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CDM's Potential in China: An Analysis Using the GTAP-E Model

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This chapter documents the promise of China-Japan environmental cooperation as a measure to reduce CO_2 emissions. A modified version of the standard GTAP (Global Trade Analysis Project) model — the GTAP-E (Energy) model — is used here. A key feature of the GTAP-E model is that energy inputs are assumed to be substitutable with other primary inputs, such as labor and capital.

It is confirmed through simulation analyses that an improvement of energy efficiency in China's power plants through CDM projects would reduce CO_2 emissions not only efficiently but also with a welfare improvement, while introducing a carbon tax in Japan — even though it would reduce CO_2 emissions — would aggravate the economy.

5.1 Introduction

In an ideal world, Annex I countries, including Japan, would faithfully follow the spirit of the Kyoto Conference, held in 1997, and reduce CO_2 emissions solely through domestic measures. However, it would be not easy for Japan to achieve its Kyoto target using domestic measures only. The Ministry of the Environment enacted the Kyoto Protocol Target Achievement Plan of 2005, therefore, stating that GHG reduction comparing with the base year would be -1.8% to -0.8% and that non-attainment part would be realized by making use of forest carbon sinks and the Kyoto mechanisms such as the CDM.[1] The main purpose of the

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CDM is not only the reduction of GHG emissions but also assistance with sustainable development in developing countries. Japan has a long history of mutually beneficial economic relations with East Asia through trade, foreign direct investment (FDI), and official development assistance (ODA), and recently an "East Asian Economic Grouping" has been proposed. Hence, environmental collaboration including implementation of the CDM in East Asia is agreeable to Japan for geopolitical reasons as well as for its economic interests in the region.

This chapter introduces a case study to show the macro-potentiality of a CDM project whose target is the power sector in China.[2] Section 5.2 gives a brief explanation of the GTAP-E model. Section 5.3 presents simulation analyses using the GTAP-E model: the first simulation estimates CO_2 emission reductions through technology transfer from Japan to China within the CDM framework; the second simulation examines how much CO_2 emissions reduction can be achieved by the introduction of a carbon tax in Japan as a reference case. Section 5.4 concludes by describing policy implications based on the results of the simulation analyses.

5.2 Outline of the GTAP-E model

The GTAP model[3] is a computable general equilibrium model (CGE Model) of the multi-region type. The origin of the GTAP model was the SALTA (analysis of the trade liberalization in the East Asia by sector) project that the Australian government promoted. The model initially had 16 regional divisions and 37 industrial divisions. A characteristic of the model was that it had detailed industrial classifications in the agriculture and forestry sectors because the model dealt with Australia's trade liberalization. Afterward, Japan, the US, the EU, and international organizations such as the OECD, UNCTAD, and the World Bank came to participate in this project, and the name was changed to GTAP. The GTAP 5th edition, used here, is enhanced to include 66 regions and 57 industries, as detailed later.

The key feature of GTAP is that researchers can customize the model structure to some extent. For example, researchers can integrate regional divisions and industrial classifications according to their research purposes, and can also adjust each parameter before implementing simulation analysis. Moreover, as the 5th edition has greatly expanded its industrial classifications, especially for the service and energy sectors, it has made the GTAP model applicable to the effects of economic deregulation, environmental policies and so forth.

The domestic economy in the GTAP model is roughly divided into two sectors: "enterprise" as a production sector and "regional household." One of the remarkable characteristics of the structure of the GTAP model is the relation between government and households. The "regional household" is a kind of integrated agent of "pure household" and government, where the government's expenditure is determined based on utility maximization of households. In other words, government expenditure is an endogenous variable in the GTAP model.

Figure 5.1 shows the structure of the enterprise, or production, sector of the GTAP-E model. As for intermediate inputs, the production scheme is of a Leontief-type fixed coefficient function, where each cell of intermediate inputs is a so-called Armington good, where domestic and imported goods are substitutable by a CES (Constant Elasticity of Substitution) function such that the share of domestic and imported goods varies contingent on the relative price. Moreover, the share of imported shipped goods changes contingent on the relative price of shipping from different source countries.[4] On the other hand, the value added is expressed by a CES function of primary inputs, such as labor, capital, land, and natural resources, which are also mutually substitutable.

