Win-win Strategies of Global and Domestic Climate Change Policy for China, Asia and Japan*

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Introduction

Climate change due to emissions of greenhouse gases (GHG) must be one of the pressing issues among many of those we have in common today. International rules for the stabilization of climate changes have been negotiated from Rio de Janeiro to Milan for the last twelve years. Among them, the most important are the third Conference of the Parties (COP3) at Kyoto in 1997 and the seventh Conference of the Parties (COP7) at Marrakech in 2001. COP7 agreed with the system design concerning the Kyoto mechanism to adopt the Marrakech accords. Kyoto mechanisms are measures to promote reduction of greenhouse gases (GHG) emissions by doing cross-border technological cooperation or trading the emission rights. There are two systems of the international technical cooperation in Kyoto mechanisms, that is, Joint Implementation (JI) and Clean Development Mechanism (CDM). JI is a technological cooperation between industrialized countries that have duty to cut GHG emissions, while CDM is one between industrialized countries (called Annex I countries) and developing countries that do not have such duty.

Anyway, as far as the agreement at the COP3 is made on the premise that there is “technological difference” or “difference in difficulties to cut GHG emissions” among nations, it is suggested that reducing GHG emissions with elimination of the technological gap would bring so-called “win-win game” that would benefit both investor and host countries.

As for the global climate change, developing countries play three important roles. One is a role as emitters of GHG. It is necessary to control an increase in GHG emissions from developing countries in the future to achieve the stabilization of GHG concentrations in the atmosphere, which is the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC). Taking a look at the trend of GHG emissions during the past thirty years (1970-2000), remarkable is growth of GHG emissions from developing countries (see Chapter 1).

Anther is a role as victims by the climate change. According to IPCC(1996), developing countries will receive more damages from the climate change than industrialized countries. While developing countries conflict with industrialized countries over criminals of global climate change, it is necessary for developing countries to adopt affirmatively some policy options on climate change measures proposed by industrialized countries as far as the strategy leads to win-win outcomes.

The other is a role of beneficiary of auxiliary benefits from climate change policy. Among the most urgent issues in developing countries are anti-air pollution measures to reduce health damages of the people. Therefore, it is important to know how much of co-benefit anti-air pollution measures will bring. Some measures are already being implemented in China to reduce SO_2 emissions. This paper will consider how technical cooperation with industrialized countries in climate change policy could contribute to make those SO_2 reducing measures more efficient.

Though CDM is similar to JI in the principle, there is a definite difference between them. While JI makes a point of cost effectiveness to reduce GHG reduction since JI is regarded as an expedient to attain the obligation of GHG reduction in Annex I countries, the primary objective of CDM is to assist developing countries to keep on a track to the sustainable development[i].

In COP3 Kyoto, Japan has been forced to have a responsibility to reduce GHG emissions by 6% under the 1990 level during the first commitment period (2008 -2012). CDM occupies an important position in the climate change measures of Japan to achieve that numerical target. And CDM is also important for China since CDM is a kind of direct investment in developing countries. This report discusses how China-Japan CDM could be designed to achieve an integration of climate change and development policy from the global, regional and domestic viewpoints.

The first part of this report is for a discussion on the potentiality of CDM and its economic impacts in China. We will project a future scenario of CO_2 and SO_2 emissions in China and also consider the effects that CDM will give in Japan and the world economy. These issues are analyzed using GTAP-E model in Chapter 2 and Energy Balance Model in Chapter 3.

The second part is for a discussion on sustainable development strategies in China. We consider China's SO_2 pollution and acid rain problem, which are becoming more serious because of the recent rapid growth, as a criterion for sustainable development in China. We also discuss the regional issue that increase in SO_2 emissions in China affect the environment in the East Asia region. These issues are analyzed in Chapter 4 using the Regional Acidification Information and Simulation model (RAINS ASIA).

Then we do a project-based cost benefit analysis on a CDM project in Shanghai Chongming power plant. We assume Shanghai Chongming power plant as the partner in China-Japan CDM and analyze environmental and economic effect in detail through the cost benefit analysis. These issues are analyzed in the Chapter 5

The last issue is to evaluate CDM from wider point of view as well as to consider the reason why few projects were planned using CDM. It will be considered what kind of policy assistance could be applicable to promote China-Japan CDM. These issues are discussed in the Chapter 6. Then we present the conclusion of this report in the last section.

Reference

Intergovernmental Panel on Climate Change (IPCC,1996), *Climate Change 1995: Economic and Social Dimensions of Climate Change* , Contribution of working group III to the second assessment report of the Intergovernmental Panel on Climate Change , Cambridge University Press, Cambridge.

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i Article 12 of Kyoto Protocol: the purpose of the CDM shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.

Chapter1 CO_2 Emission Trends in China, Japan and the Rest of the World

This chapter summarizes the recent trend in energy consumption, CO_2 emissions, and gross domestic Product (GDP) in China, Japan and the Rest of the World.

1-1 The share of CO_2 emissions in the World

Figure 1-1 showed the share of CO_2 emissions in the world at the time of 2000. The United States is ranking in the first place in classification by countries, accounting for about a quarter (1/4) of CO_2 emissions of the entire world. Total CO_2 emissions in the world were about 6422 million tons and those of the United States were 1580 million tons in 2000. It can be seen from this figure how much impact the U.S.'s withdrawal from Kyoto Protocol gave. However, if CO_2 emissions in Asian region (except Japan) are summed up, they exceed to those of the United States. In the pie graph in the right of Figure 1-1, the emissions in Asian region were classified in detail by countries. How large China's share can be again confirmed here. China has emission share of 13.7% that exceeds to half of that of the United States, ranking in the second in classification by countries. By the way, what comes in third is the former Soviet Union with about 10% and the fourth is Japan with about 5%.

Figure 1-2 shows the transition of CO_2 emissions for about 30 years (from 1971 to 2000) by countries. There is not much change in emissions of European OECD countries aside the benchmark. It might be explained by the low growth of economy; however, it also can be seen from the figure the effort these countries are making to stabilize energy consumption. In former Soviet Union, as depressed economy after the fall of the communist regime gave serious impact, the situation is unusual where CO_2 emissions of 2000 falls below those of 1971. On the other hand, CO_2 emissions of Japan increased half time though the amount is not large. The U.S. has increase of 25%.

Figure 1-3 shows the composition of CO_2 emissions by countries in Asian region. The CO_2 emissions in Asian region has increased more than three times over the last 30 years, from 587 million tons in 1971 to 1965 million tons in 2000.What draws attention most countries might be China. CO_2 emissions in China have expanded from 241 million tons in 1971 to 881 million tons in 2000, making increase of more than 3.5 times.

1-2 The Factor Analysis of the CO_2 Emissions

The following "Kaya's equation" is often used for the factor analysis of the CO_2 emissions.

$$CO_2 emissions = \frac{CO_2 emissions}{energy\ consumption} \times \frac{energy\ consumption}{\mathrm{GDP}} \times \mathrm{GDP}$$

First, CO_2 emissions per energy consumption as in the first term in the right side is graphed out in the Figure 1-4. The CO_2 emissions per energy consumption depend on the composition of the energy source. For instance, since generation of electricity by nuclear power or waterpower does not exhaust CO_2, countries where such energy sources have large shares have smaller CO2 emissions. As for fossil fuel, the CO_2 emissions per unit calorie are large in the order of coal, oil, and the natural gas. So the CO_2 emissions per energy consumption increase in the countries where coal has the large share in the composition of energy.

The CO_2 emissions of European OECD countries, Japan and NIEs have a downward trend, reflecting the conversion to nuclear power and the natural gas has been advanced in these countries. However, a rising trend is apparently seen in China, and also slightly in ASEAN regions. Traditionally China is a country where the coal dependence is high and CO_2 emissions per energy consumption are large, and the dependence seems to be growing in recent years. Surprisingly disadvantaged to oil resource, China is an import country of oil. So “Large-scale western development” has been planned to construct pipelines from the gas field in the Western area to the coast region so as to use natural gas as main energy of the city.

Then “energy consumption per GDP” as in the second term of the right side is graphed out in Figure 1-5. This figure partly depends on the industrial structure of one country and partly on the technological progress in the areas of energy efficiency and energy conservation. As for the former, it increases when it advances from the agriculture-centered stage to industrialization and decreases when economic servicing is in progress. As for the latter, usually the energy efficiency is improved when equipment or product is renewed or bought, whatever be it the productive equipment or household electric equipment or private cars.

As shown in Figure 1-5, the energy consumption per GDP has been a improved such as the United States, European OECD, Japan, and NIEs (all measured by the scale marks on the right). The efficiency of Japan excels other countries remarkably and the energy consumption is half compared with the United States. European OECD is in the middle of Japan-U.S. The influence of the progress of industrialization exceeds the effect of the introduction of the technology to improve efficiency in ASEAN region (measured by the scale marks on the right), and energy consumption per GDP shows increasing trend, which will be still noteworthy in the future. Please note that only China is measured by the scale marks on the left in the Figure 1-5. Though there might be a problem in the way GDP is measured in China, its economy has very bad energy efficiency, and about 20 times more energy was used in 1971 for the same productivity compared with Japan whose efficiency was the best. However, energy efficiency is improving sharply owing to rapid capital investment in recent years. There still exists a gap of about 10 times or less between Japan and China, even though it became smaller in 2000. It is understood that there still is a potential of a further energy efficiency improvement.

Next, the transition of "GDP" as in the third term of the right side is graphed out in Figure 1-6. Since the scales of GDP differ between advanced country group and others, 3 regions (the United States, European OECD, and Japan) are measured on the scale marks on the left, and the other 3 regions (NIEs, China, and ASEAN) are measured on the right. As for advanced country group, transition is almost parallel expect for Japan leveled off in 1990's. As for NIEs and China, however, it is apparent that the trend is obviously growing more than advanced countries. When Japan and China are compared, Japan's GDP exceeded 20 times of China's GDP in 1971; but the difference is rapidly getting smaller in 2000 to the extent that Japan's GDP become about 6 times of China's.

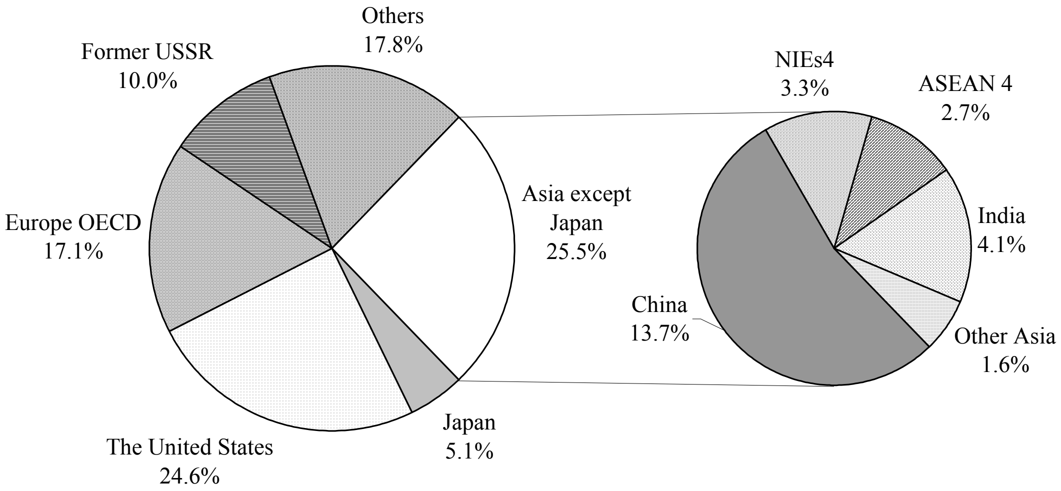
Based on Kaya's equation, the CO_2 emissions are examined by 3 factors, that is, energy consumption, energy efficiency and economic development. As a result, though there is a good sign of improving energy efficiency in China, on the other side it is also found there are many bad materials: its energy consumption is comprised mostly of coal and the standard of energy efficiency is bad, and economic development is still high.

In this paper, we try to verify to what degree the improvement of China's energy efficiency is efficient to the CO_2 emission-reduction on the ground of above-mentioned facts, citing cases of the advanced countries. Though we should not expect much from Clean Development Mechanism (CDM) in the light of this, Japan has been made China as potential target and taken hopeful view on greenhouse gases (GHG) as means of reduction.

