Chapter 3 China's Energy Balance and Environmental Problem: An Energy Balance Model Approach

Summary

One of the targets in this book is to discuss win-win strategies toward global warming with special reference to China. For Japan, besides domestic contribution, clean development mechanism (CDM) is one of the most realistic instruments. Following the previous chapter, this part also aims to investigate the effectiveness of economic instruments to reduce CO_2 emissions in China. It is confirmed that improvement of energy efficiency in China's power plants is very effective to reduce CO_2 and also SO_2 emissions. In that sense, CDM appears to be a promising candidate for win-win strategies for Japan and China.

3-1 Introduction

3-1-1 Why energy balance model?

In the previous chapter, a CGE model (GTAP-E) is used for measuring the effect of economic instrument to reduce CO_2 emission. Here, in this chapter, we use China's energy balance model for the assessment of alternative energy strategies. As well known, the energy balance table provides a convenient accounting and modeling framework to understand country's energy flow. While CGE model deals with the economic interaction worldwide (global), the energy balance model is limited to one county (local) without international repercussion. Concerning on energy flow in the economy, however, it offers more information than CGE model. Anyway, it is very important to collect informative data from various sources (or models) to give realistic judgment for alternative energy policies. That is why we developed China's energy balance model here.

3-1-2 Contents of this chapter

In this chapter, the effect of the strategy to mitigate China's environmental problem including the reduction of CO_2 and SO_2 emissions is investigated. This paper is organized as follows. First, in order to figure out China's energy situation, we compare China's energy balance table with Japan's one in Section 2.

Section 3 briefly summarizes the structure of China's energy balance model applied in this analysis.

In Section 4, with China's energy balance model, baseline forecast to 2010 is compiled and some simulations are conducted. In the simulation analyses, we highlight on the impact of more efficient power generation. This simulation result is to validate effectiveness of CDM between China and Japan. It should be compared with the one reported in the previous chapter.

Finally, in Section 5, we close this chapter showing a policy implication based on the simulation results.

3-2 Fact Findings in China's Energy Balance

3-2-1 Comparison of Energy Balance Tables in China and Japan

Table 3-1 and 3-2 are the energy balance tables for China and Japan in 2001 respectively. Figures in the tables are expressed in terms of ton of oil equivalent (toe) and those in the rightmost column explain how total primary energy is allocated to conversion sector and total final consumption. Figures in italic explain the entries' share occupied in conversion sector and total final consumption respectively.

In China, some 68.9% of total primary energy is distributed to final consumption and other 31.1% is to conversion sector. In Japan, some 65.7% of total is allocated to final consumption and the remaining 34.3% to conversion sector.

At a closer glance to the tables, however, comparison of each component's figure in both countries gives us quite different image. In conversion sector, the share of own use and distribution loss in China was more than twice as much as in Japan. This means that energy in Japan is used more efficiently than in China. In final consumption, residential sector for China dominated 38.2% of the total, while that for Japan 13.6%. This is because residential sector in the developing county like China includes more renewable energy sources such as biomass than in Japan. On the other hand, the share of road for China was 6.1%, while in Japan 23.2%. This suggests that motorization has just started in China.

Figure 3-1 and 3-2 show primary energy share by fuel type both for China and Japan. In China, coal dominated 56% of the total in 2001. While crude oil occupied its share of 19%, natural gas did only 3%. It is noteworthy that share of new energy including biomass was relatively high 19%. On the other hand, in Japan, crude oil had a dominant share of 41% and nuclear had a 16% share of the total.

Figure 3-3 shows electricity share in total final consumption. It should be noted that electricity share in China has been accelerating in the latter half of 1990s to 17.1% in 2001, which corresponds to the level Japan marked in 1977. This suggests that increasing electricity generation is an urgent issue for China to meet with the explosive demand increase.

3-2-2 CO_2 and SO_2 Emission

CO_2 grows from combustion of fossil fuels. As technology withdrawing CO_2 is not in practical use at present, all CO_2 emit into atmosphere. Unlike SO_2, the amount of CO_2 produced equals to that of CO_2 emitted.

China is the 2nd largest emitter of CO_2 following the US. In 2001, China's CO_2 emission amounts to 877 million t-c and it grew 115% since 1980. At a glance of CO_2 emission by fuel source, coal dominated the largest share of 77.4%. While 20.3% of the total stemmed from oil, while 2.3% from natural gas (Table 3-3-a).

SO_2 is contained in coal, oil and natural gas and grows from fuel combustion. How much SO_2 emits into atmosphere depends on the degree of desulphurization. Thus the amount of SO_2 produced is the upper limit of that of SO_2 emitted.

Looking at SO_2 emission by fuel sources, 92.8% of the total came from coal, 7.1% from oil and the remaining 0.1% from natural gas (Table 3-3-b).

China is the largest emitter of SO_2. Main cause of air pollution and acid rain is blamed for the large scale emission of SO_2. In order to reduce SO_2 emission, comprehensive counter policies are needed such as total quantity control, containment of coal use and an installment of desulphur equipment.

3-3 Building China's Energy Balance Model

3-3-1 Outline of the model

This section shows the outline of China's energy balance model. More detailed listing of equations can be seen in the Appendix. As a basic idea for building energy balance model, we owe much to Adams et al (2000). Based on their works, we will explain outline of the model briefly.

The key to projecting the energy balance is to tie its components firmly to economic activity and to spell out the structure of the internal linkages that make up balance. These relationships are summarized in block form in Figure 3-4, which simplifies the extended energy balance table.

The logical starting point is toward the bottom right of the table, estimating total final consumption of energy needs by sector. These are allocated to individual secondary fuels by modal split equations described later. The totals of the sectoral demands by fuels represent the secondary energy requirement by fuel.

The next block up represents conversion. The amount of electricity produced corresponds directly to the sum of domestic consumption requirements. Fuel inputs for thermal electricity generation are determined by thermal power generated and an exogenous efficiency parameter. Also refinery output is determined by crude oil input and a refinery loss parameter.

On top of the diagram, total primary energy supply includes domestic production, imports and exports. Domestic production is forecast on the basis of present and projected supply availabilities from domestic sources. Exports of oil, which account for relatively small quantities, are exogenous. Import requirements of crude petroleum and petroleum products, which are the target of the analysis, are treated as a residual. On the other hand, imports of coal are exogenous, while exports of coal are computed as a difference between domestic needs and domestic production (plus imports).

The energy balance thus serves as a framework and provides the basic identities of the system. The behavioral equations show linkages to activity in the economy at large and responses to relative energy prices and technological opportunities. These equations also recognize the important role of the number of vehicles. The structure of equations used is discussed below somewhat in detail.

3-3-1-1 Final Energy Consumption

Two-step approach is taken in the model. Total energy demand in each sector is determined, and then allocated to alternative fuels.

As the first step, linkages from economic activity to sectoral energy demand (industry and residential) take following form (Equation 2 and 12):

$$CE_i = f(GDP_i, P_i / P, CE_{i-1}), \quad (1)$$

where GDP_i represents sectoral activity, and P_i/P represents the price of energy in sector i to the price level of the overall economy. The lag coefficient allows for gradual adjustment.

With respect to energy allocation between alternative fuel sources, as the 2nd step, the ratio of alternative fuels is estimated. Originally we assume alternative fuel (CF_i and CF_j) energy demand functions as the following forms.

$$CF_i = A \cdot GDP^{\alpha} \cdot (P_i / P)^{-\beta}$$

$$CF_j = A \cdot GDP^{\gamma} \cdot (P_j / P)^{-\delta} \quad (2)$$

The ratio of consumption of fuel (i) to other fuel (j) in the logarithm form can be written as follows:

$$\log(CF_i / CF_j) = const + (\alpha - \lambda)\log(GDP) - \beta \log(P_i / P) + \delta \log(P_j / P) \quad (3)$$

Based on above equation, four such equations are estimated in our model, namely for the ratio of coal and electricity against oil in the industrial and residential sectors (Equations 4, 5, 14 and 15).

Once ratios are estimated, the individual fuel demand is determined with the modal split approach (Equations 6, 7, and 8 for industrial sector and 16, 17 and 18 for residential sector) by multiplying individual fuel ratio with total energy consumption in each sector.

There is also equation for electricity consumption in commerce and public sector (Equation 20).

Transportation, largely by road, presents a special challenge. Consumption of petroleum is determined by the number of vehicles and the relative price of oil to overall retail price (Equation 10). Fuel demand has been increasing in line with the start of motorization. It is not clear, however, whether the pace of motorization or consumption per vehicle can be sustained as the number of vehicles increases. Moreover, we distinguish between passenger cars and commercial vehicles. The growth in the number of vehicles (Equation 69) is a function of GDP and negatively of the number of vehicles per capita, in a nonlinear relationship that tends to approach a limit of one vehicle for three people in equilibrium.

With other identities, this block accounts for final consumption of sectoral fuels.

3-3-1-2 Conversion

Conversion block involves production of electricity, petroleum refining and heat. In this block, electricity generation plays important role. Figure 3-5 and 3-6 show the share of electricity generation by fuels. It is quite interesting that share of power generation by coal has been slightly on the rise in China, although it fell slightly in 2001. In Japan, shares of electricity by fuel have changed drastically in response to the fuel prices change and energy policy. Recently nuclear has increased its share in the power generation and it is also interesting that coal increases its share to the 2^{nd} largest.

By the way, to measure efficiency in power generation, following heat rate in toe terms is assumed.

LOSR = Electricity Generation / Fuel Input

This ratio measures the amount of electricity generated for each unit of fuel. Hydro is assumed to be produced without energy loss. Efficiency in nuclear power generation is assumed to be 33%.