After production and consumption are determined as stated above, the amount of investment is determined as the unconsumed residual. Since the GTAP model is for multiple countries, it is assumed that a virtual international bank determines the destination of the investments in order to equalize the expected rate of return of each country, and investments are distributed all over the world.

Although the standard GTAP model is designed to perform policy simulations easily, it has a limitation regarding analyses of environmental issues since energy is not substitutable with other inputs. Consequently, the GTAP-E model was developed as an extended version of the standard model, where energy inputs, such as coal, oil, natural gas, and electricity are not only substitutable with other primary inputs but also mutually substitutable corresponding to relative price changes.[5]

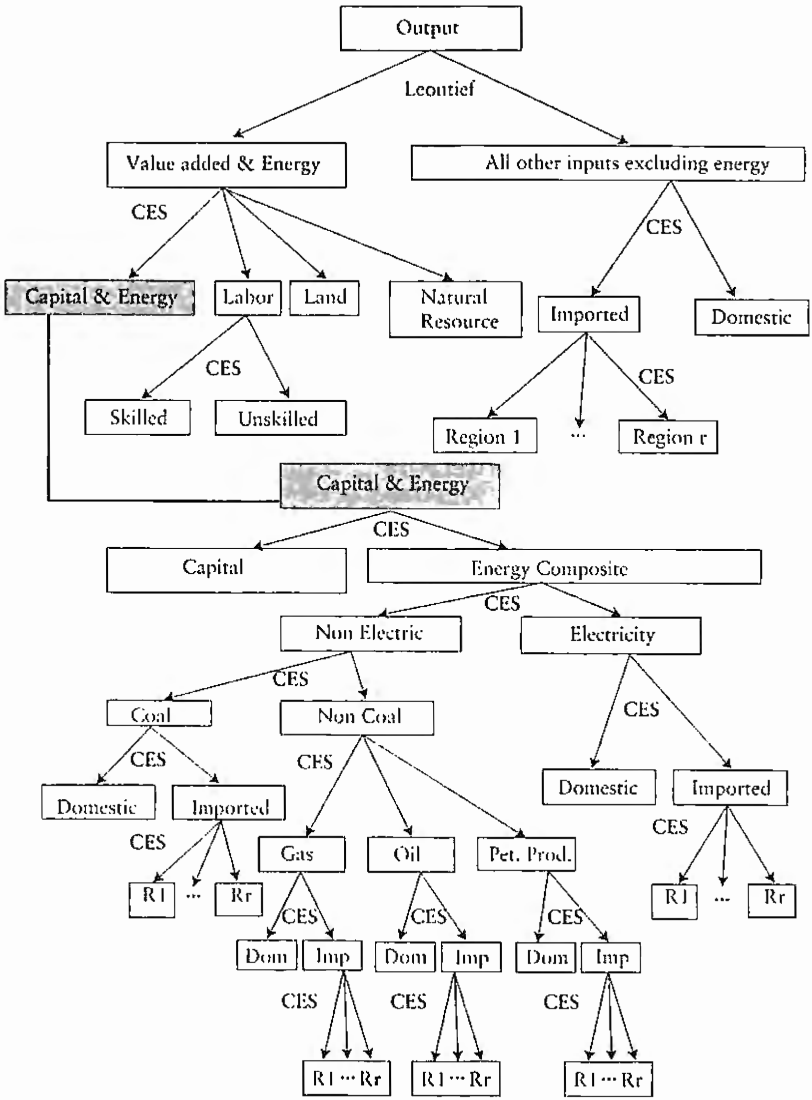

Figure 5.1

Production structure of the GTAP-E model. Source: Hertel (1997) and Burniaux and Truong (2002).

