemented until marginal CO_2 reduction costs are equalized for Annex I regions[5].

(b) Joint Implementation (JI)

The Joint Implementation means that industrial nations jointly implement greenhouse gas reduction projects and trade in emission cuts resulting from such projects. In a country where emission reduction costs are lower, enterprises from another country may implement energy conservation or other greenhouse gas reduction projects. Emission reductions may then be counted as those in that other country.

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[5] While emission ceilings are set for Annex I regions, a ceiling is set for the whole of the five Annex 1 regions. The whole ceiling is a combination of the five regional ceilings. For mathematical programming, the following equations are used:
Objective function:

$$min.\ \ TotalCost = \sum_{n=1}^{10} f_n(x_n) \qquad (1)$$

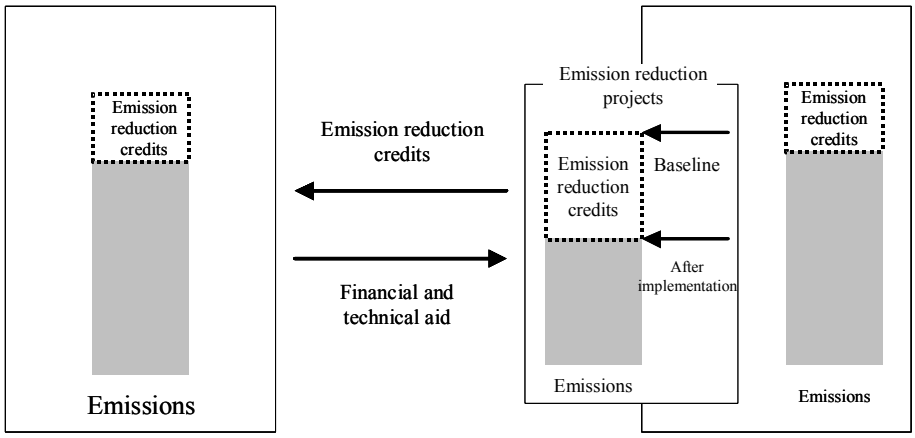
Constraint condition:

$$A_n x_n \geq b_n \qquad (2)$$

$$\sum_{n \in Annex\ \mathrm{I}} G_n x_n \leq \sum_{n \in Annex\ \mathrm{I}} e_n \qquad (4)$$

For this analysis as well, JI projects are assumed to be implemented until marginal CO_2 reduction costs are equalized for Annex I regions[6]. As in the case for the ET system, a single constraint equation is used for setting an emission ceiling for the whole of the Annex I regions, instead of region-by-region ceilings. In the JI case, however, the emission ceiling is a combination of regional baseline emissions, rather than regional emission targets. Problems exist regarding the countries of the former Soviet Union and Eastern Europe. This region's emissions are expected to slip below the target even without emission reduction measures, resulting in a gap (called "hot air") between the target and real emissions. The baseline emissions are virtual estimates based on certain assumptions. Some people say even this region would have difficulties achieving the target. For this model calculation, however, emissions for the emission target-settling case are adopted as the baseline.

Figure 3-2 Concept of Joint Implementation (JI)



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Objective function:

$$min.\ \ TotalCost = \sum_{n=1}^{10} f_n(x_n) \qquad (1)$$

Constraint condition:

$$A_n x_n \geq b_n \qquad (2)$$

$$\sum_{n \in Annex\ \mathrm{I}} G_n x_n \leq \sum_{n \in Annex\ \mathrm{I}} G_n x_n^* \qquad (5)$$