In the building of China's energy balance model, we take account of the flavor of planed economy. In order to meet with the total demand for electricity, Chinese government decides the share of electricity to be generated by fuel type, such as coal, oil, natural gas, nuclear, hydro and new energy. The share determinant is assumed to be government matter and to be treated as exogenous variable in the model. Thus, each fuel input needed to generate electricity is explained by the identity below (Equation 33 through 38).

$$Fuel\ Input_i = Share_i \times Electricity\ Generation\ /\ LOSR_i$$

Figure 3-7 depicts the development of heat rate by fuel type both in China and Japan. Heat rate for coal power generation in Japan was nearly 0.3 in early 1970s and improved to 0.4 in 1980s. It should be noted that a 0.1 point enhancement in heat rate took nearly 10 years. It has been stable at slightly lower level than 0.45. On the other hand, China's heat rate for coal power generation stayed at well below 0.3 through mid 1980s and improved to slightly below 0.35. Now heat rate in China is 0.1 points lower than that in Japan.

Recent ten years, coal heat rate for China was averaged at 0.317, while that for Japan at 0.425. The inverse of heat rate (fuel input per unit of electricity) means efficiency in power generation. Thus efficiency in China is 3.157(=1/0.317) and that in Japan is 2.354(=1/0.425). Roughly speaking, China's efficiency was 25% lower than in Japan[vii].

3-3-1-3 Domestic Primary Energy Supply, Exports and Imports

With estimates of domestic demand and appropriate assumptions about indigenous production, we compute as a residual the amount of energy imports (here crude oil and petroleum, see Equation 62 and 63). A critical factor is the availability of primary energy from domestic sources.

On the other hand, as coal is abundant in China, we treat coal exports as a residual (Equation 61). We have made exogenous estimates on the basis of trends and available information for all indigenous fuel sources. With world oil price and the exchange rate, oil imports in toe terms (Equation 64) are bridged to fuel imports in US dollar (Equation 65). Also fuel exports in US dollar (Equation 66) are determined by fuel exports in toe terms and corresponding world prices.

Fuel trade balance is crucial to China's economy. Since China became net importer of mineral fuels in 1996, fuel trade balance (Equation 67) has been restriction to its economic growth.

3-3-1-4 Output Linkages and Price Relationships

Linkage for GDP to output originating in industry is given in Equation 72. As anticipated, the elasticity of industrial output with respect to GDP is greater than unity reflecting China's rapid industrialization.

Prices take into account world oil prices and coal prices both in US dollar and the exchange rate of RMB against US dollar. Equation 74 links the Chinese coal products price to the RMB equivalent of the world coal price, and Equation 75 and 76 do so for oil products and gasoline. Electricity price is mainly determined by coal price (Equation 77). And an overall energy price (Equation 73) is computed as a weighted sum of the price of oil, coal and electricity.

3-3-2 Some Estimation Results and In-Sample-Period Simulation

The basic income and price elasticities of the model are listed in Table 3-4. Long-term income elasticities for all sectors except transportation are lower than unity. In comparison with other research works' estimates, our results appear to be smaller. This is because our estimates reflected more recent change in energy consumption pattern until 2001[viii]. The transportation sector is surprisingly higher than unity. With regard to transportation, consumption of petroleum is related to the number of vehicles.

Table 3-5 shows the result of final test for the model. Model performance is expressed in terms of mean absolute percentage errors (MAPE). MAPE appears to be reasonable except mineral fuel trade balance. Thus, roughly speaking, our model is tolerable to the prediction.

3-4 Forecast and Simulation Analysis

A baseline forecast was compiled from 2002 to 2010 (see Table 3-6). To provide exogenous inputs, base macroeconomic projections from the Global Insight (former DRI-WEFA) forecast have been extended as trends through 2010. Chinese economy (real GDP) is expected to grow 7.4% per year through 2008 and then slow to 6.2% until 2010.

Exogenous assumptions for natural gas and coal production reflect information available from the Institute of Energy Economics, Japan. Indigenous coal product is predicted to grow 2%, while natural gas product to increase 1%. Share of electricity generation by fuel type and corresponding heat rate are assumed to remain unchanged at recent level.

On the inflation front, dollar-base prices for oil and coal are expected to increase 2% respectively in the simulation period. GDP deflator and overall retail price index are forecast to grow with the same pace. RMB against US dollar (exchange rate) is assumed to be fixed through 2005 and then to appreciate 2% per year.

3-4-1 Baseline Forecast

The baseline forecast shows continuous increase of total energy consumption at 2.2%. This is slower than the growth of real GDP. As shown in Table 3-4, long-term income elasticity of energy consumption for industry and residential stay at around 0.3. A 7% economic growth needs a 2% increase of energy. Growth of consumption of oil (crude petroleum and petroleum products) continues to be rapid (4.4%), somewhat reflecting rapid motorization. The number of passenger cars will increase at a higher speed (10.9%) than GDP growth. Growth of consumption of coal is nearly zero (0.2%). Demand for electricity continues its very rapid increase (5%), while that for natural gas grows at modest pace of 2.1%.

Industrial total energy consumption will grow 2.5%, while residential total energy consumption will increase modestly by 0.7%. In industry, oil and electricity grow at higher pace (4.6% and 4.9% respectively). In residential sector, natural gas and electricity will increase, while coal and petroleum will decrease. Higher growth of energy consumption by road (9.2%) responds to higher growth of passenger cars (10.9%).

The most important finding is the very large increase of imports of fuel (mainly oil) in value terms from the level of $16 billion in 2001 to over $40 billion in 2010. The fuel exports, which amount to almost $8 billion in 2001, will be almost flat at $9.9 billion in 2010. As a result, deficit on fuel trade balance will expand from $8 billion in 2001 to $32.5 billion in 2010. Fuel trade deficit to nominal GDP will also grow from 0.7% in 2001 to 1.2% in 2010. These calculations suggest that growing energy needs will impose a serious burden on China's economy unless high export growth continues.

In line with growth of total final energy consumption, CO_2 and SO_2 emission will grow at

2-3% pace to 1091.7 million t-c in 2010.

3-4-2 Simulation 1: More efficient power generation

Here, we examine the effect of more efficient power generation. Simulation result is shown in Table 3-7. We assume that the electricity generation heat rate in coal power plant improves so that in 2010 the improvements in efficiency approach to the recent Japanese level (0.43). This means that China's efficiency rises 25% from the base case in 2010. This kind of efficiency enhancement reduces the amount of coal used for electricity generation. Consequently, China can reduce CO_2 and SO_2 emission. Also China can increase coal exports.

In this simulation, final consumption of energy does not change, so that the demand for electricity remains unchanged from the baseline. Because of the more efficient technology for power generation, coal inputs decrease. As a result, coal on primary energy basis decreases 12.6% from the baseline in 2010. In line with decrease in coal input, CO_2 emission is reduced by 9.6% (or 104.4 million t-c) from the baseline in 2010, while SO_2 emission by 11.7% (or 3.5 million t). On the other hand, coal exports increase 34.8% in 2010. Fuel trade balance improves $3,479 million and fuel trade balance to nominal GDP rises by 0.1% point.

This result should be compared with that in the previous chapter. Simulation result of GTAP-E model suggests that reduction of CO_2 emission in China is 3.63% corresponding to the efficiency improvement of 15% in power generation. In our case, the efficiency improvement of 25% reduces CO_2 by 9.6% from the baseline. Our result is almost twice as large as in GTAP-E implication.

3-4-3 Simulation 2: 1 percent increase in the growth rate of GDP

This simulation examines the effects of macroeconomic performance (1% higher economic growth) on energy consumption behavior, exports of coal and imports of oil (see Table 3-8). The higher growth rate of GDP leads to higher consumption of coal and oil as well as electricity. Total final energy consumption is higher by 1.8% from the baseline in 2010 when GDP is higher by 8.8%. Comparing the response of sectoral consumption in 2010, we can find that the effect on industrial consumption (2.6%) is larger than that on residential consumption (0.5%). The increase of consumption in the transportation sector (3.3%) is higher than that of industrial consumption. In this simulation, almost all of increase in consumption of electricity has to be matched by the increase in thermal power generation using oil and coal, so that the increase of fuel input for power generation is substantial. Mineral fuel imports increase 6.5% in 2010, while mineral fuel exports decrease 12.0%.

Because of increase in fuel use for thermal power plant, CO_2 and SO_2 emission increased 3.0% respectively from the baseline in 2010.

3-4-4 Simulation 3: Transformation from coal to natural gas in the power sector

In this simulation (see, Table 3-9), we assume that Chinese government decides to change fuel source for thermal power plant gradually from coal to natural gas. It raises the share of electricity generation by natural gas gradually by 2% points in 2010, decreasing the share of coal electricity generation by the same amount. In such a case, China can reduce the amount of coal used by 3.9% in 2010.

Our model predicts that the rise in the share of natural gas for power generation has little effect on final energy consumption behavior. However, the rise of natural gas production has substantial effect on the composition of thermal power generation. Because consumption of electricity does not change much, and because most of the natural gas goes into power generation, the use of coal for power generation drops significantly. In terms of differences, as expected, there is almost a one-to-one negative relationship in toe between gas production and exports of coal. Fuel trade balance improves by $1,281 million in 2010.

Because of reduction in coal use and increase in natural gas for power plant, CO_2 and SO_2 emission are reduced 1.3% and 3.5% respectively from the baseline.