In the GTAP-E model, energy-related inputs are taken out of the "intermediate-input-nest" to be incorporated into the "value-added nest." The incorporation of energy into the value-added nest is in two steps. First, energy commodities are separated into "electricity" and "non-electricity" groups. Some degree of substitution is allowed within the non-electricity group as well as between the electricity and the non-electricity groups. Next, the energy composite is combined with capital to produce an energy-capital composite, which is in turn combined with other primary factors in a value-added-energy (*VAE*) nest with a CES structure. The inner elasticity of Capital and Energy (σKE) is assumed to be 0.5 for most industries and is set as equal to 0.0 for coal, oil, gas, petroleum & coal products, and agriculture, forestry & fishery. These values of elasticity are on the whole parallel with the low-to-middle range of values adopted by other models, such as the OECD GREEN model (Burniaux et al., 1992) and the Carbon Emissions Trade Model (CETM) model (Rutherford et al., 1997). The elasticities (σVAE) in the value-added nest, among which are natural resources, land, labor, and the capital-energy composite, are the same as in the standard GTAP model with values ranging from 0.2 to 1.45.

In the GTAP-E model, capital and energy in the "inner nest" are still assumed to be substitutable. However, it is possible that energy and capital are complementary, despite inner substitutability. The relation of substitution elasticity of inner and outer is expressed as

$$\sigma KE_{\text{-outer}} = |\sigma KE_{\text{-inner}} - \sigma VAE| \,/\, SKE + \sigma VAE \,/\, SVAE\,, \tag{5.1}$$

where *SKE* is the cost share of the *KE*-composite in the outer (value-added) nest, and $\sigma KE_{\text{-inner}}$ and $\sigma KE_{\text{-outer}}$ indicate the inner and overall substitution elasticity between capital (*K*) and energy (*E*), respectively. Therefore, provided the value of $\sigma KE_{\text{-inner}}$ is set to be smaller than σVAE, the overall substitution elasticity $\sigma KE_{\text{-outer}}$ between capital and energy could still be negative, or complementary.

In a real economy, even if the domestic price for goods is higher than the import price, consumers still buy domestic goods to some extent, and vice versa. In other words, domestic goods and imported goods are not perfect substitutes but imperfect ones. In simulation studies of trade effects in energy markets in response to an energy-environmental shock, such as the imposition of a carbon tax, Armington elasticity may play an important role.

5.3 Simulation analysis

The purpose of the simulation analysis in this section is to show the potentiality of the CDM in China. In this section we will show the results of two types of simulation analyses with the GTAP-E model resulting in reductions of CO_2 emissions. The first simulation concerns "Improvement of energy efficiency in China's power sector" and the second "Introduction of a carbon tax in Japan," which is used as a reference case.

5.3.1 Improvement of energy efficiency in China's power sector

As mentioned before, in the GTAP-E model, the inside of the "value-added and energy" composite is a CES aggregation, but the top level of the production function is of the Leontief-type fixed coefficient:

$$QO_j = e^{ao_j t} \min[QVAE_j e^{avae_j t}, QF_{1j} e^{af_{1j} t}, \cdots, QF_{nj} e^{af_{nj} t}], \quad (5.2)$$

$$QVAE_j = e^{aeo_j t} \cdot CES\_QVAE_j(QVA_j e^{ava_j t}, E_{1j} e^{ae_{1j} t}, \cdots, E_{kj} e^{ae_{nj} t}). \quad (5.3)$$

QOj denotes the production quantity of *j* industry, *QVAEj* the composite of "Value-added and Energy" of *j* industry, *QFij* the quantity of intermediate input from *i* industry to *j* industry, *QVAj* the composite of Value-added, and *Ekj* for the quantity of *i*th energy input to *j* industry. Technological progress parameters *ao*, *avaej*, *afij*, *aeoj*, *avaj*, and *aeij* appeared in the index of exponential.