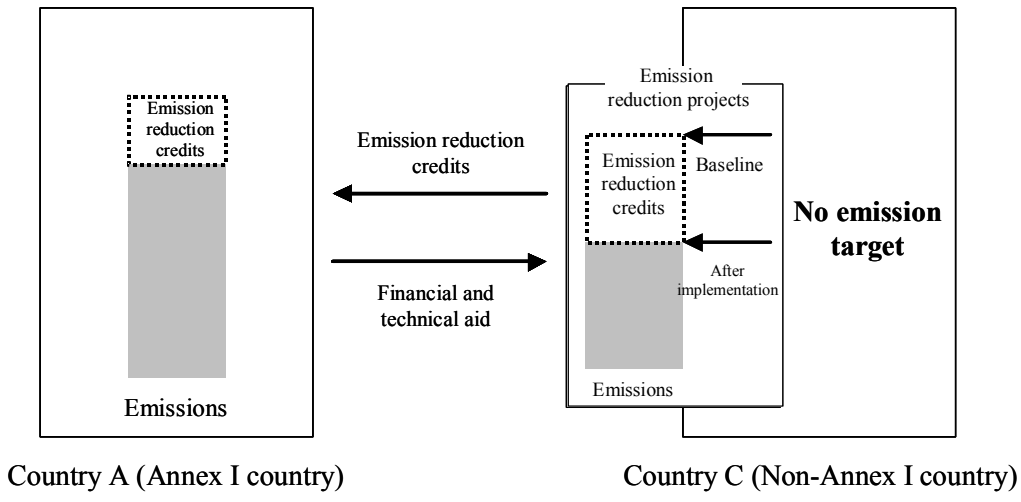
x_n^*: The optimized solution for Region n for the above emission target-setting case (mathematical programming problems comprising Equations (1), (2) and (3)).

Comparing the ET and JI models (Equations (4) and (5)), we can find that the ET system can ease the emission constraints for the whole of the Annex I regions more than the JI system as CO_2 emissions in the countries of the former Soviet Union and Eastern Europe are now expected to slip below the target even without emission reduction measures. The ET model is thus structurally different from the JI model. Under the JI model, trading in pure emission reduction credits excluding hot air can be taken into account.

(c) Clean Development Mechanism (CDM)

The basic framework for the CDM is the same as that for the JI system. But there is a clear difference. While the JI system is implemented between industrialized nations, the CDM allows industrialized nations to receive emission reductions through energy conservation and other joint projects with and in developing countries. If emissions are reduced from the baseline level through specific projects, the reductions may be certified as credits to be acquired by project-implementing industrialized nations for trading. Under the CDM and JI systems, two countries can share greenhouse gas emission reductions through their cooperation in emission-cutting projects. The CDM is used for cooperation between industrialized nations subject to numerical targets and developing countries, and the JI for cooperation between industrialized nations subject to such targets. In this sense, developing countries can take advantage of the CDM to promote environmental measures and receive technologies through investment by industrialized nations. But some problems remain to be solved, including whether any ceiling should be set on emissions subject to trading (complementarity problem) and management of emission quotas.

Figure 3-3 Concept of Clean Development Mechanism (CDM)



The three Kyoto Mechanism systems are divided by trading target into two -- the ET system for trading in emissions and the JI and CDM systems for trading in credits. Under the ET system, specific emission quotas fixed in the Kyoto Protocol's Annex B are subject to trading. Under the CDM and JI systems, however, trading can be done in credits given for emission reductions for each project. Under the JI system for emission trading among industrialized nations, the unit for trading is called an Emissions Reduction Unit, or ERU. For the CDM, the unit is called Certified Emissions Reduction Unit, or CER. Trading targets are limited to emission quotas for the ET system. Under the JI and CDM system, procedures are required to fix a baseline emission for each project,

identify a reduction through the implementation of the project and subject the reduction to trading[7]. For this analysis, however, Annex I regions are assumed to promptly acquire all of the emission reduction credits emerging in non-Annex I nations.

(d) Japan-Asia CDM Cooperation

This study also provides quantitative estimates on Japan's CDM cooperation with Asian developing countries including China that has led global energy demand and CO_2 emission growth. The CDM exploitation is cited as a key measures for Japan's energy cooperation with Asia where energy demand has been increasing conspicuously. Japan will reportedly have to exploit not only domestic measures but also the Kyoto Mechanism to achieve its greenhouse gas emission reduction target (6% from 1990). In choosing from the Kyoto Mechanism systems, Japan may have to take into account economic effects, environmental improvements, Japan's leadership and efficient emission reductions through cuts in marginal CO_2 reduction costs in the region for implementation of these systems. Then, Japan may find that its CDM implementation in Asia including China would be more desirable than its CDM cooperation with non-Asian developing countries, joint implementation of CO_2 emission reduction projects with other industrialized nations or countries in

[7] For this model analysis, credit certification and other operational problems are ignored and CDM projects are assumed to make progress until marginal CO_2 reduction costs are equalized throughout the world. A single constraint equation is used for setting a ceiling on global CO_2 emissions. The ceiling consists of emission targets for Annex I countries and baseline emissions estimated for non-Annex I nations without CDM implementation. In this case, ET and CDM transactions may be done.