3-4-5 Simulation 4: 1 percent per year increase in world oil price inflation

Because fuel demand equations have price terms, world oil price inflation decreases consumption of oil in each sector. The increase in oil prices is combined with a 0.5% increase in coal price inflation. In turn electricity prices and overall energy prices also go up.

In Table 3-10, the impact of oil price inflation is shown. Taking a look at total final consumption of energy, it is 0.9% less than baseline in 2010. A 1% per year increase in oil price inflation results in a 1.6% decline in total oil demand and a 1.8% decline in total coal demand. However, the cost of fuel imports is higher by approximately 7.1% in 2010. When the energy price rises, the response of industrial consumption (-1.1%) is larger than that of residential consumption (-0.5%). It is especially interesting to note the effect on electricity consumption is remarkably small.

3-5 Conclusion

In this chapter, as a preliminary analysis of the potentiality of CDM in China, we mainly focus on the effect of the CO_2 emission-reduction by technology transfer in thermal power plant from Japan to China using energy balance model. We can summarize the result of analysis as follows:

1) A 25% efficiency enhancement in thermal power plant can reduce CO_2 emission by 9.6% from the baseline in 2010. This result is almost twice as large as that in GTAP-E simulation. On the other hand, coal exports increase 34.8% in 2010. Fuel trade balance improves $3,479 million and fuel trade balance to nominal GDP rises by 0.1% point.

2) In case of gradual shift from coal to natural gas in thermal power plant, CO_2 and SO_2 emission are reduced 1.3% and 3.5% respectively from the baseline.

Simulation results above suggest that CDM appears to be promising for Japan.

Reference

Adams, F. G., Prazmoowski, P.A., and Y. Ichino (2000), "Economic Growth and Energy Import Requirements: An Energy Balance Model of Thailand" *Journal of Policy Modeling, Elsevier Science Inc.*

Japan Bank for International Cooperation Research Institute for Development and Finance (2000), *Energy Balance Simulations to 2010 for China and Japan*.

vii Efficiency differential is calculated as follows: (2.354-3.157)/3.157=-0.25

viii Keep in mind that total recent final consumption of energy in China did not exceed the level marked in 1998, despite continued GDP growth higher than 7%.

Appendix: China's Energy Balance Model

Final Energy Consumption Block
Industrial Sector
(01) Industrial Consumption of All Kinds of Energy
ID_TO=IDO_TO+CH_TO

(02) Industrial Consumption of All Kinds of Energy excluding Petrochemical
LOG(IDO_TO)=4.75427+.188518*(LOG(GDPIND))-.234900*(LOG(PENERGY/PWS))
+.457635*(LOG(IDO_TO(-1)))+.086286*(D92+D93+D94+D95+D96)-.085100*(D99)
t-value (3.32) (2.72) (-2.83) (2.71) (3.52) (-2.17)
OLS (1981-2001) R^2=.97 SD= .035391 DW= 1.699

(03) Industrial Consumption of Electricity, Oil and Coal
ID_SM=ID_TO-ID_NG-ID_CR-ID_HE

(04) Coal/Oil Consumption Ratio in Industry
LOG(ID_RCP)=2.12005-.175796*(LOG(GDPIND))-.219387*(LOG(PCO/PWS))
+.097563*(LOG(POIL/PWS))+.676003*(LOG(ID_RCP(-1)))
-.146558*(D85)+.151539*(D92+D93+D94+D95+D96)+.122279*(D98)-.075963*(D99+D00)
t-value (6.17) (-6.56) (-1.40) (1.19) (8.87) (-4.01) (6.40) (2.93) (-2.44)
OLS (1981-2001) R^2=.986 SD= .031483 DW= 2.378

(05) Electricity/Oil Consumption Ratio in Industry
LOG(ID_REP)=.935216-.096180*(LOG(GDPIND))-.444929*(LOG(PEL/PWS))
+.455836*(LOG(POIL/PWS))-.118813*(D85)-.049321*(D87)-.086178*(D90+D91)-.107916*(D00)
t-value (4.26) (-4.14) (-6.49) (7.29) (-4.92) (-2.05) (-4.28) (-3.90)
OLS (1981-2001) R^2=.911 SD= .022822 DW= 1.507

(06) Industrial Consumption of Coal
ID_CO=ID_SM*ID_RCP/(1+ID_RCP+ID_REP)

(07) Industrial Consumption of Petroleum
ID_PP=ID_SM/(1+ID_RCP+ID_REP)

(08) Industrial Consumption of Electricity
ID_EL=ID_SM*ID_REP/(1+ID_RCP+ID_REP)

Transportation Sector
(09) Consumption of All Kinds of Energy in Transportation
TR_TO=TR_CO+TR_PP+TR_NG+TR_EL

(10) Consumption of Petroleum in Transportation
LOG(RO_PP)=-.419360+.173269*(LOG(VEHI))-.167014*(LOG(POIL/PWS))
+.933803*(LOG(RO_PP(-1)))+.089777*(D83+D84)-.094429*(D89)-.127732*(D94)
t-value (-.55) (2.32) (-4.15) (7.81) (3.26) (-2.57) (-3.56)
OLS (1980-2001) R^2=.996 SD= .032626 DW= 2.354

(11) Transportation Use of Petroleum by Vehicles
TR_PP=RO_PP+OR_PP

Residential Sector
(12) Residential Consumption of All Kinds of Energy, excluding New Energy
LOG(RE_TO-RE_NE)=2.95252+.106959*(LOG(GDP))-.220346*(LOG(PENERGY/PWS))
+.632673*(LOG(RE_TO(-1)-RE_NE(-1)))+.086549*(D85)+.085467*(D95+D96)
-.132069*(D98)+.063414*(D00+D01)
t-value (3.74) (1.96) (-2.77) (5.44) (3.05) (3.81) (-4.31) (2.12)
OLS (1981-2001) R^2=.958 SD= .026697 DW= 2.372

(13) Residential Consumption of Coal, Oil and Electricity
RE_SM=RE_TO-RE_NE-RE_NG-RE_HE

(14) Coal/Oil Consumption Ratio in Residential Sector

LOG(RE_RCP)=2.34419-.216978*(LOG(GDP))-1.05775*(LOG(PCO(-1)/PWS(-1)))
+.178071*(LOG(POIL(-1)/PWS(-1)))+.763055*(LOG(RE_RCP(-1)))+.179208*(D82)
+.146095*(D85+D86+D87+D88)
t-value (3.09) (-3.59) (-4.77) (1.28) (11.20) (2.60) (4.10)
OLS (1981-2001) R^2=.995 SD= .058108 DW= 2.767

(15) Electricity/Oil Consumption Ratio in Residential Sector
LOG(RE_REP)=-1.01235+.089699*(LOG(GDP))-.220189*(LOG(PEL/PWS))
+.062292*(LOG(POIL/PWS))+.876828*(LOG(RE_REP(-1)))+.120469*(D82)
-.308353*(D85)+.739416*(D90)-.147934*(D95+D96)
t-value (-1.84) (1.71) (-1.55) (.54) (25.32) (2.45) (-6.77) (15.07) (-4.05)
OLS (1981-2001) R^2=.989 SD= .042758 DW= 2.533

(16) Residential Consumption of Coal
RE_CO = RE_SM * RE_RCP/ (1 + RE_RCP + RE_REP)

(17) Residential Consumption of Petroleum
RE_PP = RE_SM / (1 + RE_RCP + RE_REP)

(18) Residential Consumption of Electricity
RE_EL = RE_SM * RE_REP / (1 + RE_RCP + RE_REP)

(19) Consumption of All Kinds of Energy in Commerce and Public Services
CP_TO = CP_CO + CP_PP + CP_NG + CP_EL + CP_HE

Other Sector
(20) Consumption of Electricity in Commerce and Public Services
LOG(CP_EL)=-1.16462+.161090*(LOG(GDP))-.143824*(LOG(PEL/PWS))+.932854*(LOG(CP_EL(-1)))
+.415235*(D90)+.105016*(D94)+.115597*(D97)
t-value (-.89) (.98) (-1.43) (12.95) (9.20) (2.59) (2.82)
OLS (1986-2001) R^2=.998 SD= .038435 DW= 2.259

(21) Consumption of All Kinds of Energy in Other Sector
NO_TO = NO_CO + NO_CR + NO_PP + NO_NG + NO_EL + NO_HE

(22) Total Non-Energy Use
NU_TO = NU_CO + NU_PP

Total Final Consumption
(23) Final Consumption of All Kinds of Energy
FC_TO = ID_TO + TR_TO + CP_TO + RE_TO + NO_TO + NU_TO

(24) Final Consumption of Coal
FC_CO = ID_CO + TR_CO + CP_CO + RE_CO + NO_CO + NU_CO

(25) Final Consumption of Crude Oil
FC_CR = ID_CR + NO_CR

(26) Final Consumption of Petroleum Products
FC_PP = ID_PP + TR_PP + CP_PP + RE_PP + NO_PP + NU_PP

(27) Final Consumption of Natural Gas
FC_NG = ID_NG + TR_NG + CP_NG + RE_NG + NO_NG

(28) Final Consumption of New Energy
FC_NE = RE_NE

(29) Final Consumption of Electricity
FC_EL = ID_EL + TR_EL + CP_EL + RE_EL + NO_EL

(30) Final Consumption of Heat
FC_HE = ID_HE + CP_HE + RE_HE + NO_HE

Conversion Block
Electricity Generation
(31) Generated Electricity

EG_EL = FC_EL - OU_EL - DL_EL - IM_EL - EX_EL

(32) Generated Electricity in GW
EO_TO = REO_TO*EG_EL

(33) Coal Input to Generate Electricity
EG_CO = -(100 - RPP_EG -RNG_EG - RNC_EG - RHY_EG - RNE_EG) * EG_EL / 100 / LOSRCO_EG