Reference

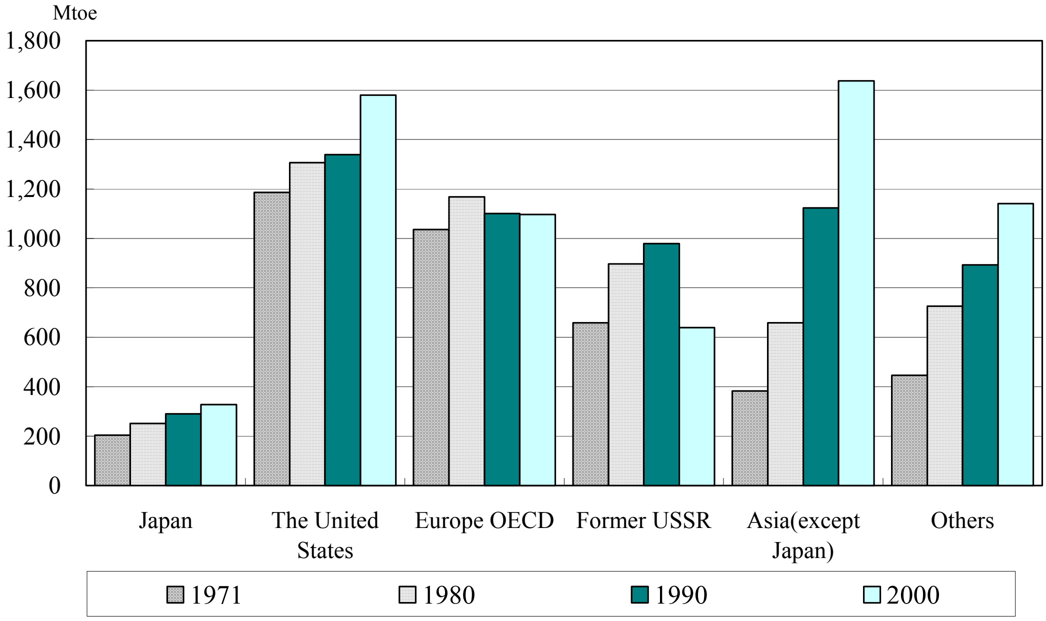
The Energy Data and Modeling Center, The Institute of Energy Economics, Japan (2003), *EDMC Handbook of Energy & Economic Statistics in Japan 2003,* The Energy Conservation Center, Japan.

Figure 1-1 The share of CO_2 Emissions in the world (2000)



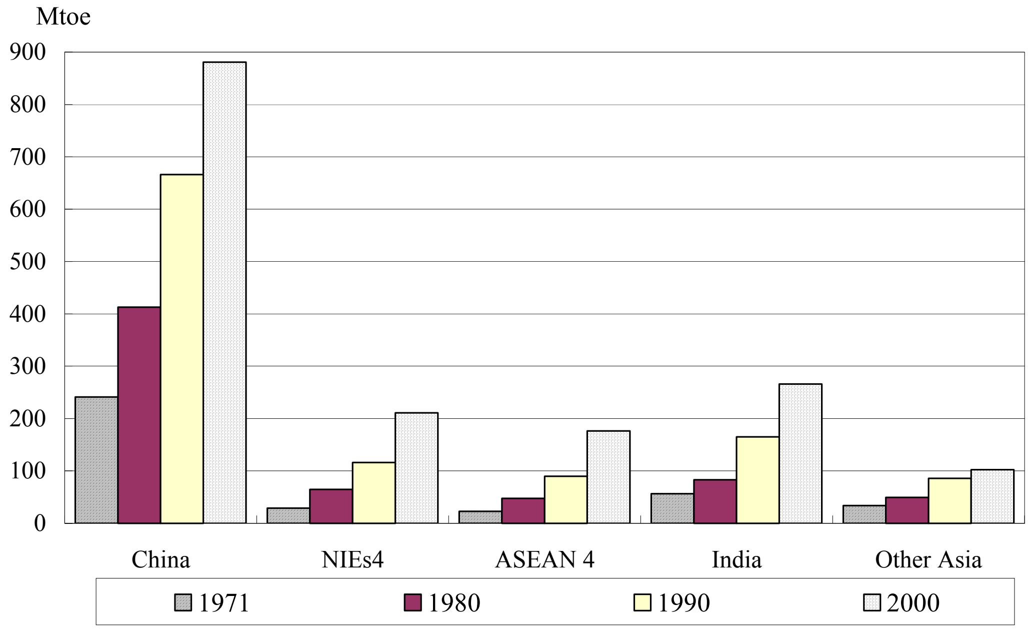
Source: The Institute of Energy Economics(2003), *EDMC Handbook of Energy & Economic Statistics 2003*.

Figure1-2 Transition of CO_2 emissions by region



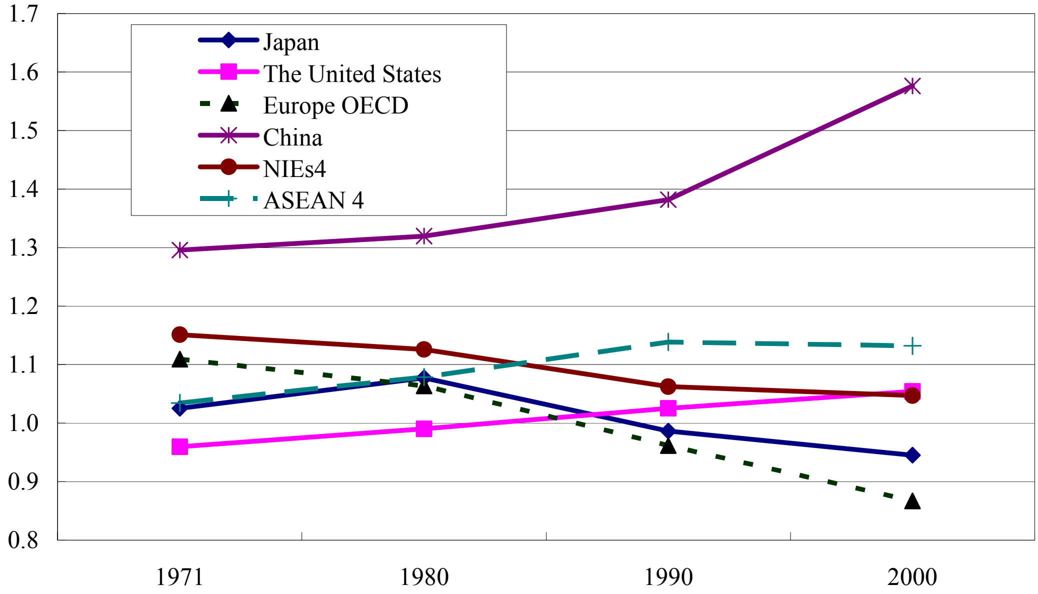
Source: The Institute of Energy Economics(2003), *EDMC Handbook of Energy & Economic Statistics 2003*.

Figure1-3 Transition of CO_2 emissions in Asian countries



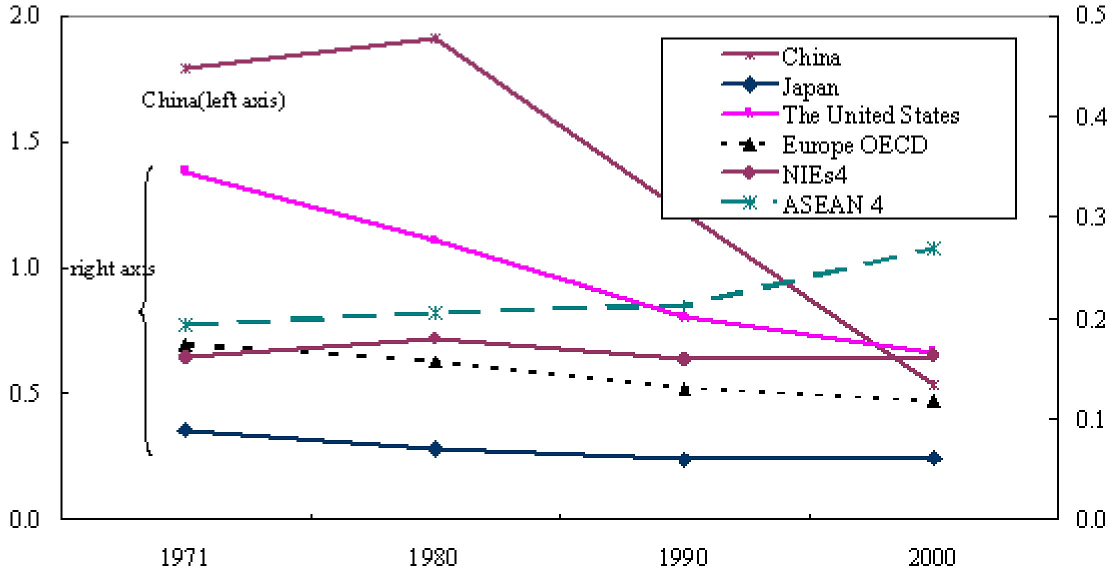
Source: The Institute of Energy Economics(2003), *EDMC Handbook of Energy & Economic Statistics 2003*.

Figure 1-4 CO_2 emissions per energy consumption



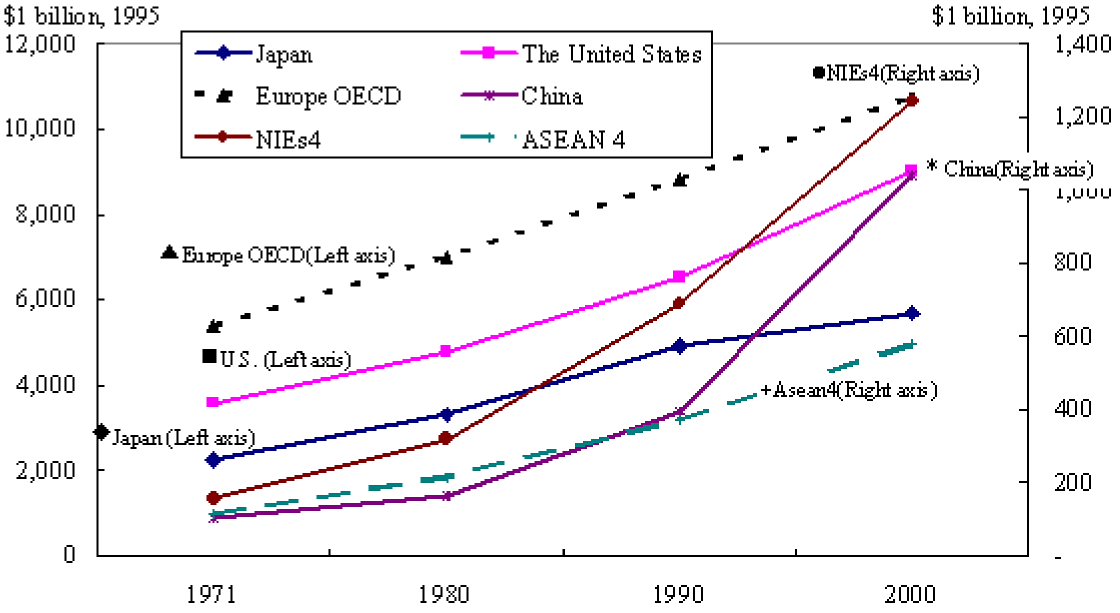
Source: The Institute of Energy Economics(2003), *EDMC Handbook of Energy & Economic Statistics 2003*.

Figure 1-5 Energy consumption per GDP



Source: The Institute of Energy Economics(2003), *EDMC Handbook of Energy & Economic Statistics 2003*.

Figure 1-6 Transition of GDP by regions



Source: The Institute of Energy Economics(2003), *EDMC Handbook of Energy & Economic Statistics 2003*.

Chapter 2 Aiming for CO2 Emission Reduction in China: Effects of Energy Efficiency Improvement and Carbon Tax

Summary

Global warming is one of the urgent issues that we are facing this century. It is said that global warming is caused by emissions of the green house gas (GHG) such as carbon dioxide (CO_2), chlorofluorocarbon (CFC), and etc. Since CO_2 emissions are closely related to consumption of fossil energies in our daily lives and production activities, 'economics' does play an important role to prevent global warming, though the mechanism of global warming itself might be an object of natural science. This chapter aims to inspect the effectiveness of economic instruments and international cooperation to reduce CO_2 emissions in China and Japan. It is confirmed that improvement of energy efficiency in China is very effective to reduce CO_2 emissions and it also improve world welfare, while introducing carbon tax in Japan aggravate the economy though it would reduce CO_2 emissions.

2-1 Introduction

2-1-1Approach to global warming issue

When in 1992 The Global Environment summit was held in Rio de Janeiro, Global Warming Convention advocated international cooperation for the prevention of global warming. Then after 5 years in 1997 the COP3 (the Third Conference of Parties to the U.N. Framework Convention on Climate Change) was held in Kyoto and the participants agreed that the advanced countries, or 'annex 1 countries', owe the duty to reduce GHG emissions by an average of 5% below 1990 emissions. It was also proposed in the Kyoto conference that they can promote the reduction of greenhouse gas emissions by the emission right trade (ET) and/or doing cross-border technological cooperation such as clean development mechanism (CDM) and joint implementation (JI)[ii]. The agreement at the Kyoto conference is made on the premise that international technological cooperation would bring so-called win-win game that would benefit both supplying and host country of technologies, or the supplying country could reduce GHG emissions and host country could proceed on a path for sustainable development.