Objective function:

$$min.\ \ TotalCost = \sum_{n=1}^{10} f_n(x_n) \qquad (1)$$

Constraint condition:

$$A_n x_n \geq b_n \qquad (2)$$

$$\sum_{n=1}^{10} G_n x_n \leq \sum_{n \in Annex\ \mathrm{I}} e_n + \sum_{n \notin Annex\ \mathrm{I}} G_n x_n^* \qquad (6)$$

If the emission ceiling is set as a combination of baseline emissions in non-Annex I countries and those in Annex I countries without the JI system, JI and CDM transactions may be done.

Objective function:

$$min.\ \ TotalCost = \sum_{n=1}^{10} f_n(x_n) \qquad (1)$$

Constraint condition:

$$A_n x_n \geq b_n \qquad (2)$$

$$\sum_{n=1}^{10} G_n x_n \leq \sum_{n=1}^{10} G_n x_n^* \qquad (7)$$

transition to becoming market economies, or emissions trading. Japan's energy supply/demand structure reportedly features relatively greater energy conservation than in any other region. Exploitation of Japan's cutting-edge energy technologies in Asian developing countries is generally expected to bring about more efficient CO_2 emission reductions and substantially cut Japan's marginal CO_2 reduction cost for achieving its Kyoto Protocol target. In this sense, this study provides a quantitative analysis of changes in CO_2 emissions through Japan's CDM cooperation with China and with all Asian developing countries and of Japan's marginal CO_2 reduction cost for achieving its Kyoto Protocol target[8].

4. Calculation Results

4-1 Quantitative Estimates for Japan-China and -Asia CDM Cooperation

CO_2 emission changes through Japan-China and Japan-Asia CDM cooperation are illustrated below:

[8] Japan-China and Japan-Asia CDM cooperation is modeled as follows:
Japan-China CDM cooperation
Under the following mathematical programming problem, CO_2 emissions and the marginal CO_2 reduction cost are estimated for the case of Japan-China CDM cooperation:

Objective function:

$$min.\ \ TotalCost = \sum_{n=1}^{10} f_n(x_n) \qquad (1)$$

Constraint condition:

$$A_n x_n \geq b_n \qquad (2)$$

$$\sum_{n \in Japan, China} G_n x_n \leq \sum_{n \in Japan} e_n + \sum_{n \in China} G_n x_n^* \qquad (8)$$

Japan-Asia CDM cooperation:
Under the following mathematical programming problem, CO_2 emissions and the marginal CO_2 reduction cost are estimated for the case of Japan-Asia CDM cooperation:

Objective function:

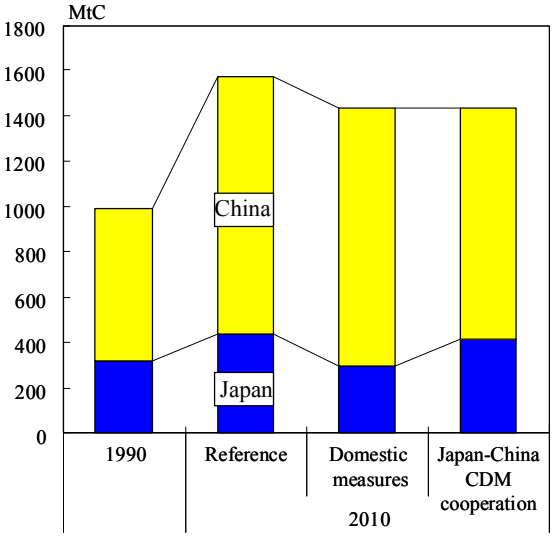
$$min.\ \ TotalCost = \sum_{n=1}^{10} f_n(x_n) \qquad (1)$$