(34) Oil Input to Generate Electricity
EG_PP = -RPP_EG * EG_EL / 100 / LOSRPP_EG - EG_CR

(35) Natural Gas Input to Generate Electricity
EG_NG = -RNG_EG * EG_EL / 100 / LOSRNG_EG

(36) Nuclear Input to Generate Electricity
EG_NC = -RNC_EG * EG_EL / 100/ LOSRNC_EG

(37) Hydro Input to Generate Electricity
EG_HY = -RHY_EG * EG_EL / 100

(38) New Energy Input to Generate Electricity
EG_NE = -RNE_EG * EG_EL / 100 / LOSRNE_EG

Heat Generation
(39) Generated Heat
HG_HE = FC_HE - OU_HE - DL_HE

(40) Coal Input to Generate Heat Gas
HG_CO = -RCO_HG * HG_HE / 100 / LOSRCO_HG

(41) Oil Input to Generate Heat Gas
HG_PP = -RPP_HG * HG_HE / 100 / LOSRPP_HG

Other
(42) Coal Transformation
CT_CO=-3680.44-.722054*(IS_CO)+13012.2*(D81+D82+D83+D84)+7494.34*(D93)
-5578.83*(D97)+5750.44*(D98)
t-value (-3.07) (-24.77) (18.43) (5.80) (-4.18) (4.24)
OLS (1981-2001) R^2=.985 SD= 1,237.33 DW= 1.954

(43) Petroleum Products Domestically Refined
PR_PP = - LOSRPP_PP * PR_CR

Own Use and Distribution Loss
(44) Coal Own Use
OU_CO=8812.25-.033560*(FC_CO)+1.00780*(OU_CO(-1))-4706.01*(D89)+8108.66*(D99)
t-value (3.04) (-3.37) (25.66) (-2.30) (3.45)
OLS (1981-2001) R^2=.978 SD= 1,951.57 DW= 1.056
(45) Oil Own Use
OU_PP=-1874.71-.043728*(FC_PP)+.382862*(OU_PP(-1))+1695.45*(D81+D82+D83)
+1840.47*(D84)-2332.63*(D97)
t-value (-4.85) (-4.43) (3.77) (4.31) (3.06) (-3.98)
OLS (1980-2001) R^2=.981 SD= 553.4094 DW= 1.593

(46) Natural Gas Own Use
OU_NG=721.709-.069779*(FC_NG)+1.01952*(OU_NG(-1))+787.638*(D81)+642.712*(D89)
-835.870*(D91)+870.822*(D97)
t-value (2.20) (-3.13) (11.37) (2.59) (2.30) (-2.81) (3.18)
OLS (1980-2001) R^2=.95 SD= 259.0876 DW= 1.806

(47) Natural Gas Distribution Loss
DL_NG=169.349-.024773*(FC_NG)+.605107*(DL_NG(-1))-178.795*(D86)+129.270*(D93)
-207.394*(D96)
t-value (2.32) (-3.13) (4.29) (-3.30) (2.43) (-3.85)
OLS (1986-2001) R^2=.911 SD= 49.2414 DW= 1.712

(48) Electricity Own Use

OU_EL=-280.546-.200001*(FC_EL)+2093.96*(D79+D80+D81)+2511.70*(D82+D83+D84)
t-value (-1.25) (-54.71) (8.60) (10.66)
OLS (1979-2001) R^2=.997 SD= 326.5382 DW= 1.956

(49) Electricity Distribution Loss
DL_EL=-139.618-.089622*(FC_EL)-1165.10*(D85+D86+D87+D88+D89)+556.618*(D94)
t-value (-2.84) (-90.52) (-17.32) (3.98)
OLS (1972-2001) R^2=.997 SD= 135.6209 DW= 1.665

(50) Heat Own Use
OU_HE=2568.04-.241223*(FC_HE)+.650152*(OU_HE(-1))
t-value (1.21) (-1.63) (3.10)
OLS (1991-2001) R^2=.956 SD= 548.6650 DW= 1.994

(51) Heat Distribution Loss
'DL_HE=102.027-.017164*(FC_HE)+.275767*(DL_HE(-1))-134.795*(D93+D94)+141.109*(D98)
t-value (1.75) (-4.04) (1.96) (-4.16) (3.18)
OLS (1989-2001) R^2=.899 SD= 41.2886 DW= 1.985

Primary Energy Block
(52) Total Primary Energy Supply
PE_TO = PE_CO + PE_CR + PE_PP + PE_NG + PE_NC + PE_HY + PE_NE + PE_EL

(53) Total Primary Energy Supply: Coal
PE_CO = FC_CO - DL_CO - OU_CO - CT_CO - GW_CO -HG_CO - EG_CO - SD_CO

(54) Total Primary Energy Supply: Crude Oil
PE_CR = FC_CR - OU_CR - PR_CR - HG_CR - EG_CR - SD_CR

(55) Total Primary Energy Supply: Petroleum Products
PE_PP = FC_PP - DL_PP - OU_PP - PR_PP - GW_PP - HG_PP - EG_PP - SD_PP

(56) Total Primary Energy Supply: Natural Gas
PE_NG = FC_NG - DL_NG - OU_NG - GW_NG - HG_NG - EG_NG - SD_NG

(57) Total Primary Energy Supply: Nuclear
PE_NC = -1 * EG_NC

(58) Total Primary Energy Supply: Hydro
PE_HY = -1 * EG_HY

(59) Total Primary Energy Supply: New Energy
PE_NE = FC_NE - HG_NE - EG_NE - SD_NE

(60) Total Primary Energy Supply: Electricity
PE_EL = FC_EL - DL_EL - OU_EL - EG_EL

(61) Exports of Coal
EX_CO = PE_CO - IM_CO - IP_CO - SC_CO

(62) Imports of Crude Oil
IM_CR = PE_CR - EX_CR - IP_CR - SC_CR

(63) Imports of Petroleum Products
IM_PP = PE_PP - EX_PP - MB_PP - SC_PP

(64) Imports of Oil
IM_OIL = IM_CR + IM_PP

(65) Imports of Mineral Fuel in US dollar
LOG(IM_MFV)=-5.01791+1.02035*(LOG(POILW*IM_OIL))-.946110*(D81+D82+D83)-.641523*(D84)
t-value (-13.78) (35.54) (-7.85) (-3.49)
OLS (1980-2001) R^2=.991 SD= .167998 DW= 1.888

(66) Exports of Mineral Fuel in US dollar
LOG(EX_MFV)=-9.01075+.357167*(LOG(-PCOW*EX_CO))

+.959039*(LOG(-POILW*(EX_CR+EX_PP)))-.198220*(D89+D90+D91+D92)+.298464*(D98+D99)
t-value (-7.17) (13.85) (12.58) (-5.31) (4.59)
OLS (1980-2001) R^2=.915 SD= .065921 DW= 1.914

(67) Balance of Mineral Fuel Trade in US dollar
TB_MFV = EX_MFV - IM_MFV

(68) Balance of Mineral Fuel Trade in US dollar vs. Nominal GDP
RTB_MFV = TB_MFV/100/(PGDP*GDP/100/CH_RATE)*100

Price and Output Linkage Block
(69) Number of Vehicles
VEHI=-21.5436+.006479*(GDP)-32635.2*(1/(POP(-1)*100/VEHI(-1)-3))+17.6381*(D85)
+37.3107*(D93+D94)-44.4160*(D96)-32.1605*(D98)+42.4000*(D01)+VEHI(-1)
t-value (-3.61) (3.86) (-2.75) (2.07) (6.57) (-5.66) (-4.05) (4.26)
OLS (1983-2001) R^2=.979 SD= 7.11386 DW= 1.664

(70) Number of Passenger Cars
VEHIPC=-34.9780+.002146*(GDP)-6225.47*(1/(POP(-1)*100/VEHIPC(-1)-3))+12.7767*(D85)
-11.0725*(D89+D90+D91)-10.6061*(D96)-22.3316*(D98)-19.1846*(D99)+17.8937*(D01)+VEHIPC(-1)
t-value (-4.93) (5.97) (-1.40) (2.83) (-4.01) (-2.40) (-4.74) (-3.81) (2.72)
OLS (1984-2001) R^2=.989 SD= 4.01542 DW= 2.159

(71) Number of Commercial Cars
VEHICC = VEHI - VEHIPC

(72) Industrial GDP
LOG(GDPIND)=-3.92622+1.27661*(LOG(GDP))+.146533*(D78+D79+D80)
t-value (-24.21) (83.22) (4.86)
OLS (1978-2001) R^2=.998 SD= .040350 DW= .565

(73) Price of Energy
LOG(PENERGY)=.213074+.344615*(LOG(PCO))+.536191*(LOG(POIL))+.069509*(LOG(PEL))
-.073308*(D94+D95)-.047067*(D96)
t-value (2.76) (8.94) (13.80) (1.30) (-5.29) (-2.57)
OLS (1979-2001) R^2=1. SD= .016707 DW= 1.903

(74) Price of Coal
LOG(PCO)=-.327591+.131744*(LOG(PCOW*CH_RATE))+.921661*(LOG(PCO(-1)))
+.096484*(D85)-.103160*(D86)+.247467*(D93)+.097259*(D94)-.094777*(D98+D99)
t-value (-2.85) (3.48) (29.55) (2.50) (-2.70) (6.51) (2.48) (-2.90)
OLS (1980-2001) R^2=.997 SD= .036518 DW= 1.808