Though the United States have declared its withdrawal from the Kyoto mechanism in January 2001, in Marrakech conference (COP7) held on November 2001, the international rule for implementation of Kyoto mechanism was agreed, and in May 2002 Japanese government has come to ratify the treaty. In the Marrakech agreement, it is stated that the ‘annex 1’ countries should work for accomplishment of each own goal domestically first and emission-reduction through international cooperation would be auxiliary. In the light of this, we should not expect much from CDM. However, CDM would be still important for Japan to fulfill the promise in COP3 and Japan has been regarded China as a potential target of CDM since it would be almost impossible that Japan will be able to reduce CO_2 emissions enough domestically during this coming decade.

Taking advantage of the fact that the goods demand more or less depends on the price, Scandinavian countries readjusted the established energy tax since around 1990 and introduced the tax to the fossil energy (or carbon contained). Other European countries have been following them. It is an approach to cut GHG emissions by controlling fossil energy consumption and substitution for new energies. Table 2-1 shows the Carbon Tax rates in Scandinavian countries that are known as early appliers of the carbon tax. As the rate of “1500 yen for each carbon ton” equals to “one yen a liter by conversion into gasoline”, Finland’s Carbon Tax rate is about 5 yen a liter of gasoline and Sweden’s is about ten yen.

In Japan, the introduction of carbon tax is actually being discussed as an urgent concern during recent a couple of years. Industrial world has been spurting backlash against compulsory measures to reduce energy consumption including carbon tax, and the most influential industrial group KEIDANREN, (Japan Federation of Economic Organization’s) has designed its own voluntary plan. However, KEIDANREN’s voluntary plan is often regarded as of limited effect. Ministry of the Environment has organized a study group for this issue and it released a tentative tax rate of ¥3,400/ton carbon on July, 2003. It is highly likely that the carbon tax will shortly be introduced in some form.

Table 2-2 shows simulation results calculated by some well-known global econometric models to simulate global worming. The right column shows rate of a carbon tax necessary for 1% of CO_2 emissions. Though Japan promised to reduce 6% of emissions below 1990 levels at COP3, Japan’s CO_2 emissions have already increased by approximately 13% during a decade after 1990. Therefore, it is necessary that Japan should reduce emissions by 19% unless Japan makes use of the Kyoto mechanism. If Japan should cut CO_2 emissions by energy tax only, the required tax rate would range from the lowest 5,130 yen (per tonC) with Goto model to the highest 36,480 yen with Yamazaki model supposing $1=100 yen. Therefore the Carbon Tax rate 34,000 yen that the ministry of environment suggested would not be enough for Japan to reduce CO_2 emissions as agreed in COP3.

2-1-2 Contents of this chapter

The United Nations Framework Convention on Climate Change (UNFCCC) has set global warming prevention in several phases. In the first phase covering 2008 to

2012, it is only the advanced countries called Annex 1 countries that are obliged to reduce emissions of greenhouse gas. However, in the second phases of next decade, it is presumed that a part of the developing countries joins Annex 1 countries. What is concerned then is trends in Asian nations, especially China. As the economic development in Asian nations has been remarkable after 1970's, their energy consumption increased rapidly in accordance with such economic development. Moreover, as the United States withdrew from Kyoto protocol insisting that "it is unfair that the developing countries have no obligation to reduce CO_2 emissions", the return of the U.S. to Kyoto protocol is related to some degree with participation of the developing countries.

One of realistic solutions to reduce CO_2 emissions in a global sense might be introduction of carbon tax in advanced countries and technology transfer from the advanced countries to developing countries financed by the carbon tax. However, it requires much information in order to do such economic and technical cooperation. For instance, it requires information regarding how much loss would be brought to the entire world including advanced countries by carbon tax and how much economical benefit would be brought to the entire world including developing countries by technology transfer.

In this chapter, the effect of the strategy to reduce CO_2 emissions (or energy consumption) is examined with a special focus on China and Japan. The discussion proceeds as follows. To offer above-mentioned information, a computable general equilibrium model (CGE model) will be used in this chapter. Section 2 explains the structure of the CGE model applied in this chapter.

CGE model is a sort of enhanced framework of the input-output model. In the framework of input-output analysis, the both sides of demand and supply are described in the respective linear relations. Therefore, the demand side is determined only by the amount of final demand and the supply side is determined only by the cost of production process. In other words, input-output analysis has a crucial problem that the demand and supply are completely separated in the model structure. Even though such problem is recognized, input-output analysis has been used because of the easiness to understand and handle. The problem that CGE model is hard to solve is solved soon by development of computers. In CGE model, the mutual-dependent relation of prices and amount in the market are considered by assuming the demand function and the supply function that respond to the price. In a word, it is a model that describes the request of the microeconomics more faithfully. However, to develop a CGE model is rather time consuming and requires massive and systematic statistical information. After all that, discussions over the simulation results by CGE models were often fruitless when there were differences in the theoretical background of the models and/or when the internal structure of the model was sometimes black box.

It is GTAP (Global Trade Analysis Project) model that has been developed in such a situation. At first, GTAP model was aiming for offering some basic information where policy makers in each country discuss influences of trade liberalization. Since trade liberalization concerns interest of many related countries, so that the model structure on which policy makers discuss should not be black box. Therefore the structure of GTAP model is open to public and a statistical package to use GTAP model is also supplied.

In Section 3, some simulations are done with GTAP model. The first simulation is to examine how much reduction of CO_2 emissions can be achieved by introduction of carbon tax in Japan. And the second one is to check effects of technology transfer from Japan to China in Japan as a simulation for comparison. This simulation is to validate effectiveness of clean development mechanism (CDM) between China and Japan. Section 4 describes a policy implication based on the results of simulation analysis in Section 3.

2-2 Outline of GTAP model

2-2-1Development of GTAP model

The GTAP model is an applied general equilibrium model (CGE Model) model of the multi-region type as related in Section 1. The starting point of the GTAP model was SALTA (analysis of the trade liberalization in the East Asian region by sectors) project that Australian government had been promoted. The model had 16 regional divisions, and 37 industrial divisions at first; characteristic was that the model had detailed industrial classification in agriculture and forestry sector because the model dealt with Australia’s trade liberalization. Afterwards, Japan, the U.S., EU and international organizations such as OECD, UNCTAD, World Bank came to participate in this project and the name was changed to GTAP (Global Trade Analysis Project). The division of GTAP 5th edition used here is enhanced so that it has 66 regions and 57 industries as is explained later.

The policy assessment by GTAP model is especially meaningful as *ex ante* information before negotiating international accords. The stake holding countries have talks based on their own quantitative analyses on the economic impact of the accord. However, the conference often gets nowhere in case the economic model each participant has is different each other. However, the GTAP model has a merit that it enables us to analyze the economic effect of policy coordination or international accord on the common base because several international organizations are involved in the development of the model and model structure is open. In a word, it can be said that the GTAP model has contributed on improvement of the efficiency of negotiations. One example that GTAP is used for international talks is Japan-South Korea joint research by regarding the free trade agreement[iii].

Researchers can integrate the regional divisions and industrial classification of

GTAP model according to the research purpose and adjust each parameter (or, can customize GTAP model) before implementing simulation analysis. In Japan there are many researches making use of GTAP model in inspecting such economic effects as Uruguay Round, participation of China to WTO and FTA formation. Moreover, as the 5th edition has expanded its industrial classification greatly especially for the service industry and energy industry, it made the GTAP model applicable to the effect of economic deregulation or environmental policies, etc.

2-2-2 Structure of GTAP model

The macro concept chart of GTAP model is shown in Figure 2-1. Though GTAP model is a multi-country model, it is described in the Figure as that of one country and overseas sector. The arrows in the Figure do not mean the direction of the flow of goods and service but the direction of the payment. The domestic sector of GTAP is divided into the production sector and the one called 'regional household'. A regional household is an integration of a 'pure household' and the government: each country has a utility function composed of household consumption, government expenditure and savings. The household consumption and the government expenditure are determined so that a regional household may maximize the utility. What is remarkably characteristic is that government expenditure is an endogenous variable in the GTAP model, while government expenditure is usually an exogenous variable (policy variable) in so-called macro econometric models.

Moreover, the key of the analysis is the 'market equilibrium', and the 'economic effect' means shift of the 'market equilibrium' from the original one to another new simulated one. Therefore, the concept of "government expenditure multiplier" that assumes dis-equilibrium beforehand such as unemployment or inventory does not exist in CGE framework.

Figure 2-2 shows the structure of the production sector of the standard GTAP model. First of all, as for intermediate input sector, the production scheme is fixed coefficient but the domestic goods and the import goods are break-downed by a CES function. Therefore, the share of domestic and imported inputs changes corresponding to the relative price. And, the share of shipping countries of imported goods corresponds to the international price change. On the other hand, the value added is expressed by a CES function which consists of labor, capital, and land.

While the production and consumption are determined as mentioned above, the amount of the investment is determined as the residual. Since GTAP model is of multi countries, it has a unique assumption on fixed investment that the saving is once deposited in the international bank of 'financial institution of the entire world' and the bank determines the distribution of the fixed investment. On the rule of distribution of the fixed investment there are two options; the one is that the bank follows the investment pattern of each country and the other is that the bank determines an international distribution so that the rate of profitability of each country is equalized.

The former corresponds to the case where capital is not liberalized, and the latter corresponds to the case where the international flow of capital is liberalized. In the simulation of this chapter, it is assumed that international capital movement is liberalized.

2-2-3 Structure of GTAP-E model

Section 2-2 was a rough explanation on the structure of the "standard" GTAP model. Though the standard GTAP model is well-designed and easy to handle, it has a limitation for analyses on environmental issues. Energy is an important commodity in many economic activities and environmental issues like CO_2 emissions, but energy substitution is not considered in the standard GTAP model. Then what is developed is an extended version of GTAP model called GTAP-E where such energy inputs as coal, oil, natural gas, and electricity are mutually substitutable according to relative price changes. This section is for a explanation on GTAP-E model based on Burniaux and Truong(2002).

In GTAP-E model, energy inputs are taken out of the 'intermediate-input-nest' to be incorporated into the 'value-added nest' (see Figure 2-3). 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 then 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 through a CES structure.

In GTAP-E, as shown in Table 2-3, the inner elasticity Capital and Energy (σ_{KE}) is assumed to be 0.5 for most industries and is set equal to 0.0 for coal, oil, gas, petroleum and coal products, and agriculture, forestry & fishery. These values of elasticity are on the whole parallel with low-to-middle range of the values adopted by other models, such as the OECD GREEN model and the model of Rutherford *et al.* (1997). Table 2-4 shows the value of elasticity (σ_{VAE}) in the value added nest. Those are the same values as currently used in the standard GTAP model. The values range from 0.2 to 1.45 and that seems to be slightly larger than those adopted by other models.

In GTAP-E, Capital and Energy in the 'inner nest' are still assumed to be substitutes. However, provided the value of σ_{KE} is set at a level lower than σ_{VAE}, the overall substitution elasticity (as viewed from the 'outer nest') between capital and energy may still be negative. The relation of substitution elasticity of inner and overall, or outer, is expressed as follows:[iv]

$$\sigma_{KE\text{-}outer} = [\sigma_{KE\text{-}inner} - \sigma_{VAE}] / S_{KE} + \sigma_{VAE} / S_{VAE}$$

where S_{KE} 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 elasticities between Capital (*K*) and Energy (*E*) respectively. Table 2-5 shows the values of overall substitution elasticity between Capital and Energy ($\sigma_{KE\text{-}outer}$) in the USA and Japan. It can be seen that most industries (with the exception of 'electricity' in the USA, and 'electricity', 'ferrous metals', and 'chemical, rubber, plastic products' in Japan) are the overall elasticity between energy and capital are negative, which means that energy and capital have complementary relationship despite the fact that inner elasticity substitution ($\sigma_{KE\text{-}inner}$) is non-negative (substitutable).

In the real economy, even if the domestic price is higher than the import price, consumers buy domestic goods to some extend and *vice versa*. In other words, domestic goods and imported goods are not perfect substitutes but imperfect substitutes. The substitution elasticity between domestic goods imported goods or between imported goods from different regions is called Armington elasticity after the name of the researcher who suggested the specification. In simulation studies for trade effects in energy market in response to an energy-environmental shock (such as the imposition of a carbon tax), the Armington elasticity may play an important role. The Armington elasticity for the substitution between domestic and imported good (σ_D) is shown in Table 2-6, and the Armington elasticity between imported goods from different regions (σ_M) is shown in Table 2-7. The values of σ_D and σ_M for GTAP-E are taken from the standard GTAP model, and are seen to be lower than some of the values used in other models, such as those in Babiker *et al.*(1997).