Constraint condition:

$$A_n x_n \geq b_n \qquad (2)$$

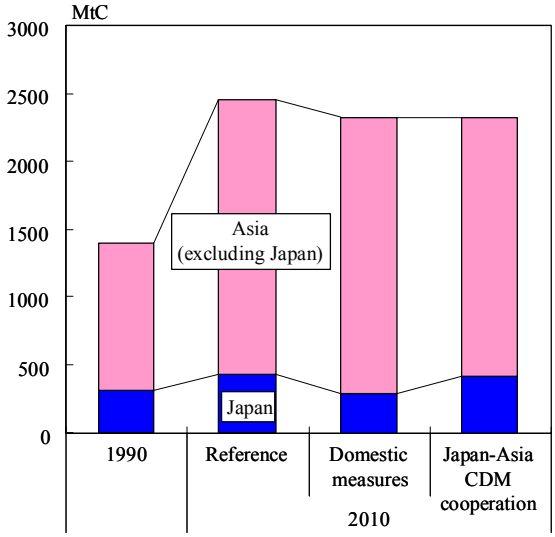
$$\sum_{n \in Japan, China, otherAsiancountries} G_n x_n \leq \sum_{n \in Japan} e_n + \sum_{n \in China, otherAsiancountries} G_n x_n^* \qquad (9)$$

Figure 4-1 CO_2 Emissions (Japan-China)



Source: Author's model calculation

Figure 4-2 CO_2 Emissions (Japan-Asia)



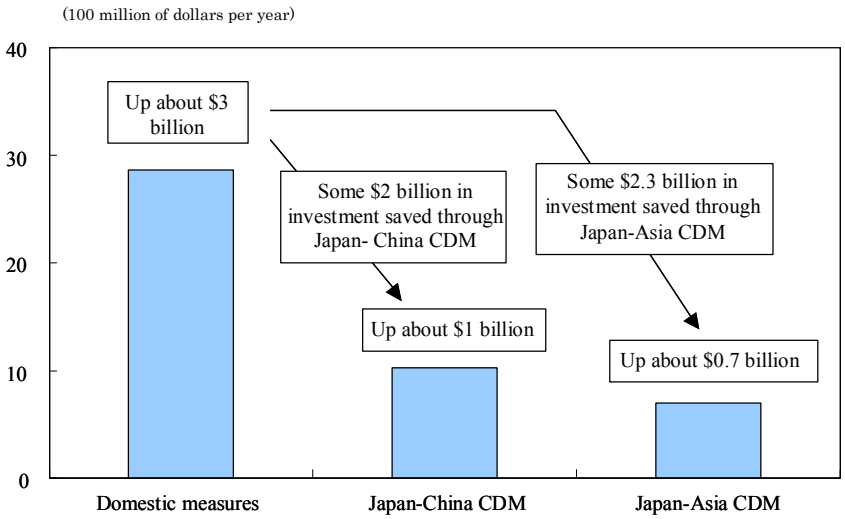
Source: Author's model calculation

* "Domestic measures" mean the case in which Japan will depend only on domestic measures for achieving the Kyoto Protocol emission target.

Figure 4-3 indicates additional energy investment (total energy system costs including energy production costs, costs of the energy conversion sector including power plants and oil refineries, and energy transportation costs) in 2010 for each case. The figure shows the costs' increase from the reference case ("costs for each case" minus "reference costs") in 2010. If Japan were to take only domestic measures to achieve its CO_2 emission reduction target under the Kyoto Protocol, as indicated by the figure, it would have to invest some $3 billion per year more than in the reference case. Japan's CDM cooperation with China, including energy conservation projects, would work to cut the additional annual investment to some $1 billion. If Japan implements CDM cooperation with China and other Asian developing countries, the additional annual investment would be limited to some $0.7 billion (see Figure 1). Japan could thus take advantage of the CDM system to save additional annual investment by $2 billion to $2.3 billion from the reference case while achieving the Kyoto Protocol target. In this way, introduction of the CDM system as part of the Kyoto Mechanism may bring about substantial economic effects.