(75) Price of Oil Products
LOG(POIL)=-.228819+.148021*(LOG(POILW*CH_RATE))+.920732*(LOG(POIL(-1)))
+.405904*(D93+D94)+.150486*(D95)+.278266*(D00)
t-value (-1.38) (2.46) (31.92) (10.13) (2.67) (4.48)
OLS (1980-2001) R^2=.997 SD= .052895 DW= 2.075

(76) Price of Gasoline
LOG(CPI_GA)=.072595+.878460*(LOG(POILW*CH_RATE))+.806433*(D77+D78)-.398731*(D84+D85)
-.591729*(D89)
t-value (.18) (9.87) (5.08) (-3.71) (-4.02)
OLS (1977-1996) R^2=.868 SD= .142580 DW= 1.675

(77) Price of Electricity
LOG(PEL)=-.061487+.306822*(LOG(PCO))+.720776*(LOG(PEL(-1)))+.122142*(D93)+.172424*(D94)
t-value (-1.52) (7.32) (17.37) (4.00) (6.09)
OLS (1980-2001) R^2=.999 SD= .023629 DW= 2.198

Emission Block
(78) CO2 Emission from Coal
CO2_CO = RCO2_CO * (PE_CO - NU_CO)

(79) CO2 Emission from Oil

CO2_OL = RCO2_OL * (PE_CR + PE_PP - CH_CR - CH_PP - NU_PP)

(80) CO2 Emission from Natural Gas
CO2_NG = RCO2_NG * PE_NG

(81) Total CO2 Emission
CO2_TO = CO2_CO + CO2_OL + CO2_NG

(82) SO2 Emission from Coal
SO2_CO = RSO2_CO * (PE_CO - NU_CO)

(83) SO2 Emission from Oil
SO2_OL = RSO2_OL * (PE_CR + PE_PP - CH_CR - CH_PP - NU_PP)

(84) SO2 Emission from Natural Gas
SO2_NG = RSO2_NG * PE_NG

(85) Total SO2 Emission
SO2_TO = SO2_CO + SO2_OL + SO2_NG

	Endogenous Variable	Code	Unit
(01)	CO2_CO	CO2 Emission from Coal	1000t-c
(02)	CO2_NG	CO2 Emission from Natural Gas	1000t-c
(03)	CO2_OL	CO2 Emission from Oil	1000t-c
(04)	CO2_TO	Total CO2 Emission	1000t-c
(05)	CP_EL	Consumption of Electricity in Commerce and Public Services	1000toe
(06)	CP_TO	Consumption of All Kinds of Energy in Commerce and Public Services	1000toe
(07)	CPI_GA	Price of Gasoline	1000toe
(08)	CT_CO	Coal Transformation	1000toe
(09)	DL_EL	Electricity Distribution Loss	1000toe
(10)	DL_HE	Heat Distribution Loss	1000toe
(11)	DL_NG	Natural Gas Distribution Loss	1000toe
(12)	EG_CO	Coal Input to Generate Electricity	1000toe
(13)	EG_EL	Generated Electricity	1000toe
(14)	EG_HY	Hydro Input to Generate Electricity	1000toe
(15)	EG_NC	Nuclear Input to Generate Electricity	1000toe
(16)	EG_NE	New Energy Input to Generate Electricity	1000toe
(17)	EG_NG	Natural Gas Input to Generate Electricity	1000toe
(18)	EG_PP	Oil Input to Generate Electricity	1000toe
(19)	EO_TO	Generated Electricity in GW	1000toe
(20)	EX_CO	Exports of Coal	1000toe
(21)	EX_MFV	Exports of Mineral Fuel in US dollar	M$
(22)	FC_CO	Final Consumption of Coal	1000toe
(23)	FC_CR	Final Consumption of Crude Oil	1000toe
(24)	FC_EL	Final Consumption of Electricity	1000toe
(25)	FC_HE	Final Consumption of Heat	1000toe
(26)	FC_NE	Final Consumption of New Energy	1000toe
(27)	FC_NG	Final Consumption of Natural Gas	1000toe
(28)	FC_PP	Final Consumption of Petroleum Products	1000toe
(29)	FC_TO	Final Consumption of All Kinds of Energy	1000toe
(30)	GDPIND	Industrial GDP	100MYuan
(31)	HG_CO	Coal Input to Generate Heat Gas	1000toe
(32)	HG_HE	Generated Heat	1000toe
(33)	HG_PP	Oil Input to Generate Heat Gas	1000toe
(34)	ID_CO	Industrial Consumption of Coal	1000toe
(35)	ID_EL	Industrial Consumption of Electricity	1000toe
(36)	ID_PP	Industrial Consumption of Petroleum	1000toe
(37)	ID_RCP	Coal/Oil Consumption Ratio in Industry	
(38)	ID_REP	Electricity/Oil Consumption Ratio in Industry	
(39)	ID_SM	Industrial Consumption of Electricity, Oil and Coal	1000toe
(40)	ID_TO	Industrial Consumption of All Kinds of Energy	1000toe
(41)	IDO_TO	Industrial Consumption of All Kinds of Energy excluding Petrochemical	1000toe
(42)	IM_CR	Imports of Crude Oil	1000toe
(43)	IM_OIL	Imports of Oil	1000toe
(44)	IM_PP	Imports of Petroleum Products	1000toe
(45)	M_MFV	Imports of Mineral Fuel in US dollar	M$
(46)	NO_TO	Consumption of All Kinds of Energy in Other Sector	1000toe
(47)	NU_TO	Total Non-Energy Use	1000toe
(48)	OU_CO	Coal Own Use	1000toe
(49)	OU_EL	Electricity Own Use	1000toe
(50)	OU_HE	Heat Own Use	1000toe
(51)	OU_NG	Natural Gas Own Use	1000toe
(52)	OU_PP	Oil Own Use	1000toe
(53)	PCO	Price of Coal	1990=100
(54)	PE_CO	Total Primary Energy Supply: Coal	1000toe
(55)	PE_CR	Total Primary Energy Supply: Crude Oil	1000toe
(56)	PE_EL	Total Primary Energy Supply: Electricity	1000toe
(57)	PE_HY	Total Primary Energy Supply: Hydro	1000toe
(58)	PE_NC	Total Primary Energy Supply: Nuclear	1000toe
(59)	PE_NE	Total Primary Energy Supply: New Energy	1000toe
(60)	PE_NG	Total Primary Energy Supply: Natural Gas	1000toe
(61)	PE_PP	Total Primary Energy Supply: Petroleum Products	1000toe
(62)	PE_TO	Total Primary Energy Supply	1000toe
(63)	PEL	Price of Electricity	1990=100
(64)	PENERGY	Price of Energy	1990=100
(65)	POIL	Price of Oil Products	1990=100
(66)	PR_PP	Petroleum Products Domestically Refined	1000toe
(67)	RE_CO	Residential Consumption of Coal	1000toe
(68)	RE_EL	Residential Consumption of Electricity	1000toe
(69)	RE_PP	Residential Consumption of Petroleum	1000toe
(70)	RE_RCP	Coal/Oil Consumption Ratio in Residential Sector	
(71)	RE_REP	Electricity/Oil Consumption Ratio in Residential Sector	
(72)	RE_SM	Residential Consumption of Coal, Oil and Electricity	1000toe
(73)	RE_TO	Residential Consumption of All Kinds of Energy, excluding New Energy	1000toe
(74)	RO_PP	Consumption of Petroleum in Transportation	1000toe
(75)	RTB_MFV	Balance of Mineral Fuel Trade in US dollar vs.. Nominal GDP	M$
(76)	SO2_CO	SO2 Emission from Coal	1000t
(77)	SO2_NG	SO2 Emission from Natural Gas	1000t
(78)	SO2_OL	SO2 Emission from Oil	1000t
(79)	SO2_TO	Total SO2 Emission	1000t
(80)	TB_MFV	Balance of Mineral Fuel Trade in US dollar	M$
(81)	TR_PP	Transportation Use of Petroleum by Vehicles	1000toe
(82)	TR_TO	Consumption of All Kinds of Energy in Transportation	1000toe
(83)	VEHI	Number of Vehicles	10000
(84)	VEHICC	Number of Commercial Cars	10000
(85)	VEHIPC	Number of Passenger Cars	10000