So far the structure of the GTAP model has been explained. In the following section 2-4, more details of GTAP model will be explained taking one sector closed economy as an example.

2-2-4 illustration of closed GTAP model with one sector[v]

(1) Budget constraint and Walras' law

Here, the simplified model of the closed economy is considered as follows. Industry sector consists of only one sector, and the goods are demanded as consumption by the household, and as investment and as intermediate input by the industry sector. The government is omitted for simplification. The primary inputs are assumed to be only labor and capital.

Walras' law should hold in the general equilibrium model. Walras' law defines that when there are *n* markets, the number of markets we need to consider equilibrium condition is not *n* but if *n*-1 and the rest one market is naturally in the equilibrium. In other words, as each economic agent acts based on the budget constraint, one will not be independent among *n* markets equilibrium equation or the *n* prices cannot be determined corresponding to *n* markets. Therefore, the general equilibrium model assumes the price of a certain goods to be a 'numeraire', and that the prices of other goods are expressed as the relative price measured by this 'numeraire'.

First let us begin with the budget constraint of the household. The household supplies labor and the capital to the industry sector, expends the obtained income for consumption, and saves the remainder. The demand for saving in GTAP means the demand for investment goods at the same time. Investment is determined by the banking sector, and its amount and price of saving is expressed by $QSAVE$ and $PSAVE$ respectively. The budget constraint of the household can be expressed as follows.

$$W \cdot L^S + R \cdot K^S = P \cdot C + PSAVE \cdot QSAVE^d, \tag{1}$$

where, W stands for wage, L^S for labor supply, R for the rate of rental, K^S for capital stock, P for price of goods, and C for consumption, and $QSAVE^d$ for the savings demand.

Next, the supply function of the industry sector (zero profit condition) can be expressed as follows.

$$P \cdot Q = W \cdot L^d + R \cdot K^d + P \cdot QF, \tag{2}$$

where, Q stands for the quantity of goods, L^d for labor (demand), K^d for capital stock (demand), and QF for intermediate input demand.

Next, the role of the bank is to invest household saving, the source of capital accumulation, in place of the household. the budget constraint of the bank is as follows.

$$PSAVE \cdot QSAVE^S = P \cdot QCGDS^d, \tag{3}$$

where $QSAVE^S$ stands for savings supply and $QCGDS^d$ stands for the investment demand. If both sides of the above mentioned equation (1), (2), and (3) are added, we get the Walras' law expressed as the equation (4). The equation (4) expresses the total of the excess demand such three markets as labor, capital stock, and goods equals to the difference of the savings investment. In other words, it shows that the market of the investment goods (or saving) will reach equilibrium without fail if such three markets on the left side as labor, capital stock and goods are in the equilibrium.

$$\begin{aligned} &W(L^d - L^S) + R(K^d - K^S) + P(C + QF + QCGDS^d - Q) \\ &= PSAVE(QSAVE^d - QSAVE^s) \end{aligned} \tag{4}$$

(2) Behavior of each economic agent

(2-a) Behavior of production sector

The production sector produces goods using labor, capital stock, and intermediate input. It is assumed that the structure of production the top stage is of the Leontief type of the value-added and the total intermediate input.

$$Q = \min\left\{\frac{QV}{\alpha}, \frac{QF}{\beta}\right\}, \tag{5}$$

where QV stands for the value-added, α for input coefficient of value-added, β for input coefficient of the intermediate input. As to the value-added the aggregation is of CES type of primary inputs such as capital and labor.

$$QV = \left[(\theta)^{\frac{1}{\sigma}} (L^d)^{\frac{\sigma-1}{\sigma}} + (1-\theta)^{\frac{1}{\sigma}} (K^d)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{6}$$

where σ for the elasticity of the substitute of capital and labor in CES, and θ for distribution coefficient. The production sector determines demand for value-added and intermediate input so that the cost would be minimized under the given output level Q. In the first stage, the demands of the value-added and the intermediate input are determined under the given Q. The demand for the value-added and the intermediate input is as follows:

$$QV = \alpha Q \tag{7}$$

$$QF = \beta Q \tag{8}$$

Then in the second stage, demands of labor L and capital K are determined under the demanded total value-added QV so as to minimize cost. The demand equation of the industrial sector is obtained by solving the problem expressed the equation (9) with (6) as the restriction.

$$Min. \quad PQV = WL^d + RK^d \tag{9}$$

The demand function of labor L and capital K is defined respectively as follows:

$$L^d = \theta \left(\frac{W}{P_V} \right)^{-\sigma} \alpha Q \tag{10}$$

$$K^d = (1-\theta) \left(\frac{R}{P_V} \right)^{-\sigma} \alpha Q \tag{11}$$

In addition, the price of value-added is defined as the dual of CES function as follows.

$$P_V = \left[\theta W^{1-\sigma} + (1-\theta) R^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \tag{12}$$

where P_V is the minimum cost to produce one unit of value-added.

(2-b) Behavior of households

As for the utility of the households, Cobb=Douglas type function is assumed as follows:

$$U=(C)^{\delta}(QSAVE^{d})^{1-\delta} \tag{13}$$

Solving a maximization problem that the equation (13) is maximized under the budget constraint expressed in the equation (1), the demand for the goods of the household and that for saving are obtained as follows:

$$C=\frac{\delta\left(WL^{S}+RK^{S}\right)}{P} \tag{14}$$

$$QSAVE^{d}=\frac{(1-\delta)\left(WL^{S}+RK^{S}\right)}{PSAVE} \tag{15}$$

(2-c) Equilibrium

By Walras' law mentioned before in the equation (4), Independent markets as to the equilibrium conditions of such four markets as goods, labor, capital stock and the saving. If the market equilibrium condition of saving is omitted, the whole model can be expressed as follows:

(i)Price of goods

$$PQ=WL^{d}+RK^{d}+P\cdot QF \tag{2}$$

(ii)Demand-supply equilibrium in labor market (wage)

$$L^{S}=L^{d} \tag{16}$$

(iii)Demand-supply equilibrium in capital stock market (rental)

$$K^{S}=K^{d} \tag{17}$$

(iv)Demand-supply equilibrium in goods market

$$Q=C+QF+QCGDS^{d} \tag{18}$$

(v)Labor demand

$$L^{d}=\theta\left(\frac{W}{P_{V}}\right)^{-\sigma}\alpha Q \tag{10}$$

(vi)Capital stock demand

$$K^{d}=(1-\theta)\left(\frac{R}{P_{V}}\right)^{-\sigma}\alpha Q \tag{11}$$

(vii)Consumer goods demand

$$C=\frac{\delta\left(WL^{S}+RK^{S}\right)}{P} \tag{14}$$

(viii)Intermediate goods demand.

$$QF = \beta Q \tag{8}$$

(ix)Price of value-added

$$P_V = \left[\theta W^{1-\sigma} + (1-\theta)R^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{12}$$

where, L^s and K^s are given outside of the model as an exogenous variable (or, initial value) beforehand. Though there are ten endogenous variables, such as *P*, *W*, *R*, *PV*, *Q*, and $QCGDS^d$, *QF*, L^d, K^d, and *C*, the number of the equations is nine. For instance, if the price of goods *P* is assumed as numeraire, it is decided as the other price benchmark, that is the relative price to the price of goods.

Incidentally, substitute the equations (8) and (14) for demand function of goods, the equation (10) for the labor demand function, and the equation (11) for the demand function of goods respectively, and then express by the relative price measured by the price of goods *P*, the model can be consolidated in the following five equations:

$$Q = \left(\frac{W}{P}\right)L^S + \left(\frac{R}{P}\right)K^S + \beta Q \tag{19}$$

$$L^S = \theta\left(\frac{W/P}{P_V/P}\right)^{-\sigma}\alpha Q \tag{20}$$

$$K^S = (1-\theta)\left(\frac{R/P}{P_V/P}\right)^{-\sigma}\alpha Q \tag{21}$$

$$Q = \delta\left\{\left(\frac{W}{P}\right)L^S + \left(\frac{R}{P}\right)K^S\right\} + \beta Q + QCGDS^d \tag{22}$$

$$\frac{P_V}{P} = \left[\theta\left(\frac{W}{P}\right)^{1-\sigma} + (1-\theta)\left(\frac{R}{P}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{23}$$

The equation (19) is the supply function of goods (zero profit condition), and (20), (21), (22) are the market equilibrium equations, and (23) is the definition of the pride of value-added P_V. It is interpreted that total of five equations decide three relative prices *W/P* (wage), *R/P* (rental price), P_V/P (value-added price), and two amounts *Q*(production), and $QCGDS^d$ (investment goods demand) are determined.

2-3 Simulation analysis

In this section we show the results of some simulation analyses on the measures to reduce CO_2 emissions with GTAP-E model. The point of the simulation analysis here is the comparison the following two scenarios:

Senario1: Reduction of the energy consumption by carbon tax in Japan.
Senario2: Improvement of the energy efficiency in China's power generation.

2-3-1 Energy Consumption and Its Composition in GTAP Database

The standard GTAP model has 66 regional divisions and 57 industrial classifications in the database. And in the GTAP-E released in the GTAP technical paper #16 (original GTAP-E), 66 regional divisions are aggregated to 8 regions and 57 industrial classifications are aggregated to 8 sectors.

As to industrial aggregation we adopted the same classification as the original GTAP-E as shown in Table 2-8. However, China and India are mingled in the original GTAP-E, which is a problem to analyze improvement of the energy efficiency in China alone. Therefore we re-aggregated GTAP database in order to split 'China-India region' into two independent countries. As a result, the regional aggregation in our GTAP-E is as shown in Table 2-9.

There are two factors that determine the results in CGE model: the parameters of the model equations and the initial values of the data. Since the parameters of the model equations are already explained in the previous section, in this section some initial values related with energy consumption in GTAP database before discussions on the simulation results.

Figure 2-4 shows regional share in energy consumption in GTAP database whose base year is 1997. The United States is ranking in the first place, accounting for about a quarter (24.9%) of total energy consumption of the entire world, followed by EU(15.6%), 'East Europe and former Soviet Union'(13.2%), and China(10.9%). Taking it into consideration that Japan's share in energy consumption is only 5.7%, it is obvious that China's share is relatively large comparing China's economic size.

Figure 2-5 shows the energy composition of each region defined in this chapter. Since '2 Oil' stands for 'crude oil", the total of '2 Oil' and '4 Oil Pcts' corresponds to so-called 'Oil'. What is remarkable feature in the figure are China's high coal share of 68.1% and its low gas share of merely 2.2%. Since gas related energy technologies are generally speaking newly-developed, improvement of energy efficiency in China by energy conversion would be promising.

Figure 2-6 shows regional share in CO_2 emissions in GTAP database. Total emissions in the world were about 6.2 billion tons and those of the United States were 1.5 billion tons (24.3%) in 1997. While the USA already withdrew from Kyoto Protocol in 2001, it can be seen from this figure how much impact that gave.

However, if CO_2 emissions of China(13.7%), Idea(3.9%) and ROW(10.1%) are summed up, they exceed those of the United States. While EU's share is large enough as 14.8%, how large China's share is confirmed here. China has emission share of 13.7% ranking in the second in the world as a single country. And what is notable is share in CO_2 emissions is larger that that in energy consumption by 2.8%. That is because of China's high share of coal consumption as seen in Figure 2-5 and Figure 2-7. Those figures suggest that reduction of CO_2 emissions in China by energy conversion would be also promising.

2-3-2 Introduction of carbon tax in Japan

Since the indirect taxes which the standard GTAP model assumes is '*ad valorem*' taxes such as the Japanese present general consumption tax in Japan, the standard GTAP could not handle the energy tax imposed on the carbon contents of various fuels. However, GTAP-E has made it possible to handle this kind of tax.

In this section we assumed the following three cases as the tax rate per ton carbon in order to implement carbon tax simulations. The middle case is almost parallel with the rate that the Ministry of Environment proposed in July, 2003.

(i) low case: 15 dollars per ton carbon
(ii) middle case: 30 dollars per ton carbon
(iii) high case: 45 dollars per ton carbon

The carbon contents of various fuels are different and the original prices of various fuels per TOE are also different, therefore, the tax rates when it was converted to '*ad valorem*' rate are different among various fuels. Table 2-10 shows that the *ad valorem* tax rates corresponding \$15, \$30, and \$45 carbon tax rates per ton carbon. Since coal contains the most carbon among fossil fuels, the '*ad valorem*' rate is the higher. Though the carbon contents of crude oil and oil products are assumed same in the GTAP-E data base, 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 a forth of the price of oil products.