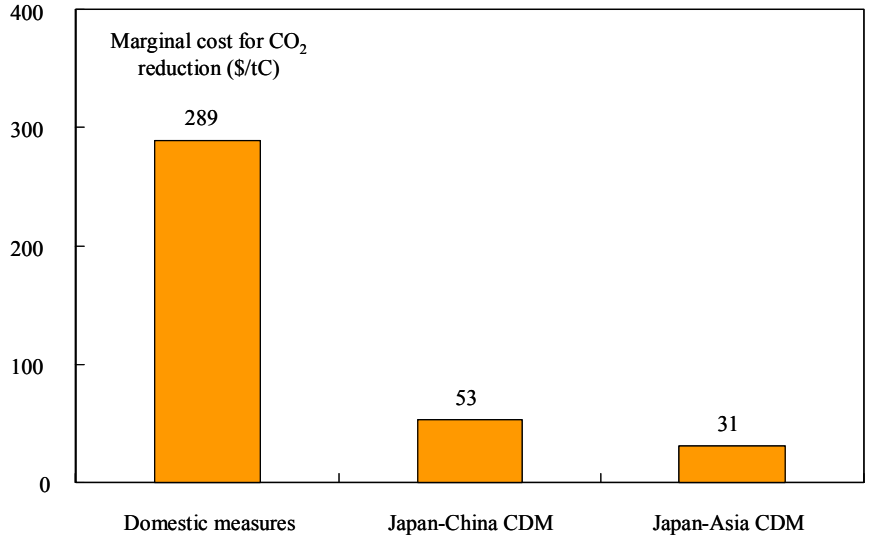
Figure 4-4 indicates the marginal cost for CO_2 reduction in the reference case in which Japan depends only on domestic measures for achieving the Kyoto Protocol target, in the case of Japan's CDM cooperation with China, and in that of Japan's CDM cooperation with China and other Asian developing countries. The marginal cost for CO_2 reduction is estimated to total about $290 per ton of carbon-equivalent (t-C) if Japan depends only on domestic measures. The cost is expected to fall to about $50/t-C or one-sixth through Japan's CDM cooperation with China and to about $30/t-C through such cooperation with China and other Asian developing nations.

Figure 4-3 Japan's Additional Energy Investment Required to Achieve Kyoto Protocol Target (2010)



Source: Author's model calculation

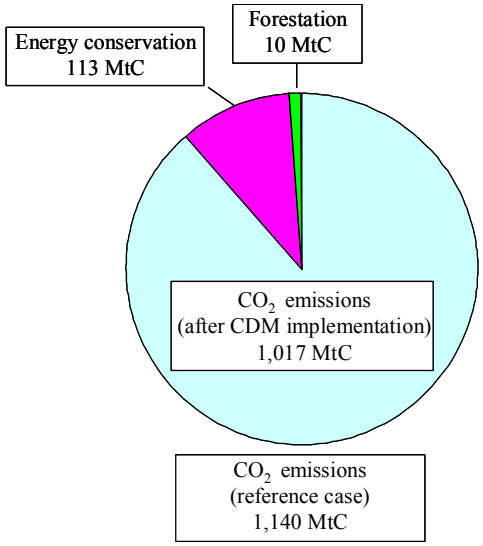
Figure 4-4 Japan's Marginal CO_2 Reduction Cost (CO_2 Shadow Price) (2010)



Source: Author's model calculation

Figure 4-5 shows a breakdown of the CO_2 emission reductions for the case in which Japan achieves its Kyoto Protocol emission target through its CDM cooperation with China. The Japan-China CDM cooperation is estimated to work to reduce China's CO_2 emissions in 2010 by the equivalent of 123 million tons of carbon from 1,140 Mt-C to 1,017 Mt-C. The reduction includes 113 Mt-C through energy conservation, indicating Japan's transfer of energy conservation technologies to China would greatly contribute to reducing China's CO_2 emissions.

Figure 4-5 Breakdown of CO_2 Emission Reduction through Japan's CDM Cooperation with China (2010)



Source: Author's model calculation

Industrial countries' CO_2 emission reduction alone cannot be used to deal with global warming. In the future, they will have to cooperate with others including Asian developing countries where CO_2 emissions are expected to increase rapidly. There may be many inexpensive CO_2 reduction measures in Asian developing countries. Given the fast increase in CO_2 emissions in China and other Asian developing countries, Japan's domestic measures may have only a limited impact on environmental constraints. Industrial nations' smooth transfers of energy conservation and other technologies to reduce the load on the environment would be more cost effective for the whole of Asia. China and other Asian developing countries reportedly have great room to improve energy efficiency. There is great room for energy conservation and technological cooperation in these countries. Such cooperation will become the source of industrial countries' agreements with developing nations on global joint CO_2 emission reductions. In this sense, industrialized countries should take maximum advantage of the CDM, JI and ET systems under the Kyoto Protocol. International energy development cooperation including technology transfers would grow more important. An important challenge for industrial countries would be to further enhance technology transfers and financial assistance to and human resources development in Asian developing countries.