	Exogenous Variable	Code	Unit
(01)	CH_NG	Chemical and Petrochemical: Natural Gas	1000toe
(02)	CH_RATE	Exchange Rate	Yuan/$
(03)	CH_TO	Chemical and Petrochemical: Total Energy Consumption	1000toe
(04)	CP_CO	Commercial and Public Services: Coal	1000toe
(05)	CP_HE	Commercial and Public Services: Heat	1000toe
(06)	CP_NG	Commercial and Public Services: Natural Gas	1000toe
(07)	CP_PP	Commercial and Public Services: Petroleum products	1000toe
(08)	DXX	Dummy Variable for the Year 19XX	
(09)	DL_CO	Distribution Loss: Coal	1000toe
(10)	DL_HE	Distribution Loss: Heat	1000toe
(11)	DL_PP	Distribution Loss: Petroleum products	1000toe
(12)	EG_CR	Electricity Generation: Crude Oil	1000toe
(13)	EX_CR	Exports: Crude Oil	1000toe
(14)	EX_EL	Exports: Electricity	1000toe
(15)	EX_PP	Exports: Petroleum Products	1000toe
(16)	GDP	GDP at constant price	100MYuan
(17)	GW_CO	Gas Works: Coal	1000toe
(18)	GW_NG	Gas Works: Natural Gas	1000toe
(19)	GW_PP	Gas Works: Petroleum products	1000toe
(20)	HG_CR	Heat: Crude Oil	1000toe
(21)	HG_NE	Heat: New Energy	1000toe
(22)	HG_NG	Heat: Natural Gas	1000toe
(23)	ID_CR	Industrial Energy Consumption: Crude Oil	1000toe
(24)	ID_HE	Industrial Energy Consumption: Heat	1000toe
(25)	ID_NG	Industrial Energy Consumption: Natural Gas	1000toe
(26)	IM_CO	Imports: Coal	1000toe
(27)	IM_EL	Imports: Electricity	1000toe
(28)	IP_CO	Indigenous Production: Coal	1000toe
(29)	IP_CR	Indigenous Production: Crude Oil	1000toe
(30)	IS_CO	Iron and Steel: Coal	1000toe
(31)	LOSRCO_EG	Heat rate: Electricity Generation: Coal	
(32)	LOSRCO_HG	Heat rate: Heat Generation: Coal	
(33)	LOSRNC_EG	Heat rate: Electricity Generation: Nuclear	
(34)	LOSRNE_EG	Heat rate: Electricity Generation: New Energy	
(35)	LOSRNG_EG	Heat rate: Electricity Generation: Natural Gas	
(36)	LOSRPP_EG	Heat rate: Electricity Generation: Petroleum Products	
(37)	LOSRPP_HG	Heat rate: Heat Generation: Petroleum Products	
(38)	LOSRPP_PP	Refinery Ratio	
(39)	MB_PP	Marine Bankers: Petroleum Products	1000toe
(40)	NO_CO	Non-specified Other : Coal	1000toe
(41)	NO_CR	Non-specified Other : Crude Oil	1000toe
(42)	NO_EL	Non-specified Other : Electricity	1000toe
(43)	NO_HE	Non-specified Other : Heat	1000toe
(44)	NO_NG	Non-specified Other : Natural Gas	1000toe
(45)	NO_PP	Non-specified Other : Petroleum	1000toe
(46)	NU_CO	Non-Energy Use: Coal	1000toe
(47)	NU_PP	Non-Energy Use: Petroleum	1000toe
(48)	OR_PP	Transport Sector Other than Road: Petroleum	1000toe
(49)	OU_CR	Own Use: Crude Oil	1000toe
(50)	OU_HE	Own Use: Heat	1000toe
(51)	OU_PP	Own Use: Petroleum Products	1000toe
(52)	PCOW	Coal Price:AUSTRALIA	US$/MT
(53)	PGDP	GDP Deflator	1990=100
(54)	POILW	Petroleum Price: Average Crude Price	US$/BBL
(55)	POP	Population	million
(56)	PR_CR	Petroleum Refineries: Crude Oil	1000toe
(57)	PWS	General Retail Price Indexd	1990=100
(58)	RCO2_CO	CO2 factor for Coal	
(59)	RCO2_NG	CO2 factor for Natural Gas	
(60)	RCO2_OL	CO2 factor for Oil	
(61)	RCO_HG	Share of coal heat generation	%
(62)	REO_TO	GWh/ktoe factor	
(63)	RE_HE	Residential Consumption of Heat	1000toe
(64)	RE_NE	Residential Consumption of New Energy	1000toe
(65)	RE_NG	Residential Consumption of Natural Gas	1000toe
(66)	RHY_EG	Share of Hydro: Electricity Generation	%
(67)	RNC_EG	Share of Nuclear: Electricity Generation	%
(68)	RNE_EG	Share of New Energy: Electricity Generation	%
(69)	RNG_EG	Share of Natural Gas: Electricity Generation	%
(70)	RPP_EG	Share of Petroleum: Electricity Generation	%
(71)	RPP_HG	Share of Petroleum: Heat Generation	%
(72)	RSO2_CO	CO2 factor for Coal	
(73)	RSO2_NG	CO2 factor for Natural Gas	
(74)	RSO2_OL	CO2 factor for Oil	
(75)	SC_CO	Stock Change: Coal	1000toe
(76)	SC_CR	Stock Change: Crude Oil	1000toe
(77)	SC_PP	Stock Change: Petroleum Products	1000toe
(78)	SD_CO	Statistical Discrepancy: Coal	1000toe
(79)	SD_CR	Statistical Discrepancy: Crude Oil	1000toe
(80)	SD_NE	Statistical Discrepancy: New Energy	1000toe
(81)	SD_NG	Statistical Discrepancy: Natural Gas	1000toe
(82)	SD_PP	Statistical Discrepancy: Petroleum	1000toe
(83)	TR_CO	Transportation Use of Coal	1000toe
(84)	TR_EL	Transportation Use of Electricity	1000toe
(85)	TR_NG	Transportation Use of Natural Gas	1000toe

Table 3-1 China's Energy Balance Table in 2001

INDUSTRY	Coal and Coal Products	Crude, NGL and Feedstock	Petroleum Products	Natural Gas	Nuclear	Hydro	Geothermal, Solar, Wind, Other, Renewables & Heat Prod	Electricity	Heat	Total	*Share (%)*
Production	698,779	164,131	0	31,365	4,553	23,859	215,930	0	0	1,138,617	*99.9*
Imports	1,369	60,260	28,315	0	0	0	0	155	0	90,098	*7.9*
Exports	-67,316	-7,550	-11,495	0	0	0	0	-876	0	-87,238	*-7.7*
International Marine Bunkers	0	0	-3,969	0	0	0	0	0	0	-3,969	*-0.3*
Stock Changes	4,526	-1,297	-1,369	0	0	0	0	0	0	1,860	0.2
Total Primary Energy Supply	637,358	215,544	11,481	31,365	4,553	23,859	215,930	-722	0	1,139,369	100.0
Statistical Differences	13,753	-3,824	-1,989	-3,988	0	0	0	0	0	3,952	*-1.1*
Electricity Plants (Public & Auto producer)	-290,951	-816	-11,103	-1,344	-4,553	-23,859	-838	126,563	0	-206,903	*58.5*
Heat Plants (Public & Auto producer)	-35,986	-123	-4,096	-1,697	0	0	-490	0	36,585	-5,807	*1.6*
Gas Works	-4,670	0	-228	3,827	0	0	0	0	0	-1,072	*0.3*
Petroleum Refineries	0	-204,068	201,793	0	0	0	0	0	0	-2,275	*0.6*
Coal Transformation	-45,850	0	0	0	0	0	0	0	0	-45,850	*13.0*
Own Use	-30,016	-4,422	-15,046	-7,822	0	0	0	-19,240	-9,335	-85,882	*24.3*
Distribution Losses	-126	0	-17	-643	0	0	0	-8,881	-430	-10,097	2.9
Total Final Consumption	243,511	2,291	180,795	19,697	0	0	214,602	97,720	26,820	785,435	68.9
Total Industry Sector	165,870	2,092	51,984	12,449	0	0	0	61,562	20,110	314,067	*40.0*
Iron and Steel	55,192	0	3,516	173	0	0	0	10,011	3,193	72,084	*9.2*
Chemical and Petrochemical	22,503	1,017	29,124	10,001	0	0	0	12,730	8,002	83,377	*10.6*
Other Industries	88,175	1,075	19,343	2,275	0	0	0	38,821	8,915	158,605	*20.2*
Total Transport Sector	5,280	0	69,161	228	0	0	0	1,307	0	75,977	*9.7*
Road	0	0	48,133	51	0	0	0	0	0	48,183	*6.1*
Transport Sector Other than Road	5,280	0	21,028	178	0	0	0	1,307	0	27,794	*3.5*
Total Other Sectors	63,543	199	45,786	7,019	0	0	214,602	34,850	6,710	372,709	*47.5*
Commercial and Public Services	5,400	0	16,014	588	0	0	0	6,439	450	28,892	*3.7*
Residential	43,981	0	13,652	6,431	0	0	214,602	15,817	5,581	300,064	*38.2*
Non-specified Other	14,162	199	16,119	0	0	0	0	12,594	679	43,753	*5.6*
Non-Energy Use	8,818	0	13,865	0	0	0	0	0	0	22,683	2.9

Note: Unit in ktoe. Figures in italic are percentage share of the sub-total.
Source: Energy Balances of Non-OECD Countries, 2003 Edition, IEA