Table 2-11 shows the change of 'Equivalent Variation' in each country when \$15, \$30, and \$45 carbon tax is imposed on fossil energies such as coal, oil, natural gas and oil products in Japan. Supposed the effect of the carbon tax is measured by the 'Equivalent Variation' (EV), Japan solely is the big loser. Actually the change in GDP is almost same as EV. The rate of GDP decrease in Japan is such marginal as 0.047% in \$15 case, 0.096% in \$30, and 0.146%, \$45. On the other hand, EV is positive in all countries except for Japan and Energy Exporting Countries. This is because that the carbon tax raises the price of goods and service made in Japan, so that import of Japan from abroad increase and Japan's export to abroad is substituted by other Annex 1 countries. 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, EV becomes negative.

Table 2-12 shows the change in the CO_2 emissions by carbon tax introduction in Japan. The reduction of CO_2 emissions is -4.42%, -8.12%, -11.29% corresponding to the tax rates of \$15, \$30, and \$45, respectively. Since it seems that the carbon tax rate to cut 1% of CO_2 emissions is approximately \$3.7/tonC, the carbon tax rate to cut 20% of CO_2 emissions which is the required level for present Japan is approximately \$74(=20 * \$3.7). The world total reduction of CO_2 emissions in the middle case is 0.45% or 28.0 million tons.

However, we should note two important things to evaluate those figures. First, in CGE models, free and immediate movement of labor and capital is assumed. That is to say, full employment of labor and full operation of capital stock is guaranteed as the model specification. This is the reason why the GDP decrease caused by exogenous shocks often seems too small. Second, this simulation is a pure static analysis. That is to say, the figures shown here include only the price effect and do not include the effect of technological change induced by the price changes. Therefore, as to CO_2 emissions, it is possible that those figures could be underestimated if long-run effects are taken into consideration.

2-3-3 Improvement of energy efficiency in China

In GTAP-E model, though the inside of composite of 'value-added and energy' is of CES aggregation but the top level of the production function is defined as the fixed Leontief type:

$$QO_j = e^{ao_j t} \min[QVAE_j e^{avae_j t}, QF_{1j} e^{af_{1j} t}, \Lambda\ , QF_{nj} e^{af_{nj} t}] \tag{24}$$

$$QVAE_j = e^{aeo_j t} \cdot CES\_QVAE_j(QVA_j e^{ava_j t}, E_{1j} e^{ae_{1j} t}, \Lambda\ , E_{kj} e^{ae_{nj} t}) \tag{25}$$

The QO_j stands for the production quantity of j industry, $QVAE_j$ for composite of 'Value-added and Energy' of j industry, QF_{if} for the quantity of intermediate input from i industry to j industry, QVA_j for composite of Value-added, and E_{kj} for the quantity of ith energy input to j industry. Technological progress parameters are ao, $avae_j$, af_{ij}, aeo_j, ava_j, and ae_{ij} appeared in the index of exponential.

Here, what we have mind on the simulation analysis here is repair and/or construction of power plants in China by technological granting from Japan. In case we assumed an energy-input increase type of technological progress, the technology parameters aeo_j, and/or ae_{ij} would be changed. As a matter of fact, while the energy composition of power generation will occasionally be changed from coal to natural gas, the room of the energy efficiency improvement of the coal power plant is also large. Since, it could be arbitrary to determine the parameters to change and the size of change, we do not assume biased technological progress, simple 'output increase' type or 'Hicks neutral' technological progress in this section. For the case neutral technological progress is assumed, the parameter to change is *ao* in the right side of the equation (24)[vi].

We assumed such three cases of rates of technological progress as 5%, 10%, and 15% as the degree of the energy efficiency improvement in China's power generation. As stated in the previous chapter, the energy efficiency of China is about ten times "more energy consumed" compared with Japan. The above mentioned efficiency improvement in power generation in China would not be exaggerating as assumed technological progress in clean development mechanism (CDM) projects between China and Japan.

Table 2-13 shows the equivalent variation in the simulations. In the middle case (10% improvement), it is expected that Equivalent Valuation (EV) in China would be positive 3.8 billion dollars. As related in the previous section, the change in GDP is almost same as EV, increase in GDP in China is 3.724 billion dollars or 0.436 % of 1997 level. The most significant difference from the case of carbon tax in Japan is that efficiency improvement in China hardly negative influences to other regions. As for EVs other than China, the total effect depends on which effects are stronger; the effect of China's price competitiveness that deprives other countries of their export markets or the effect of China's economic size that creates the export markets for other countries. As for Japan and EU, the latter effect is larger giving positive effect to EV. As for EEFSU (East Europe & former Soviet Union), the USA, EEX (energy exporting countries), however, the former effect is rather stronger giving negative effect to EV. That is because their exports of energy to China decrease. Although their EVs are negative, they are insignificant compared to the positive effect for China.

Table 2-14 shows change in the CO_2 emissions. The reduction of CO_2 emissions in China is -1.33%, -2.53%, -3.63% corresponding to the efficiency improvement of 5%, 10%, and 15%, respectively. Though the rate of reduction seems small, the quantity of CO_2 emissions is not small since the CO_2 emissions in China is as 2.5 time as large as Japan's. Therefore, the above mentioned reductions in Chain correspond to such large rates as 3.31%, 6.33%, and 9.08% respectively. The world total reduction of CO_2 emissions in the middle case is 0.35% or 21.4 million tons, which is almost same as reduction in the middle case of carbon tax in Japan.

What is noteworthy is reduction of this amount could be possible only in one industry of power generation and that 10% efficiency improvement is not a impossibly difficult matter though \$30/tonC carbon tax is against very hard opposition. Furthermore, introduction if carbon tax means decrease of world welfare while improvement of energy efficiency means increase of world welfare.

2-4 Conclusion

In this chapter, the effect of the CO_2 emission-reduction by technology transfer from Japan to China was analyzed with GTAP-E model. The result of analysis is as follows:

Figure 2-8 shows the relation between EV decrease and reduction of CO_2 emissions in the case of (i) introduction of carbon tax in Japan and the relation between EV increase and reduction of CO_2 emissions in the case of (ii) efficiency improvement in China's power plants. In the case of (i), reduction of CO_2 emissions can be realized by downsize of world economy. However, suppose Japan is a donor country of technology to improve efficiency of power plants, it can be interpreted that reduction of CO_2 emissions is realized by Japan's donation of 'welfare' or GDP to China. If the cost of repair and construction of power plants is same as the 'welfare' or GDP gained by technology transfer, this result suggests that it can be possible to share CDM type cooperation and introduction of carbon tax in Japan to reduce CO_2 emissions. It is apparent from the figure that the technology transfer (or donation of GDP to China) is better contribution for the welfare improvement of the world.

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[ii] Generally these economic means are called the Kyoto mechanism. While CDM is the technological cooperation given from the advanced countries (called Annex I Parties) that have duty to cut emissions to the developing countries (called Non-Annex I Parties) that do not, JI is the cooperation between advanced countries with such duty. However, they have same basic principle.

[iii] A joint symposium of Japan-South Korea was held in Tokyo in September 2000. The report then are Japan External Trade Organization Institute of Developing Economies (2000), and South Korea external economy policy research academy (2000)

[iv] As to derivation of the outer elasticity, see the appendix.

[v] The description in this section is based on (Ban, 2001).

[vi] Assuming biased technological progress where the degree of improvements of coal, oil, and the natural are not same is one of assignments in the next paper.

Appendix Outer Elasticity of Substitution

A-1 Purpose of this appendix

GTAP-E assumes multi-stage CES aggregation in the production function. The following (A1) and (A2) show an example two Stage CES function: Value added is defined by a CES function of labor and composite input of capital and energy,

(A1) $V^{\rho_v} = L^{\rho_v} + G^{\rho_v}$,

and composite input of "capital and energy" is also defined by a CES function,

(A2) $G^{\rho_g} = K^{\rho_g} + E^{\rho_g}$.

This appendix will illustrate it is possible that capital and energy is complementary in the top level expressed by equation (1), even if they are substitutable in the second level expressed by equation (2).

A-2 Cost minimization on capital-energy composite "G"

(A3) $Min. \quad C_g = w_k K + w_e E \qquad s.t. \quad G^{\rho_g} = K^{\rho_g} + E^{\rho_g}$

The first order condition of cost minimization is equality of input price ratio and marginal rate of substitution.

(A4) $\dfrac{w_k}{w_e} = \dfrac{K^{\rho_g - 1}}{E^{\rho_g - 1}}$, then $\dfrac{w_k K}{w_e E} = \dfrac{K^{\rho_g}}{E^{\rho_g}}$

Adding 1 to the both side of (4), we get

(A5) $\dfrac{C_g}{w_e E} = \dfrac{w_k K + w_e E}{w_e E} = \dfrac{K^{\rho_g} + E^{\rho_g}}{E^{\rho_g}} = \dfrac{G^{\rho_g}}{E^{\rho_g}}$.

Soloing (A5) by *E*, we get

(A6) $E = C_g^{\frac{1}{1-\rho_g}} G^{\frac{\rho_g}{\rho_g - 1}} w_e^{\frac{1}{\rho_g - 1}}$.

Since E and K are symmetric, we get

(A7) $K = C_g^{\frac{1}{1-\rho_g}} G^{\frac{\rho_g}{\rho_g - 1}} w_k^{\frac{1}{\rho_g - 1}}$.

Therefore, the cost function is derived as follows:

(A8) $C_g = w_k K + w_e E = C_g^{\frac{1}{1-\rho_g}} G^{\frac{\rho_g}{\rho_g - 1}} (w_k^{\frac{\rho_g}{\rho_g - 1}} + w_k^{\frac{\rho_g}{\rho_g - 1}})$

(A8') $C_g = G(w_k^{\frac{\rho_g}{\rho_g - 1}} + w_e^{\frac{\rho_g}{\rho_g - 1}})^{\frac{\rho_g - 1}{\rho_g}} = Gw_g$,

where $w_g = (w_k^{\frac{\rho_g}{\rho_g - 1}} + w_e^{\frac{\rho_g}{\rho_g - 1}})^{\frac{\rho_g - 1}{\rho_g}} = (w_k^{1-\sigma_g} + w_e^{1-\sigma_g})^{\frac{1}{1-\sigma_g}}$. Since the second term of the right hand side is a unit cost, it is interpreted as the price of G

The conditional demand function of each input is the partial derivative of the cost function on corresponding input.

(A9) $K = \frac{\partial C_g}{\partial w_k} = G(\frac{w_k}{w_g})^{\frac{1}{\rho_g - 1}} = G(\frac{w_k}{w_g})^{-\sigma_g}$

(A10) $E = \frac{\partial C_g}{\partial w_e} = G(\frac{w_e}{w_g})^{\frac{1}{\rho_g - 1}} = G(\frac{w_e}{w_g})^{-\sigma_g}$

The calculation the ration of E and K, we get elasticity of substitution.

(A11) $\frac{K}{E} = (\frac{w_k}{w_e})^{-\sigma_g}$.