Next, we assume in the simulation analysis that there is renovation and/or construction of power plants in China through technological granting from Japan through the CDM. If we assume an energy-input augmenting technological progress, the technology parameters *aeij* should be enlarged. However, to determine which parameters are to be changed, and by how much, could be arbitrary; we therefore do not assume such biased technological progress but a simple "output augmenting" type of technological progress[6] in this section. In the case where neutral technological progress is assumed, the parameter to change is *ao* on the right side of equation (5.3).

We assumed the following three rates of technological progress as the degree of efficiency improvement in China's power generation.

(i) low case: 5% efficiency improvement
(ii) middle case: 10% efficiency improvement
(iii) high case: 15% efficiency improvement

As stated previously, since China is eight times as energy intensive as Japan, the above-mentioned efficiency improvements in power generation in China would not be overly optimistic, assuming technological progress from CDM projects between China and Japan.

The left part of Table 5.1 shows the "equivalent variation"[7] in this simulation. In the middle case (10% improvement), Equivalent Valuation (EV) in China would be $3.8 billion.[8] As for the EVs of other countries, the sign of the EV depends on which effects are stronger — the effect of China's stronger price competitiveness, which deprives other countries of export markets, or the effect of China's enlarged economic size, which creates an export market for other countries. With regard to Japan, the EU, and India, the latter effect is larger, but for EEFSU (East Europe & former Soviet Union), the US, and EEx (energy-exporting countries) the

Table 5.1
Equivalent variation (Unit: million dollars)

	improvement in energy efficiency in China			introduction of carbon tax in Japan		
	5% improvement	10% improvement	15% improvement	$15/ t-C	$30/ t-C	$45/ t-C
USA	-3.1	-5.9	-8.5	265.5	516.9	756.7
EU	21.8	42.7	62.6	570.5	1105.0	1609.7
RoE	-15.0	-29.3	-43.1	5.4	12.3	20.1
Japan	2.1	4.2	6.3	-2137.8	-4390.6	-6710.6
RoA	-6.6	-13.5	-20.8	-82.4	-144.0	-191.3
EEx	-69.9	-135.7	-197.8	-356.7	-683.6	-985.6
China	1958.6	3797.1	5529.4	14.0	29.2	45.2
India	3.0	5.8	8.5	25.7	49.6	72.0
RoW	11.6	26.0	43.8	189.7	370.8	544.2
Total	1902.4	3691.3	5380.4	-1506.1	-3134.3	-4839.6

Source: Author's calculations.

former effect is somewhat stronger than the latter. The reason why the EVs of EEFSU, the US, and EEx decrease is that their exports of energy to China decrease. Indeed their EVs are negative, but they are insignificant when compared with the positive EV of China.

The left part of Table 5.2 shows the change in CO_2 emissions in this simulation. The reduction of CO_2 emissions in China corresponding to efficiency improvements of 5%, 10% and 15% is 11.17 million tons of carbon(t-C), 21.36 million t-C and 30.63 million t-C, (or 1.32%, 2.54% and 3.66%), respectively. Although the rate of reduction seems small, the actual volume is not, because China's CO_2 emissions are approximately three times greater than Japan's. If the above-mentioned reductions in China were converted to Japanese base, they would correspond

Table 5.2
Change in CO_2 emissions in the simulations

	improvement in energy efficiency in China			introduction of carbon tax in Japan		
	5% improvement	10% improvement	15% improvement	$15/ t-C	$30/ t-C	$45/ t-C
	% change			% change		
USA	0.00	0.01	0.01	0.02	0.05	0.07
EU	0.00	0.00	0.00	0.04	0.09	0.12
RoE	-0.01	-0.02	-0.03	0.01	0.01	0.02
Japan	0.01	0.02	0.02	-4.42	-8.12	-11.29
RoA	0.00	-0.01	-0.01	0.10	0.18	0.25
EEx	0.00	0.01	0.01	0.02	0.04	0.06
China	-1.33	-2.53	-3.63	-0.25	-0.44	-0.59
India	0.00	0.00	0.00	0.00	0.00	0.01
RoW	-0.01	-0.02	-0.04	0.07	0.13	0.18
Total	-0.18	-0.35	-0.50	-0.25	-0.45	-0.63
	Volume change (Mill. ton)			Volume change (Mill. ton)		
USA	0.05	0.10	0.14	0.36	0.70	1.02
EU	0.02	0.03	0.03	0.41	0.78	1.13
RoE	-0.06	-0.14	-0.23	0.04	0.09	0.14
Japan	0.03	0.06	0.08	-14.91	-27.37	-38.09
RoA	-0.01	-0.02	-0.03	0.25	0.46	0.65
EEx	0.03	0.06	0.08	0.13	0.26	0.40
China	-11.17	-21.36	-30.63	-2.12	-3.72	-4.98
India	0.00	0.01	0.01	0.00	0.01	0.02
RoW	-0.06	-0.15	-0.27	0.41	0.79	1.13
Total	-11.17	-21.42	-30.83	-15.43	-28.00	-38.57