Table 3-2 Japan's Energy Balance Table in 2001

INDUSTRY	Coal and Coal Products	Crude, NGL and Feedstock	Petroleum Products	Natural Gas	Nuclear	Hydro	Geothermal, Solar, Wind, Other, Renewables & Heat Prod	Electricity	Heat	Total	*Share (%)*
Production	1,581	702	0	2,169	83,357	7,238	9,045	0	0	104,092	*20.0*
Imports	99,510	212,116	49,366	62,029	0	0	0	0	0	423,020	*81.2*
Exports	-1,156	0	-4,772	0	0	0	0	0	0	-5,928	*-1.1*
International Marine Bunkers	0	0	-4,067	0	0	0	0	0	0	-4,067	*-0.8*
Stock Changes	251	595	2,167	600	0	0	0	0	0	3,612	0.7
Total Primary Energy Supply	100,186	213,412	42,694	64,797	83,357	7,238	9,045	0	0	520,729	100.0
Statistical Differences	-3,442	-3,169	-2,510	2,370	0	0	0	0	0	-6,751	*3.8*
Electricity Plants (Public & Auto producer)	-51,495	-4,917	-17,444	-46,395	-83,357	-7,238	-5,964	88,854	0	-127,957	*71.8*
Heat Plants (Public & Auto producer)	-14	0	-33	-269	0	0	-91	0	396	-11	*0.0*
Gas Works	-167	0	-276	167	0	0	0	0	0	-276	*0.2*
Petroleum Refineries	0	-208,852	208,142	0	0	0	0	0	0	-710	*0.4*
Coal Transformation	-21,952	0	0	0	0	0	0	0	0	-21,952	*12.3*
Own Use	-2,351	0	-8,197	-270	0	0	-1	-6,510	-4	-17,332	*9.7*
Distribution Losses	0	0	0	0	0	0	0	-3,184	-62	-3,246	1.8
Total Final Consumption	20,765	1,011	217,482	20,399	0	0	2,990	79,064	416	342,126	65.7
Total Industry Sector	20,765	1,011	58,411	8,396	0	0	2,195	32,126	0	122,903	*35.9*
Iron and Steel	9,597	0	2,068	1,986	0	0	0	5,581	0	19,232	*5.6*
Chemical and Petrochemical	716	1,011	36,247	1,663	0	0	40	4,121	0	43,798	*12.8*
Other Industries	10,452	0	20,096	4,747	0	0	2,155	22,424	0	59,873	*17.5*
Total Transport Sector	0	0	94,478	0	0	0	0	1,597	0	96,075	*28.1*
Road	0	0	79,272	0	0	0	0	0	0	79,272	*23.2*
Transport Sector Other than Road	0	0	15,206	0	0	0	0	1,597	0	16,803	*4.9*
Total Other Sectors	0	0	55,893	12,004	0	0	795	45,340	416	114,448	*33.5*
Commercial and Public Services	0	0	29,896	4,492	0	0	21	23,083	385	57,878	*16.9*
Residential	0	0	16,172	7,512	0	0	774	22,118	30	46,606	*13.6*
Non-specified Other	0	0	9,825	0	0	0	0	139	0	9,965	*2.9*
Non-Energy Use	0	0	8,700	0	0	0	0	0	0	8,700	2.5

Note: Unit in ktoe. Figures in italic are percentage share of the sub-total.
Source: Energy Balances of OECD Countries, 2003 Edition, IEA

Table 3-3-a CO_2 Emission by Energy Source (1000t-c)

CO2 Emission	1971	1980	1990	1995	2000	2001
Coal	207347	333013	553082	703289	699567	678823
%	86.2	81.6	84.9	83.8	78.5	77.4
Oil	31263	67550	87982	123861	173850	178416
%	13.0	16.5	13.5	14.8	19.5	20.3
Natural Gas	2008	7666	10142	11897	18031	20105
%	0.8	1.9	1.6	1.4	2.0	2.3
Total	240618	408229	651206	839047	891447	877343

Note: CO2 emission is calculated from IEA energy data.
Emission factors are 1.08 for Coal, 0.837 for Oil and 0.641 for Natural Gas respectively.
See Li ZhiDong(1999), *Environmental Protection System in China*, Toyo-Keizai-Shimposha.

Table 3-3-b SO_2 Emission by Fuels Sources (1000t)

SO2 Emission	1971	1980	1990	1995	2000	2001
Coal	7065	11347	18846	23964	23837	23130
%	95.7	94.3	95.5	95.1	93.2	92.8
Oil	312	673	877	1234	1732	1778
%	4.2	5.6	4.4	4.9	6.8	7.1
Natural Gas	3	8	9	11	17	20
%	0.0	0.1	0.0	0.0	0.1	0.1
Total	7380	12028	19731	25209	25587	24928

Note: SO2 emission is calculated from IEA energy data.
Emission factors are 2t/toe*1.15%*80%*2 for Coal, 0.3%*2 for Oil and toe*0.046%*2 for Natural Gas.
See Li ZhiDong(1999), *Environmental Protection System in China*, Toyo-Keizai-Shimposha.

Table 3-4 Elasticity of the Model

Industry

All Energy	Income	Relative Price	Lag
Short	0.188611	-0.234960	0.457389
Long	0.347599	-0.433017	

Residential

All Energy	Income	Relative Price	Lag
Short	0.122816	-0.195725	0.590415
Long	0.299855	-0.477862	

Transportation

Petroleum	Vehicle	Relative Price	Lag
Short	0.17327	-0.16701	0.93380
Long	2.61748	-2.52298	

Source: authors' estimation

Table 3-5 Sample Period Errors

Variable	MAPE
Total Final Consumption	0.8
Final Consumption of Coal	1.3
Final Consumption of Petroleum	1.3
Industrial Consumption of All Kind of Energy	1.6
Residential Consumption of All Kind of Energy	0.2
Consumption of Petroleum in Transportation	4.9
Number of Vehicle	0.4
Generated Electricity	1.3
Imports of Mineral Fuels	14.2
Exports of Mineral Fuels	11.2
Mineral Fuel Trade Balance	38.9
Industrial GDP	1.5
Energy Price	1.2
Total CO2 Emission	1.0

Note: MAPE means mean absolute percentage Errors.

Table 3-6 Baseline Forecast EBM Version 03.1

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	'10/'01(%)
(1) Final Energy Consumption											
Coal	238,445	235,313	234,632	235,142	236,173	237,281	238,561	240,000	241,575	243,257	0.2
Oil	184,105	189,762	196,549	204,308	213,007	222,431	232,762	244,162	256,801	270,870	4.4
Natural Gas	19,697	20,046	20,414	20,803	21,214	21,648	22,107	22,592	23,105	23,648	2.1
Electricity	98,108	101,588	106,090	111,355	117,268	123,475	130,016	136,975	144,422	152,424	5.0
New Energy	214,602	216,748	218,915	221,104	223,315	225,549	227,804	230,082	232,383	234,707	1.0
Heat	26,820	26,948	27,077	27,207	27,338	27,469	27,600	27,733	27,866	27,999	0.5
Total	781,777	790,405	803,677	819,919	838,315	857,852	878,850	901,544	926,152	952,904	2.2
Share (%)											
Coal	30.5	29.8	29.2	28.7	28.2	27.7	27.1	26.6	26.1	25.5	
Oil	23.5	24.0	24.5	24.9	25.4	25.9	26.5	27.1	27.7	28.4	
Natural Gas	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
Electricity	12.5	12.9	13.2	13.6	14.0	14.4	14.8	15.2	15.6	16.0	
Electricity excluding renewables*	17.3	17.7	18.1	18.6	19.1	19.5	20.0	20.4	20.8	21.2	
New Energy	27.5	27.4	27.2	27.0	26.6	26.3	25.9	25.5	25.1	24.6	
Heat	3.4	3.4	3.4	3.3	3.3	3.2	3.1	3.1	3.0	2.9	
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
(2) Industry											
Coal	160,703	161,243	162,818	164,792	166,857	168,770	170,702	172,693	174,753	176,876	1.1
Oil	52,922	54,939	57,398	60,150	63,131	66,099	69,154	72,343	75,697	79,238	4.6
Natural Gas	12,449	12,449	12,449	12,449	12,449	12,449	12,449	12,449	12,449	12,449	0.0
Electricity	62,422	65,039	68,273	71,911	75,846	79,786	83,755	87,811	91,990	96,316	4.9
Heat	20,110	20,210	20,312	20,413	20,515	20,618	20,721	20,824	20,929	21,033	0.5
Total	308,607	313,881	321,250	329,715	338,799	347,722	356,780	366,120	375,817	385,912	2.5
Share (%)											
Coal	52.1	51.4	50.7	50.0	49.2	48.5	47.8	47.2	46.5	45.8	
Oil	17.1	17.5	17.9	18.2	18.6	19.0	19.4	19.8	20.1	20.5	
Natural Gas	4.0	4.0	3.9	3.8	3.7	3.6	3.5	3.4	3.3	3.2	
Electricity	20.2	20.7	21.3	21.8	22.4	22.9	23.5	24.0	24.5	25.0	
Heat	6.5	6.4	6.3	6.2	6.1	5.9	5.8	5.7	5.6	5.5	
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
(3) Residential											
Coal	44,082	40,673	38,668	37,442	36,635	36,045	35,597	35,240	34,939	34,673	-2.6
Petroleum	13,939	13,665	13,543	13,508	13,526	13,555	13,584	13,610	13,629	13,639	-0.2
Natural Gas	6,431	6,753	7,090	7,445	7,817	8,208	8,618	9,049	9,502	9,977	5.0
Electricity	15,275	15,297	15,601	16,121	16,823	17,638	18,558	19,574	20,684	21,888	4.1
Heat	5,581	5,609	5,637	5,665	5,693	5,722	5,750	5,779	5,808	5,837	0.5
Total	299,909	298,745	299,454	301,285	303,809	306,716	309,911	313,334	316,944	320,719	0.7
(4) Transport											
Road	50,018	53,932	58,382	63,424	69,124	75,552	82,799	90,984	100,250	110,768	9.2
Total	77,862	81,644	85,987	90,947	96,591	102,989	110,234	118,445	127,767	138,371	6.6
(5) Primary Energy											
Coal	627,838	644,316	652,465	664,050	678,074	693,050	709,193	726,749	745,905	766,833	2.2
Oil	228,113	228,394	235,742	244,155	253,587	263,780	274,920	287,180	300,739	315,794	3.7
Natural Gas	31,293	28,613	29,979	31,410	32,912	34,489	36,146	37,890	39,727	41,664	3.2
Nuclear	4,580	4,741	4,950	5,194	5,469	5,756	6,060	6,383	6,728	7,100	5.0
Hydro	23,997	24,843	25,937	27,217	28,655	30,164	31,754	33,446	35,256	37,202	5.0
Heat	215,935	218,110	220,316	222,550	224,812	227,098	229,410	231,747	234,111	236,504	1.0
Total	1,131,032	1,148,296	1,168,668	1,193,855	1,222,787	1,253,615	1,286,761	1,322,673	1,361,745	1,404,374	2.4
Share (%)											
Coal	55.5	56.1	55.8	55.6	55.5	55.3	55.1	54.9	54.8	54.6	
Oil	20.2	19.9	20.2	20.5	20.7	21.0	21.4	21.7	22.1	22.5	
Natural Gas	2.8	2.5	2.6	2.6	2.7	2.8	2.8	2.9	2.9	3.0	
Nuclear	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	
Hydro	2.1	2.2	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.6	
Heat	19.1	19.0	18.9	18.6	18.4	18.1	17.8	17.5	17.2	16.8	
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
(6) Trade: M$											
Imports of Mineral Fuel	15,969	15,828	17,910	20,321	23,071	26,113	29,512	33,329	37,634	42,507	11.5
Exports of Mineral Fuel	7,998	8,113	8,566	8,907	9,174	9,423	9,643	9,821	9,942	9,990	2.5
Trade Balance	-7,971	-7,715	-9,343	-11,414	-13,897	-16,690	-19,869	-23,508	-27,691	-32,517	16.9
Trade Balance vs. GDP	-0.7	-0.6	-0.7	-0.7	-0.8	-0.9	-1.0	-1.0	-1.1	-1.2	
(7) Vehicle: 1000 Unit											
Vehicles	1,808	1,957	2,115	2,283	2,463	2,645	2,832	3,025	3,228	3,440	7.4
Passenger Cars	993	1,123	1,262	1,411	1,572	1,741	1,919	2,107	2,306	2,516	10.9
(8) Emission											
CO_2 1000t-c	861,515	877,829	893,656	914,126	938,131	963,845	991,667	1,022,007	1,055,222	1,091,667	2.7
SO_2 1000t	24,586	25,193	25,555	26,053	26,649	27,287	27,975	28,725	29,545	30,442	2.4