3 Cost minimization on Value-added "*V*"

(A12) $L = \frac{\partial C_v}{\partial w_l} = V(\frac{w_l}{w_v})^{\frac{1}{\rho_v - 1}} = V(\frac{w_l}{w_v})^{-\sigma_v}$

(A13) $G = \frac{\partial C_v}{\partial w_g} = V(\frac{w_g}{w_v})^{\frac{1}{\rho_v - 1}} = V(\frac{w_g}{w_v})^{-\sigma_v}$

Then,

(A14) $K = \frac{\partial C_g}{\partial w_k} = G(\frac{w_k}{w_g})^{\frac{1}{\rho_g - 1}} = V(\frac{w_g}{w_v})^{-\sigma_v}(\frac{w_k}{w_g})^{-\sigma_g}$

(A15) $E = \frac{\partial C_g}{\partial w_e} = G(\frac{w_e}{w_g})^{\frac{1}{\rho_g - 1}} = V(\frac{w_g}{w_v})^{\sigma_v}(\frac{w_e}{w_g})^{\sigma_g}$

or

(A14’) $\ln K = \ln V + (\sigma_g - \sigma_v)\ln w_g - \sigma_v \ln w_v + \sigma_g \ln w_k$

(A15’) $\ln E = \ln V + (\sigma_g - \sigma_v)\ln w_g - \sigma_v \ln w_v + \sigma_g \ln w_e$

A-4 Outer elasticity of substitution of *K* and *E*

Outer elasticity of substitution of *K* and *E*, which is sometimes called Allen’s elasticity of *K*-*E*, is defined as follows:

(A16) $\sigma_{KE} = \dfrac{d \ln K}{d \ln w_e} / S_e$

where S_e is the share of *E* in value added *V*. σ_{KE} can be expressed as follows:

(A16’) $\sigma_{KE} = (\sigma_g - \sigma_v)/S_g + \sigma_v$

Therefore, in case the elasticity of labor and capital-energy composite σ_v is small enough and the share of capital-energy composite S_g is small enough, σ_{KE} could be positive, which means that capital and energy are mutually complementary. The following is a derivation of equation (16’)

A-5 Derivation of Allen’s elasticity of *K*-*E*

Taking natural logs of (14) and partial differentiating by lnw_e yields

(A17) $\dfrac{d \ln K}{d \ln w_e} = \left(\sigma_g - \sigma_v\right)\dfrac{\partial \ln w_g}{\partial \ln w_e} + \sigma_v \dfrac{\partial \ln w_v}{\partial \ln w_e}$

The price of capital-energy composite w_g is defined as $w_g^{1-\sigma_g} = w_k^{1-\sigma_g} + w_e^{1-\sigma_g}$ by duality. Differentiating with respect to w_e, we get

(A18) $\dfrac{\partial w_g}{\partial w_e} = \left(\dfrac{w_e}{w_g}\right)^{-\sigma_g}$

The price of value-added w_v is defined as $w_v^{1-\sigma_v} = w_l^{1-\sigma_v} + w_g^{1-\sigma_v}$ by duality. Differentiating with respect to w_e, we get

(A19) $\dfrac{\partial w_v}{\partial w_e} = \left(\dfrac{w_g}{w_v}\right)^{-\sigma_v} \dfrac{\partial w_g}{\partial w_e} = \left(\dfrac{w_g}{w_v}\right)^{-\sigma_v} \left(\dfrac{w_e}{w_g}\right)^{-\sigma_g}$

Substituting (18) and (19) into (17) yields the followings:

(A20) $\dfrac{\partial \ln K}{\partial \ln w_e} = \left(\sigma_g - \sigma_v\right)\left(\dfrac{w_g}{w_e}\right)^{1-\sigma_g} + \sigma_v \left(\dfrac{w_g}{w_v}\right)^{1-\sigma_v} \left(\dfrac{w_e}{w_g}\right)^{1-\sigma_g}$

Since the cost share in the value added (S_e)is express as equation (21),

$$\text{(A21)}\quad S_e = \frac{w_e V \left(\frac{w_g}{w_v}\right)^{-\sigma_v} \left(\frac{w_e}{w_g}\right)^{-\sigma_g}}{w_v V},$$

dividing equation (20) by S_e, we get Allen's elasticity of substitution between E and K on the top level.

$$\text{(A22)}\quad \frac{\frac{d\log K}{d\log w_e}}{S_e} = \frac{w_v V(\sigma_g - \sigma_v)\left(\frac{w_e}{w_g}\right)^{1-\sigma_g}}{w_e V \left(\frac{w_g}{w_v}\right)^{-\sigma_v} \left(\frac{w_e}{w_g}\right)^{-\sigma_g}} - \frac{w_v V \sigma_v \left(\frac{w_g}{w_v}\right)^{1-\sigma_v} \left(\frac{w_e}{w_g}\right)^{1-\sigma_g}}{w_e V \left(\frac{w_g}{w_v}\right)^{-\sigma_v} \left(\frac{w_e}{w_g}\right)^{-\sigma_g}}$$

And, since the cost share of K-E composite (S_g) is defined as equation (23),

$$\text{(A23)}\quad S_g = \frac{w_g V \left(\frac{w_g}{w_v}\right)^{\sigma_v}}{w_v V}$$

we get Allen's elasticity of substitution between E and K on the top level as equation (A24) which is same as equation (A16').

$$\text{(A24)}\quad \frac{\frac{d\log K}{d\log w_e}}{S_e} = \sigma_{KE} = \frac{(\sigma_g - \sigma_v)}{S_g} + \sigma_v$$

Tables and Figures of Chapter2

Table 2-1 Rate of Carbon Taxes in North European Countries

	Dollar / ton Carbon	Yen / ton Carbon
Finland	53.9	6,807
Sweden	113.5	14,315
Norway	Minimum 40.1	Minimum 5,009
Denmark	43.0	5,357

Source: Ministry of Environment (2001).
http://www.env.go.jp/earth/report/h13-05/index.html
Exchange rates are those in May 2001.

Table 2-2 Simulation results on carbon tax by selected global models

Model	Loss of GDP	Carbon tax rate
Goto (Univ. of Tokyo)	0.02	$2.7
Ban (Osaka Univ.)	0.05	$5.6
Mori (Tokyo Science	0.22	$17.0
Yamaji (Univ. of Tokyo)	0.23	$18.5
Ito (EDMC)	0.29	$16.5
Yamazaki (CRC Research)	0.41	$19.2
Nihon Keizai Shinbun	0.16	$51.8
Shishido (International	1.16	$55.0

* % of GDP loss to reduce 1% of CO_2 emission.

** Dollar / ton Carbon in order to reduce 1% of CO_2 emissions.

Source: Amano (1994)

Table 2-3 Energy Substitution Elasticity in GTAP-E and Other Models

	Capital-Energy (*K-E*)			Inter-Fuel			
				GTAP-E (e)			
SECTOR	GTAP-E (a)	GREEN (b)	Rutherford (c)	Electric vs. Non-electric	Coal vs. other non-electric	between non-coal, non-electric	GREEN
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crude Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Petroleum, coal products	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.5	0.0 - 0.8	-(d)-	1.0	0.5	1.0	0.25 - 2.0
Ferrous metals	0.5	0.0 - 0.8	0.5	1.0	0.5	1.0	0.25 - 2.0
Chemical, rubber, plastic products	0.5	0.0 - 0.8	0.5	1.0	0.5	1.0	0.25 - 2.0
Other manufacturing; trade, transport	0.5	0.0 - 0.8	0.5	1.0	0.5	1.0	0.25 - 2.0
Agriculture, forestry, and fishery	0.0	0.0 - 0.8	0.5	1.0	0.5	1.0	0.25 - 2.0
Commercial/public services, dwellings	0.5	0.0 - 0.8	0.5	1.0	0.5	1.0	0.25 - 2.0

(a) To ensure capital and energy are complements in the short run, while substitutes in the long run, the elasticity of substitution between K and E aggregate must be set lower than the elasticity between K and other primary factors (σVAE).

(b) In the GREEN model, if the long-term elasticity between K and E is equal to 2.0 and the short run value set equal to 0.25, then the 'intermediate' term (approximately 5 years) elasticity - which depends on the vintage structure of the capital - will be about 0.8 (see Figure 5, Burniaux et al. (1992), p. 66).

(c) In Rutherford models, a value of 0.5 is set for substitution between energy composite and land-labor-capital composite in the non energy-producing industries (Babiker et al. (1997)), or between energy composite and labor-capital composite (Rutherford et al (1997), and Bohringer and Pahlke (1997)).

(d) K-E substitution for the electricity industry is determined, not by an econometric parameter, but by the specification of alternative electricity-generation technologies in the 'process model'.

(e) This is based on the values of 1.0 chosen for the substitution between electric and non-electric, and between non-coal fossil fuels in (Babiker et al. (1997)), Rutherford et al. (1997). Bohringer and Pahlke (1997) however, chose a value of 2.0 for the substitution between non-coal fossil fuels. For substitution between coal and non-coal fossil fuels, Babiker et al. (1997) chose a value of 0.5, whereas Bohringer and Pahlke (1997) chose a value of 0.25 if the non-coal aggregate includes electricity.

Source: Burniaux and Truong (2002) GTAP Technical Paper No 16

Table 2-4 Elasticity of Substitution between Different Factors of Production

Sector	GTAP-E a) (σVAE)	GREEN		Rutherford d)
		L –KEF b)	E –KF c)	
Coal	0.2	0.0	0.0	1.0
Crude Oil	0.2	0.0	0.0	1.0
Gas	0.84	0.0	0.0	1.0
Petroleum, coal products	1.26	0.0	0.0	1.0
Electricity	1.26	0.0	0.0 - 0.8	1.0
Ferrous metals	1.26	0.12 - 1.0	0.0 - 0.8	1.0
Chemical, rubber, plastic products	1.26	0.12 - 1.0	0.0 - 0.8	1.0
Other manufacturing; trade, transport	1.45	0.12 - 1.0	0.0 - 0.8	1.0
Agriculture, forestry, and fishery	0.23	0.12 - 1.0	0.0 - 0.8	1.0
Commercial/public services, dwellings	1.28	0.12 - 1.0	0.0 - 0.8	1.0

(a) In GTAP-E: between land, natural resources, aggregate labor, and capital-energy composite.

(b) Between labor (L), and energy-capital-fixed factor composite (EKF).

(c) Between energy (E) and capital-fixed factor composite (KF).

(d) Between land, labor, and capital (see Babiker et al. (1997)), or between labor and capital (Rutherford et al (1997), and Bohringer and Pahlke (1997)).

Source: Burniaux and Truong (2002) GTAP Technical Paper No 16

Table 2-5 The Relationship between Inner (σKE -inner) and Outer (σKE -outer) Elasticity of Substitution for the Cases of Japan and the US

Sector	$\sigma KE - inner$	σVAE	Japan			USA		
			S_{VAE}	S_{KE}	$\sigma KE - outer$	S_{VAE}	S_{KE}	$\sigma KE - outer$
Coal	0.0	0.2	0.49	0.11	-1.50	0.67	0.16	-0.97
Crude Oil	0.0	0.2	0.64	0.24	-0.52	0.69	0.34	-0.30
Gas	0.0	0.84	0.97	0.95	-0.02	0.81	0.55	-0.49
Petroleum, coal products	0.0	1.26	0.68	0.59	-0.28	0.91	0.88	-0.04
Electricity	0.5	1.26	0.83	0.71	0.45	0.84	0.71	0.43
Ferrous metals	0.5	1.26	0.51	0.34	0.27	0.43	0.18	-1.35
Chemicals, rubber, plastics	0.5	1.26	0.42	0.26	0.05	0.50	0.30	-0.05
Other manu. Trade , Transport	0.5	1.45	0.46	0.16	-2.65	0.51	0.18	-2.45
Agriculture, forestry, & fishery	0.0	0.23	0.58	0.20	-0.77	0.46	0.26	-0.38
services, dwellings	0.5	1.28	0.62	0.30	-0.58	0.63	0.23	-1.41

(a)Note: $\sigma_{KE-outer} = [\sigma_{KE-inner} - \sigma_{VAE}]/S_{KE} + \sigma_{VAE}$, where $S_{KE}, \sigma_{KE-inner}$ are the cost share and substitution elasticity respectively for the capital-energy composite and S_{KE}, σ_{VAE} are the cost share and substitution elasticity respectively for the value-added-energy composite.