Source: Author's calculations.

to large rates: 3.31%, 6.35%, and 9.14%, respectively.[9] Although this CDM project has an effect on other countries' CO_2 emissions to some extent, after summing them up, the total worldwide reduction of CO_2 emissions for the middle case would be 21.42 million tons, or 0.35% of the world total.

What is noteworthy is that a CO_2 reduction of this amount (6.35% from a Japanese standpoint) was possible through a CDM project in only one industry — power generation — and that a 10% efficiency improvement is not excessively optimistic taking into account the present Japan-China technological gap.

5.3.2 Introduction of a carbon tax in Japan

Since the standard GTAP model assumes that indirect taxes are *ad valorem*, such as the current Japanese general consumption tax, it could not handle an energy tax imposed on the carbon content of various fuels. However, the GTAP-E model has made it possible to handle this kind of tax.

In this section we make a simulation analysis, as a reference case of CDM implementation, assuming that Japan introduces a carbon tax. The following three cases are assumed as tax rates per ton carbon (t-C). In October 2006, the Ministry of Environment of Japan proposed a tax rate that is midway between the low case and the middle case.

(i) low case: $15 per t-C
(ii) middle case: $30 per t-C
(iii) high case: $45 per t-C

The carbon contents of various fuels are different, and the original prices of various fuels per toe (ton of oil equivalent) are also different, therefore, the tax rates, when converted to ad valorem rates, are different among the various fuels. Table 5.3 shows the ad valorem tax rates corresponding to carbon tax rates of $15, $30, and $45 per ton carbon. Since coal contains the most carbon among fossil fuels, the ad valorem rate is the highest. Although the carbon content of crude oil and oil products is assumed to be the same in the GTAP-E database, the ad valorem rate for crude oil is approximately four times as high as that for oil products since the price per toe of crude oil is approximately one fourth of the price of oil products.

Table 5.3
Carbon tax rate (converted ad valorem, %)

	15 dollars/ t-C	30 dollars/ t-C	45 dollars/ t-C	Carbon contents per toe (ton)
Coal	20.3%	40.6%	60.8%	1.0336
Oil	8.8%	17.7%	26.5%	0.7756
Gas	5.7%	11.4%	17.1%	0.5641
Oil products	2.1%	4.3%	6.4%	0.7756

Source: author's calculations

The right part of Table 5.1 shows the change of equivalent variation in each country when a $15, $30, and $45 carbon tax is imposed on fossil energies in Japan. Supposing that the effect of the carbon tax introduction in Japan is measured by EV, it is Japan that loses,[10] although the EVs of the EEx and the RoA (Rest of Asia) are also slightly negative. This is because the carbon tax raises the price of goods and service made in Japan, so imports to Japan increase while other Annex I countries' exports substitute for Japan's. As a result, income levels of almost all other countries except Japan increase. However, in energy exporting countries, since their export of energy to Japan decreases, their EVs become negative. And the world total EV is a large negative because of the large negative figure in Japan.