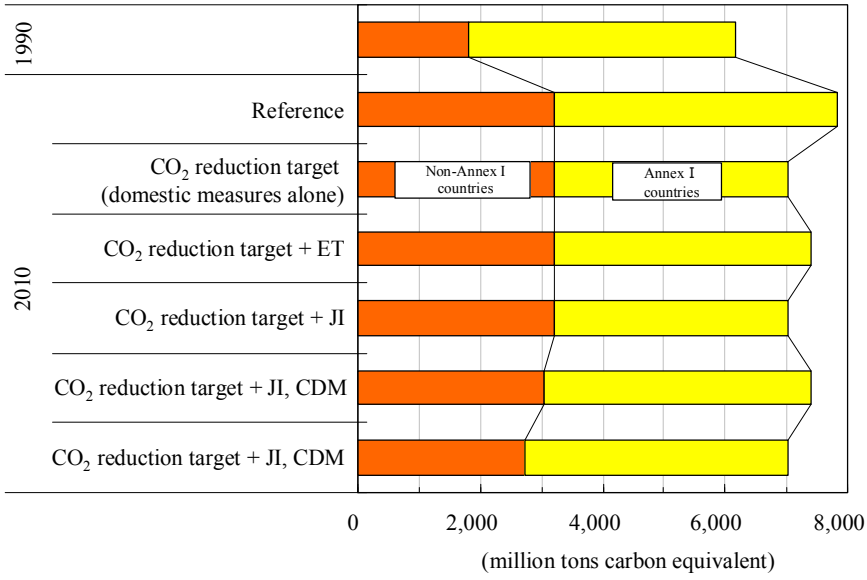
It is important to have extra-long-term perspectives and create a flexible future framework where both industrial and developing countries would participate in managing the risk of global warming. For example, it would be effective for Asian developing countries to include anti-global warming measures into their economic plans and set voluntary targets for CO_2 emission reductions

and energy efficiency targets for industrial, transportation, household and other sectors. If these countries grow more conscious of curbing CO_2 emissions through such efforts, the effects of the market mechanism and public policy enhancement may be combined to stimulate autonomous development of technologies for alternative energies and energy conservation.

4-2 Quantitative Assessment of Kyoto Mechanism in World

This section provides estimated global CO_2 emissions in 2010. Estimates are given for Annex I and other countries. They indicate that emissions in non-Annex I countries including developing nations may increase remarkably from 1990. In a reference case in which no targets are set for emission reductions, global CO_2 emissions in 2010 may reach some 8 billion t-C. If Annex I countries achieve their respective targets under the Kyoto Protocol, global emissions in the year may total about 7 billion t-C, 1 billion t-C less than in the baseline case. In cases where the ET system is utilized (emission targets plus ET, emission targets plus ET and CDM), emissions are estimated to exceed those in other cases excluding the reference case because the Kyoto Mechanism is expected to work to provide the market with hot air in the countries of the former Soviet Union and Eastern Europe. Russia's greenhouse gas emission target for 2010 under the Kyoto Protocol is 100% of the 1990 level. Its emissions in 2010 are now estimated at 73% of the 1990 level. The gap of 27% may be released in the CO_2 emission rights market.

Figure 4-6 Global CO_2 Emissions

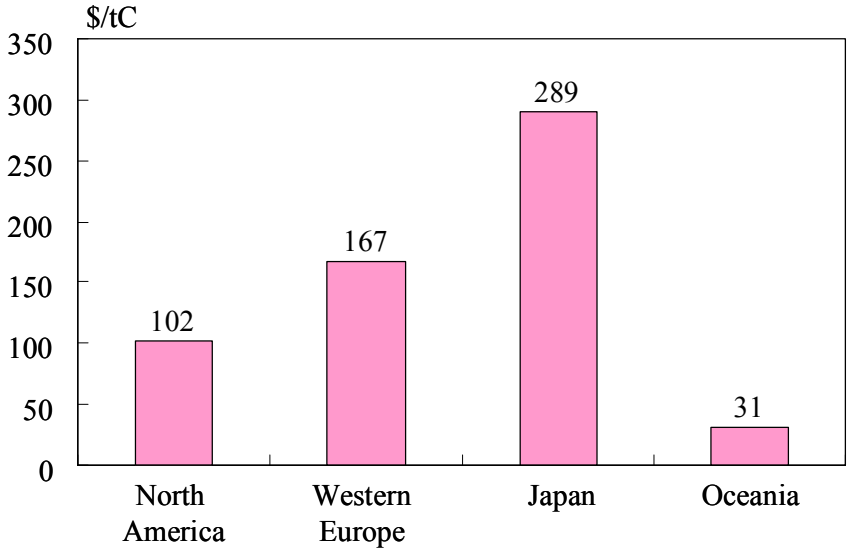


Source: Author's model calculation

Figure 4-7 shows Annex I countries' marginal cost for CO_2 emission reductions (CO_2