Source: Burniaux and Truong (2002) GTAP Technical Paper No 16

Table 2-6 Elasticity of Substitution between Domestic and Foreign Sources (D)

Sector	GTAP-E	GREEN b)	Rutherford c) Low-High
Coal	2.80	4.0	2.0
Crude Oil	10.0 a)	∞	∞
Gas	2.80	4.0	2.0
Petroleum, coal products	1.90	4.0	2.0
Electricity	2.80	0.3	2.0
Ferrous metals	2.80	2.0	4.0 – 8.0
Chemical, rubber, plastic products	1.90	2.0	4.0 – 8.0
Other manufacturing, trade, transport	2.59	2.0	4.0 – 8.0
Agriculture, forestry, and fishery	2.47	3.0	4.0 – 8.0
Commercial/public services, dwellings	1.91	2.0	4.0 – 8.0

(e) This is higher than the standard value of 2.8 used in most GTAP applications.
(f) Burniaux et al. (1992), p. 76.
(g) Babiker et al. (1997),
Source: Burniaux and Truong (2002) GTAP Technical Paper No 16

Table 2-7 Elasticity of Substitution between Different Regions (σM)

Sector	GTAP-E	GREEN b)	Rutherford c)
			Low-High
Coal	5.60	5.0	4.0
Crude Oil	20.0 a)	∞	∞
Gas	5.60	5.0	4.0
Petroleum, coal products	3.80	3.0	4.0
Electricity	5.60	0.5	4.0
Ferrous metals	5.60	3.0	8.0 - 16.0
Chemical, rubber, plastic products	3.80	3.0	8.0 - 16.0
Other manufacturing, trade, transport	6.04	3.0	8.0 - 16.0
Agriculture, forestry, and fishery	4.62	4.0	8.0 - 16.0
Commercial/public services, dwellings	3.80	3.0	8.0 - 16.0

(h) This is higher than the standard value of 5.6 used in most GTAP applications.
(i) Burniaux et al. (1992), p. 76.
(j) Babiker et al. (1997).
Source: Burniaux and Truong (2002) GTAP Technical Paper No 16

Table 2-8 Commodity / Industry in our GTAP-E Model

New Code	Industry Description
1 Agri	Agriculture, forestry & Fishery
2 Coal	Coal mining
3 Oil	Crude oil
4 Gas	Natural gas
5 OilPro	Refined oil
6 Elect	Electricity
7 EnInt	Energy intensive industry
8 Other	Other industries & services

GTAP Number	Our Number	Symbols	Commodity / Industry
1	1	pdr	Paddy rice
2	1	wht	Wheat
3	1	gro	Cereal grains nec.
4	1	v_f	Vegetables, fruit, nuts
5	1	osd	Oil seeds
6	1	c_b	Sugar cane, sugar beet
7	1	pfb	Plant-based fibers
8	1	ocr	Crops nec.
9	1	ctl	Cattle, sheep, goats, horses
10	1	oap	Animal products nec.
11	1	rmk	Raw milk
12	1	wol	Wool, silk-worm cocoons
13	1	for	Forestry
14	1	fsh	Fishing
15	2	col	Coal
16	3	oil	Oil
17	4	gas	Gas
18	7	omn	Minerals nec.
19	8	cmt	Meat: cattle, sheep, goats, horse
20	8	omt	Meat products nec.
21	8	vol	Vegetable oils and fats
22	8	mil	Dairy products
23	8	pcr	Processed rice
24	8	sgr	Sugar
25	8	ofd	Food products nec.
26	8	b_t	Beverages and tobacco products
27	8	tex	Textiles
28	8	wap	Wearing apparel
29	8	lea	Leather products
30	8	lum	Wood products
31	8	ppp	Paper products, publishing
32	5	p_c	Petroleum, coal products
33	7	crp	Chemical, rubber, plastic prods
34	7	nmm	Mineral products nec.
35	7	i_s	Ferrous metals
36	7	nfm	Metals nec.
37	8	fmp	Metal products
38	8	mvh	Motor vehicles and parts
39	8	otn	Transport equipment nec.
40	8	ele	Electronic equipment

Table 2-8 Commodity / Industry in our GTAP-E Model (continued)

GTAP Number	Our Number	Symbols	Commodity / Industry
41	8	ome	Machinery and equipment nec.
42	8	omf	Manufactures nec.
43	6	ely	Electricity
44	4	gdt	Gas manufacture, distribution
45	8	wtr	Water
46	8	cns	Construction
47	8	trd	Trade
48	8	otp	Transport nec.
49	8	wtp	Sea transport
50	8	atp	Air transport
51	8	cmn	Communication
52	8	ofi	Financial services nec.
53	8	isr	Insurance
54	8	obs	Business services nec.
55	8	ros	Recreation and other services
56	8	osg	Public Admin, Defense, Health, Education
57	8	dwe	Dwellings

Table 2-9 Country / Region in our GTAP-E Model

New Code	Region Description
1 USA	USA
2 EU	European Union
3 EEFSU	Eastern Europe & former Soviet Union
4 JPN	Japan
5 ROA1	Other Annex 1
6 EEX	Net energy exporters
7 CHN	China
8 IND	India
9 ROW	Other regions

GTAP Number	Our Number	Symbol	Country / Region
1	5	aus	Australia
2	5	nzl	New Zealand
3	7	chn	China
4	9	hkg	Hong Kong
5	4	jpn	Japan
6	9	kor	Korea
7	9	Twn	Taiwan
8	6	Idn	Indonesia
9	6	Mys	Malaysia
10	9	Phl	Philippines
11	9	sgp	Singapore
12	9	tha	Thailand
13	6	vnm	Vietnam
14	9	bgd	Bangladesh
15	8	ind	India
16	9	lka	Sri Lanka
17	9	xsa	Rest of South Asia
18	5	can	Canada
19	1	usa	United States
20	6	mex	Mexico
21	9	xcm	Central America, Caribbean
22	6	col	Colombia
23	9	per	Peru
24	6	ven	Venezuela
25	6	xap	Rest of Andean Pact
26	6	arg	Argentina
27	9	bra	Brazil
28	9	chl	Chile
29	9	ury	Uruguay
30	9	xsm	Rest of South America
31	2	aut	Austria
32	2	bel	Belgium
33	2	dnk	Denmark
34	2	fin	Finland
35	2	fra	France
36	2	deu	Germany
37	2	gbr	United Kingdom
38	2	grc	Greece
39	2	irl	Ireland
40	2	ita	Italy

Table 2-9 Country / Region in our GTAP-E Model (continued)

GTAP Number	Our Number	Symbol	Country / Region
41	2	lux	Luxembourg
42	2	nld	Netherlands
43	2	prt	Portugal
44	2	esp	Spain
45	2	swe	Sweden
46	5	che	Switzerland
47	5	xef	Rest of EFTA
48	3	hun	Hungary
49	3	pol	Poland
50	3	xce	Rest of Central European Assoc
51	3	xsu	Former Soviet Union
52	9	tur	Turkey
53	6	xme	Rest of Middle East
54	9	mar	Morocco
55	6	xnf	Rest of North Africa
56	9	bwa	Botswana
57	9	xsc	Rest of SACU (Namibia,RSA)
58	9	mwi	Malawi
59	9	moz	Mozambique
60	9	tza	Tanzania
61	9	zmb	Zambia
62	9	zwe	Zimbabwe
63	6	xsf	Other Southern Africa
64	9	uga	Uganda
65	6	xss	Rest of Sub-Saharan Africa
66	6	xrw	Rest of World

Table 2-10 Carbon Tax Rate (converted ad valorem, %)

Carbon Tax per ton Carbon	15 dollars	30 dollars	45 dollars	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

Table 2-11 Equivalent Variation
by Introduction of Carbon Tax in Japan (Million Dollars)

	$15/ tonC	$30/ tonC	$45/ tonC
USA	265.5	516.9	756.7
EU	570.5	1105.0	1609.7
EEFSU	5.4	12.3	20.1
JPN	-2137.8	-4390.6	-6710.6
RoA1	-82.4	-144.0	-191.3
EEx	-356.7	-683.6	-985.6
CHN	14.0	29.2	45.2
IND	25.7	49.6	72.0
ROW	189.7	370.8	544.2
Total	-1506.1	-3134.3	-4839.6

Table 2-12 Change in CO2 Emissions by Introduction of Carbon Tax in Japan

	% change			Volume change(Million ton)		
	$15/ tonC	$30/ tonC	$45/ tonC	$15/ tonC	$30/ tonC	$45/ tonC
USA	0.02	0.05	0.07	0.36	0.70	1.02
EU	0.04	0.09	0.12	0.41	0.78	1.13
EEFSU	0.01	0.01	0.02	0.04	0.09	0.14
JPN	-4.42	-8.12	-11.29	-14.91	-27.37	-38.09
RoA1	0.10	0.18	0.25	0.25	0.46	0.65
EEx	0.02	0.04	0.06	0.13	0.26	0.40
CHN	-0.25	-0.44	-0.59	-2.12	-3.72	-4.98
IND	0.00	0.00	0.01	0.00	0.01	0.02
ROW	0.07	0.13	0.18	0.41	0.79	1.13
Total	-0.25	-0.45	-0.63	-15.43	-28.00	-38.57

Table 2-13 Equivalent Variation
by Improvement in Energy Efficiency in China (Million Dollars)

	5% improvement	10% improvement	15% improvement
USA	-3.1	-5.9	-8.5
EU	21.8	42.7	62.6
EEFSU	-15.0	-29.3	-43.1
JPN	2.1	4.2	6.3
RoA1	-6.6	-13.5	-20.8
EEx	-69.9	-135.7	-197.8
CHN	1958.6	3797.1	5529.4
IND	3.0	5.8	8.5
ROW	11.6	26.0	43.8
Total	1902.4	3691.3	5380.4

Table 2-14 Change in CO2 Emissions by Improvement in Energy Efficiency in China

	% change			Volume change(Million ton)		
	5% improvement	10% improvement	15% improvement	5% improvement	10% improvement	15% improvement
USA	0.00	0.01	0.01	0.05	0.10	0.14
EU	0.00	0.00	0.00	0.02	0.03	0.03
EEFSU	-0.01	-0.02	-0.03	-0.06	-0.14	-0.23
JPN	0.01	0.02	0.02	0.03	0.06	0.08
RoA1	0.00	-0.01	-0.01	-0.01	-0.02	-0.03
EEx	0.00	0.01	0.01	0.03	0.06	0.08
CHN	-1.33	-2.53	-3.63	-11.17	-21.36	-30.63
IND	0.00	0.00	0.00	0.00	0.01	0.01
ROW	-0.01	-0.02	-0.04	-0.06	-0.15	-0.27
Total	-0.18	-0.35	-0.50	-11.17	-21.42	-30.83