The right part of Table 5.2 shows the change in CO_2 emissions due to the introduction of a carbon tax in Japan. The reduction of CO_2 emissions is -4.42%, -8.12%, and -11.29%, corresponding to tax rates of $15, $30, and $45, respectively. The world total reduction of CO_2 emissions in the middle case is 28 million tons, or 0.45% of total worldwide emissions.

5.4 Concluding remarks

In this chapter, using the GTAP-E model, we analyzed the effects on CO_2 emissions of a technology transfer from Japan to China through the CDM. The result of the simulation analysis summarized in Figure 5.2 shows the relation between Equivalent Variation (EV) increases in the world and reductions of CO_2 emissions in the world. Since the volume of Japan's CO_2 emissions in 1997 (based on the GTAP database) is 337.2 million t-C, a reduction of 21.36 million t-C, as in the case of a 10%

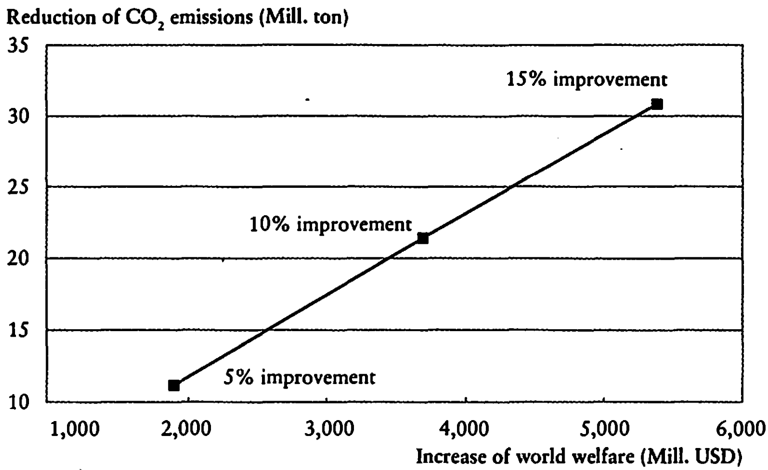

Figure 5.2

Efficiency improvement in power generation in China (Equivalent valuation and CO_2 reduction). Source: author's calculations

efficiency improvement in China's power sector, corresponds to as much as 6.35% reduction.

On the other hand, in the case of the introduction of a carbon tax in Japan, reduction of CO_2 emissions can be realized by downsizing the world economy, in other words, by reducing consumer benefits. If Japan wants to reduce 20 million t-C of CO_2 emissions, it needs to introduce a carbon tax at a rate of almost $30 per t-C. This would create a welfare loss of $4.39 billion, which corresponds to approximately 1% of Japanese GDP.

These simulation results suggest that CDM-based cooperation between Japan and China is promising, and that technology transfer would be a better measure to reduce CO_2 emissions than the introduction of a carbon tax in Japan, in the context of costs/benefits for the world.

Notes

1. http://www.env.go.jp/earth/ondanka/kptap/plan080328/gaiyo.pdf
2. As will be mentioned in section 5.2, China is the largest GHG emitter in Asia and the power sector is the largest energy consumer in China.
3. As to the details of GTAP, see Hertel (1997) or the following website: https://www.gtap.agecon.purdue.edu/

4. The substitution elasticity between domestic goods and imported goods (s_D), or between imported goods from different regions (s_M), is called Armington elasticity, named after the researcher who suggested the specification, Paul Armington. The values of Armington elasticity for the GTAP-E model are basically taken from the standard GTAP model and are, generally speaking, assumed to be lower than those used in GREEN or the Carbon Emissions Trade Movel (CETM).
5. As to detailed explanations of GTAP-E, see Burniaux and Truong (2002).
6. In other words, Hicks neutral-type technical progress.
7. Corresponds to a benefit change evaluated in monetary terms.
8. On the other hand, the increase in GDP in China is $3.724 billion, or 0.436% of the 1997 level.
9. Remembering the Japanese commitment in the Kyoto Protocol is a 6% reduction.
10. The rate of GDP decrease in Japan is marginal, at 0.047% in the $15 case, 0.096% in the $30 case, and 0.146% in the $45 case.

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