shadow prices) to achieve Kyoto Protocol targets with domestic measures alone. As of 2007, however, only Western Europe (EU) and Japan have vowed to comply with the protocol. Japan's marginal CO_2 reduction cost is estimated at $290/t-C, the highest among Annex I regions, followed by $170/t-C for Western Europe, $100/t-C for North America and $30/t-C for Oceania. North America and Oceania have not ratified the protocol.

Figure 4-7 Marginal Costs for CO_2 Emission Reductions (CO_2 shadow prices) to Achieve Kyoto Protocol Targets

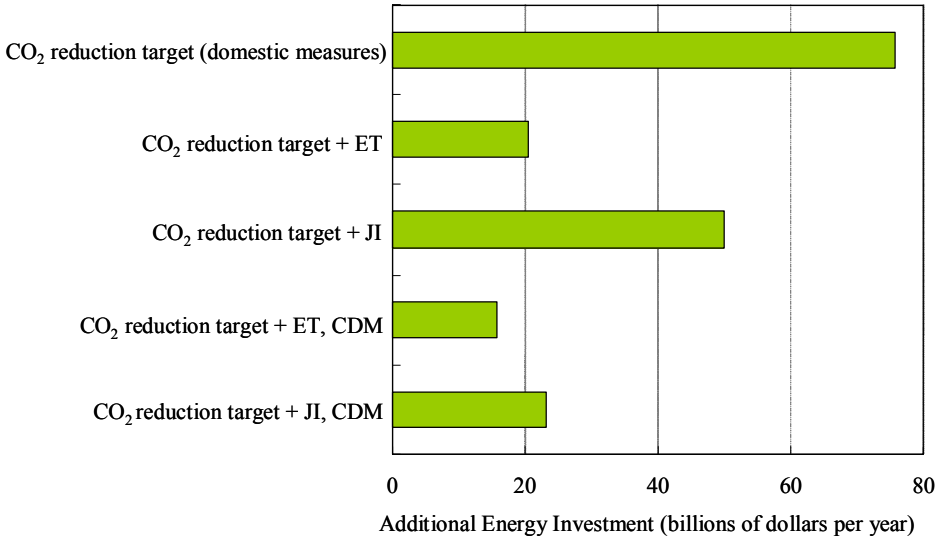


Source: Author's model calculation

* As of 2007, only Western Europe (EU) and Japan have vowed to comply with the protocol.

Next, Figure 4-8 shows the world's additional energy investment in 2010 (an excess of cost for each case over the reference case cost).

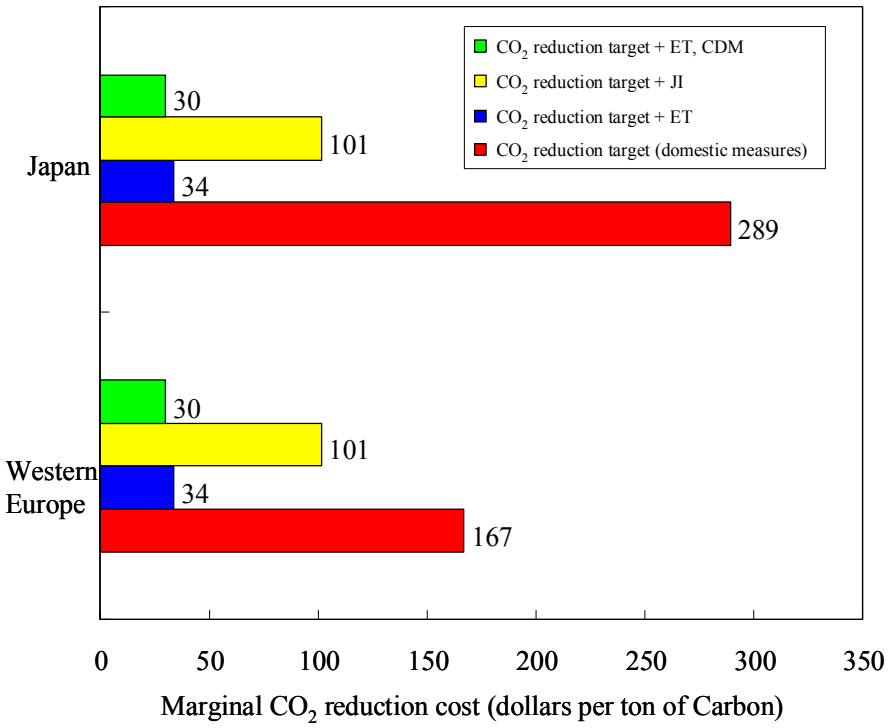
Figure4-8 World's Additional Energy Investment (2010)