Figure 2-1 Macro Structure of GTAP Model

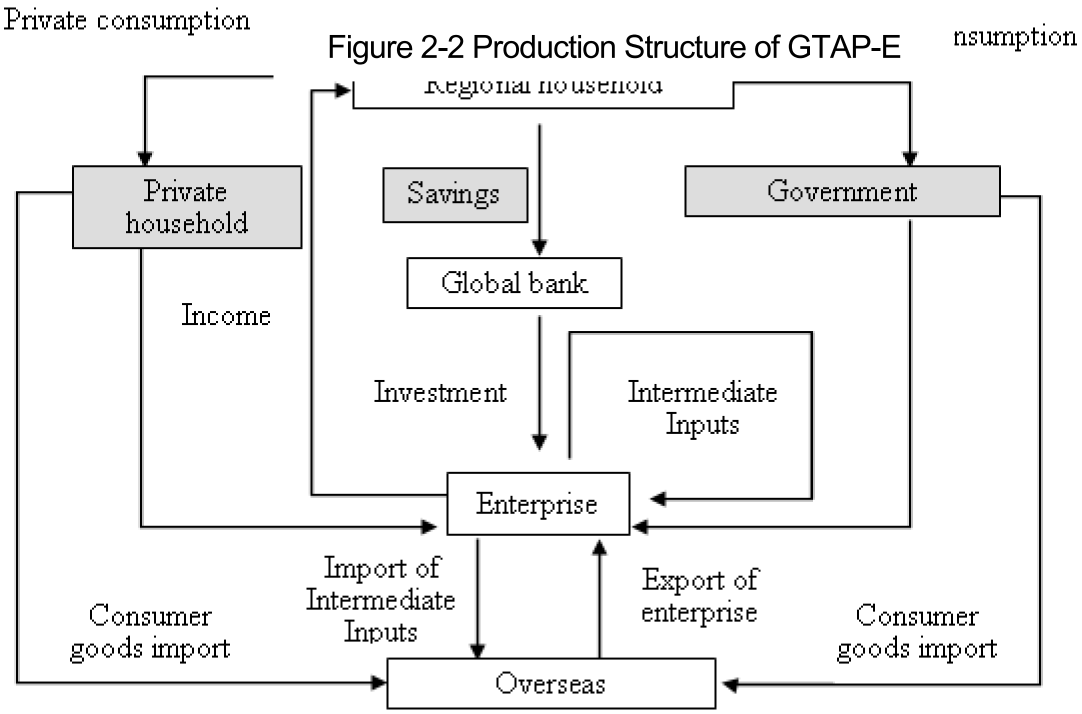


Figure 2-2 Production Structure of GTAP-E

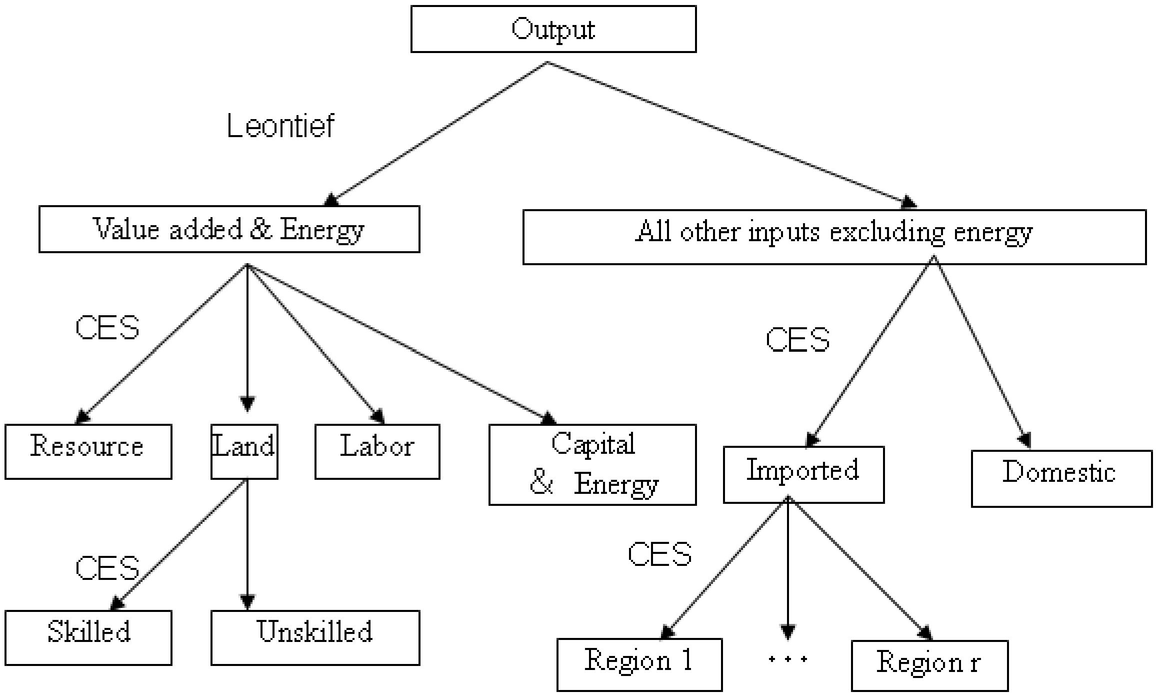


Figure 2-3 Capital & Energy structure of GTAP-E

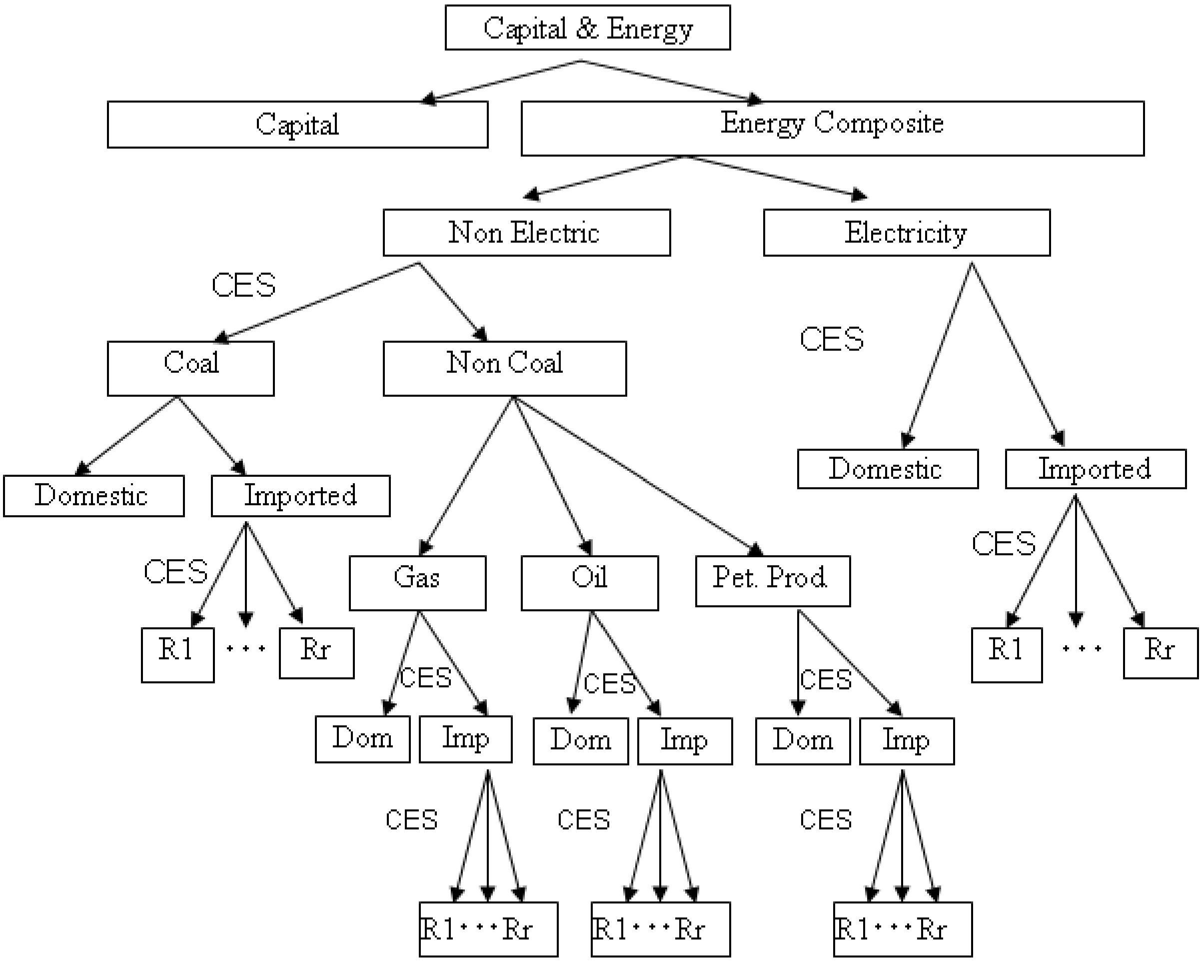
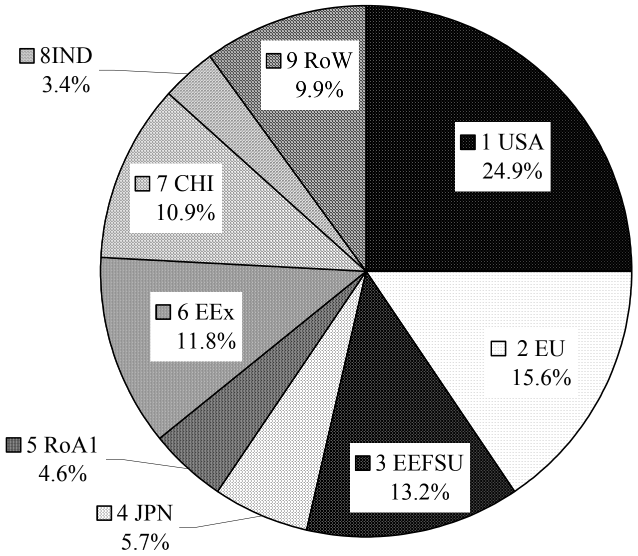
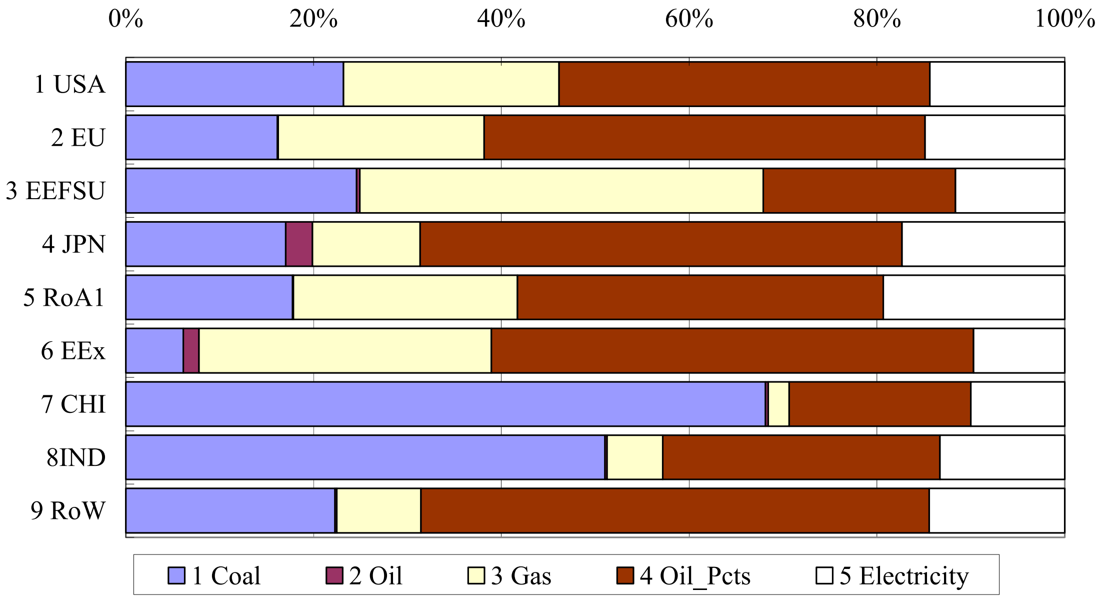


Figure 2-4 Regional Share in Energy Demands



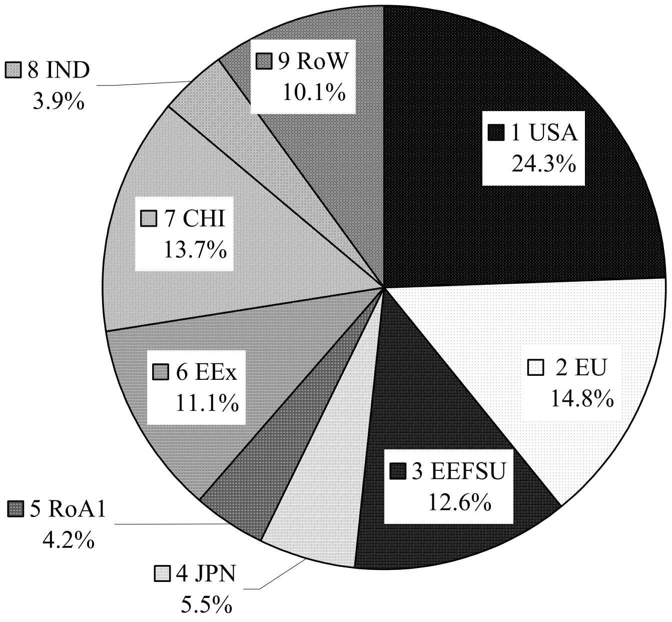
Source: GTAP ver5 data base (base year : 1997)
World total demand is 8.92 billion TOE.

Figure 2-5 Energy demand Structure of Each Region



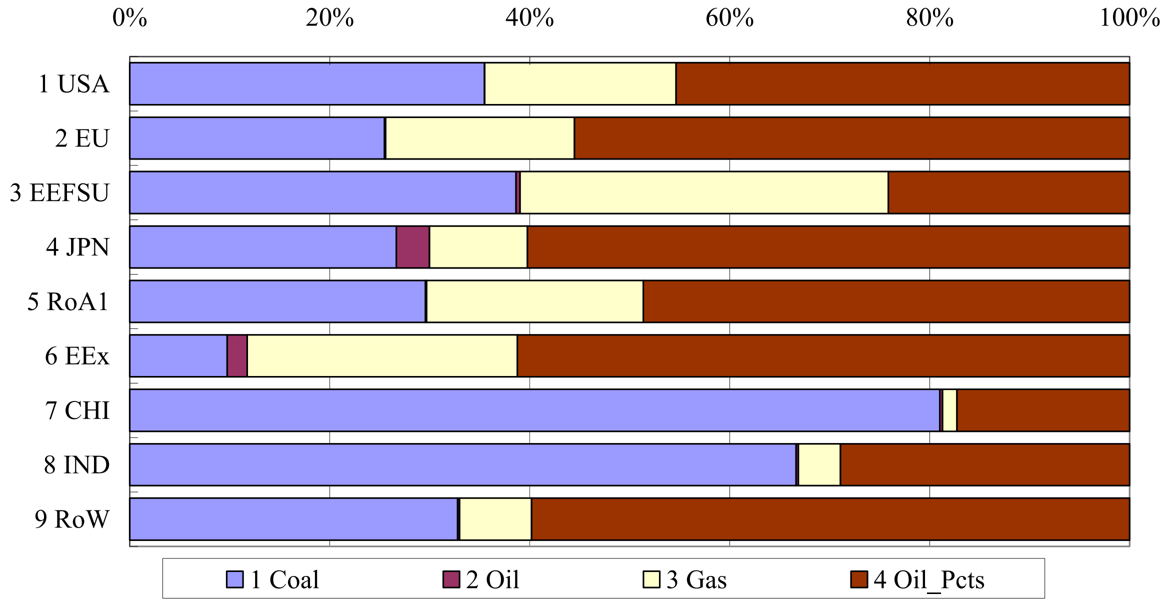
Source: GTAP ver5 data base (base year : 1997)

Figure 2-6 Regional Shares in CO2 Emissions



Source: GTAP ver5 data base (base year : 1997)
World total emission is 6.17 billion carbon ton.

Figure 2-7 Structure in CO2 Emissions



Source: GTAP ver5 data base (base year : 1997)

Figure 2-8 EV and CO2 Reduction