Source: Author's model calculation

As indicated by the figure, the Annex I countries that are to achieve their respective Kyoto Protocol CO_2 emission targets with domestic measures alone may have to annually invest additional $80 billion more than in the reference case. If the Annex I countries utilize the ET system in addition to domestic measures, their additional annual investment may be limited to $20 billion, with some $60 billion saved. If the JI system is exploited along with domestic measures, the annual additional investment may be some $30 billion less than in the case for domestic measures alone. Since the hot air for the former Soviet Union and Eastern Europe is not counted as emission reduction credits for an analysis of the JI system in this case, the additional investment for the JI case is more than for the ET case. Additional investment for the "CO_2 reduction target plus ET and CDM" case may be some $5 billion less than for the "CO_2 reduction target plus ET" case, while additional investment for the "CO_2 reduction target plus JI and CDM" case may be some $27 billion less than for the "CO_2 reduction target plus JI" case. Savings for the ET-CDM combination may be less than for the JI-CDM combination. This is interpreted as indicating that the countries of the former Soviet Union and Eastern Europe as providers of hot air are competing with non-Annex I countries as providers of emission reduction credits. These estimates indicate that even the ET system alone may help save costs sufficiently for achieving CO_2 emission reduction targets in the first commitment period.

Figure 4-9 Marginal CO_2 Reduction Cost (2010)



Source: Author's model calculation

Lastly, Figure 4-9 shows marginal CO_2 reduction costs in 2010 for Western Europe and Japan that have ratified the Kyoto Protocol. In mathematical optimization problems, the marginal CO_2 reduction cost (CO_2 shadow price) is theoretically equal to a carbon tax rate required to achieve the same CO_2 emission reduction, indicating the degree of difficulty in reducing CO_2 emissions. If Japan were to achieve its Kyoto Protocol target with domestic measures alone, its marginal cost may be as high as \$290/t-C. If the global ET and JI systems are implemented within the Kyoto Protocol framework, marginal emission reduction costs in Annex I countries may be equalized and reduced to \$34/t-C for the ET implementation case and \$101/t-C for the JI implementation case. If the CDM is implemented in addition to the ET and JI systems, the marginal costs may be equalized and cut to \$30/t-C. In particular, Japan can be expected to substantially reduce the marginal cost for its achievement of the emission reduction target by exploiting the international Kyoto Mechanism.

5. Conclusion

This study has exploited a world economy and energy model to estimate CO_2 emissions, costs for relevant measures and the marginal CO_2 reduction cost under the Kyoto Mechanism. However, these estimates are for an hypothetical and ideal situation in which real problems

regarding the Kyoto Mechanism implementation are ignored. These estimates indicate that the Kyoto Mechanism may lower the cost to $20 billion per year for CO_2 reductions amounting to the equivalent of 1 billion tons of carbon. Japan's marginal cost for CO_2 emission reduction may be cut to some $30/t-C from about $290t-C. This study's analytical results depend on uncertain economic growth, technology and cost projections with real Kyoto Mechanism implementation problems ignored and should be interpreted carefully. In reality, CO_2 emission reductions are certified and implemented for specific CDM and JI projects. In this sense, more realistic estimates may depend on a bottom-up approach using a model that can take into account details of specific measures for CO_2 emission reductions. Since such an approach is difficult at present, this study has adopted a macro approach to indicate the effectiveness of the Kyoto Mechanism on a case-by-case basis. This point is worthy of attention.

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