Table 3-7 Impact of Efficiency Increase in Coal Power Generation
EBM Version 03.1: (Simulation 1 - Baseline)/Baseline (%)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	'10/'01(%)
(5) Primary Energy										
Coal	-1.4	-2.8	-4.1	-5.5	-7.0	-8.4	-9.8	-11.2		-1.5
Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	-0.8	-1.5	-2.3	-3.1	-3.8	-4.6	-5.4	-6.1	-6.9	-0.8
Share (%)*										
Coal*	-0.3	-0.7	-1.0	-1.4	-1.8	-2.2	-2.6	-3.0	-3.4	
Oil*	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.4	1.7	
Natural Gas*	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
Nuclear*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Hydro*	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	
Heat*	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.1	1.2	
Total*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(6) Trade										
Imports of Mineral Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Exports of Mineral Fuel	4.1	7.5	10.7	14.1	17.5	21.1	25.1	29.5	34.8	3.5
Trade Balance (M$)*	334	642	957	1,296	1,654	2,039	2,462	2,936	3,479	-1.5
Trade Balance vs. GDP (%)*	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
(7) Vehicle										
Vehicles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Passenger Cars	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8) Emission										
CO2*(1000t-c)	-9,577	-19,429	-29,736	-40,619	-52,047	-64,070	-76,770	-90,241	-104,582	-1.1
CO2	-1.1	-2.2	-3.3	-4.3	-5.4	-6.5	-7.5	-8.6	-9.6	
SO2*(1000t)	-326	-662	-1,013	-1,384	-1,773	-2,183	-2,616	-3,075	-3,564	-1.4
SO2	-1.3	-2.6	-3.9	-5.2	-6.5	-7.8	-9.1	-10.4	-11.7	

Note: * denotes difference from the baseline, otherwise % difference.

Table 3-8 Impact of 1% GDP Growth Rate Increase

EBM Version 03.1: (Simulation 2 - Baseline)/Baseline

	2002	2003	2004	2005	2006	2007	2008	2009	2010	'10/'01(%)
(1) Final Energy Consumption										
Coal	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.0
Oil	0.1	0.3	0.6	0.9	1.3	1.8	2.3	2.9	3.5	0.4
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.2	0.5	1.0	1.5	2.1	2.7	3.3	4.0	4.7	0.5
New Energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	0.2	0.4	0.6	0.8	1.0	1.2	1.5	1.8	0.2
Share (%)*										
Coal*	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	
Oil*	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	
Natural Gas*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Electricity*	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	
New Energy*	0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.4	
Electricity excluding renewable products	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	
Heat*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	
Total*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(2) Industry										
Coal	0.1	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.8	0.1
Oil	0.3	0.8	1.4	2.0	2.7	3.4	4.1	4.8	5.5	0.6
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.2	0.6	1.1	1.6	2.2	2.8	3.4	4.0	4.6	0.5
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.2	0.4	0.7	1.0	1.3	1.6	2.0	2.3	2.6	0.3
Share (%)*										
Coal*	0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.7	-0.8	
Oil*	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	
Natural Gas*	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	
Electricity*	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	
Heat*	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	
Total*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(3) Residential										
Coal	0.0	0.0	0.0	-0.1	-0.3	-0.4	-0.7	-1.0	-1.3	-0.1
Petroleum	0.2	0.6	1.0	1.5	2.1	2.7	3.2	3.7	4.3	0.5
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.3	0.8	1.5	2.3	3.2	4.2	5.2	6.3	7.3	0.8
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.1
(4) Transport										
Road	0.1	0.2	0.4	0.8	1.2	1.8	2.4	3.2	4.1	0.5
Total	0.0	0.1	0.3	0.5	0.9	1.3	1.9	2.5	3.3	0.4
(5) Primary Energy										
Coal	0.1	0.3	0.6	0.9	1.2	1.6	2.0	2.4	2.9	0.3
Oil	0.1	0.3	0.6	0.9	1.2	1.7	2.1	2.7	3.3	0.4
Natural Gas	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.0
Nuclear	0.2	0.5	1.0	1.5	2.1	2.7	3.3	4.0	4.6	0.5
Hydro	0.2	0.5	1.0	1.5	2.1	2.7	3.3	4.0	4.6	0.5
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	0.3	0.5	0.7	1.0	1.3	1.7	2.1	2.5	0.3
Share (%)*										
Coal*	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	
Oil*	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	
Natural Gas*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	
Nuclear*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Hydro*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	
Heat*	0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	
Total*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(6) Trade: M$										
Imports of Mineral Fuel	0.4	0.9	1.6	2.3	3.1	3.9	4.8	5.6	6.5	0.8
Exports of Mineral Fuel	-0.4	-1.0	-1.7	-2.7	-3.8	-5.1	-6.8	-9.0	-12.0	-1.4
Trade Balance*	-90	-251	-480	-783	-1,168	-1,650	-2,254	-3,011	-3,972	1.5
Trade Balance vs. GDP (%)*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(7) Vehicle										
Vehicles	0.3	0.8	1.5	2.2	3.0	3.9	4.7	5.6	6.5	0.8
Passenger Cars	0.2	0.5	0.9	1.4	2.0	2.6	3.3	4.0	4.7	0.6
(8) Emission										
CO2* (1000t-c)	1,095	2,981	5,483	8,538	12,129	16,279	21,040	26,489	32,734	0.3
CO2	0.1	0.3	0.6	0.9	1.3	1.6	2.1	2.5	3.0	
SO2* (1000t)	32	87	159	245	346	461	591	738	905	0.3
SO2	0.1	0.3	0.6	0.9	1.3	1.6	2.1	2.5	3.0	

Note: * denotes difference from the baseline, otherwise % difference.

Table 3-9 Impact of transformation from Coal to Natural Gas

EBM Version 03.1: (Simulation 3 - Baseline)/Baseline

	2002	2003	2004	2005	2006	2007	2008	2009	2010	'10/'01(%)
(5) Primary Energy										
Coal	-0.3	-0.6	-1.0	-1.4	-1.7	-2.1	-2.6	-3.0	-3.9	-0.4
Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	6.6	13.1	19.7	26.4	33.1	39.9	46.8	53.8	67.6	6.1
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0
Share (%)*										
Coal*	-0.2	-0.3	-0.5	-0.7	-0.9	-1.2	-1.4	-1.6	-2.1	
Oil*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Natural Gas*	0.2	0.3	0.5	0.7	0.9	1.1	1.3	1.6	2.0	
Nuclear*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Hydro*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Heat*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(6) Trade										
Imports of Mineral Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Exports of Mineral Fuel	0.9	1.8	2.7	3.8	4.9	6.2	7.7	9.4	12.8	1.4
Trade Balance (M$)*	77	156	244	346	461	595	751	938	1,281	-0.5
Trade Balance vs. GDP (%)*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(7) Vehicle										
Vehicles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Passenger Cars	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8) Emission										
CO2* (1000t-c)	-940	-1,962	-3,088	-4,335	-5,704	-7,206	-8,855	-10,668	-14,071	-0.1
CO2	-0.1	-0.2	-0.3	-0.5	-0.6	-0.7	-0.9	-1.0	-1.3	
SO2* (1000t)	-71	-149	-235	-329	-433	-548	-673	-811	-1,069	-0.4
SO2	-0.3	-0.6	-0.9	-1.2	-1.6	-2.0	-2.3	-2.7	-3.5	

Note: * denotes difference from the baseline, otherwise % difference.

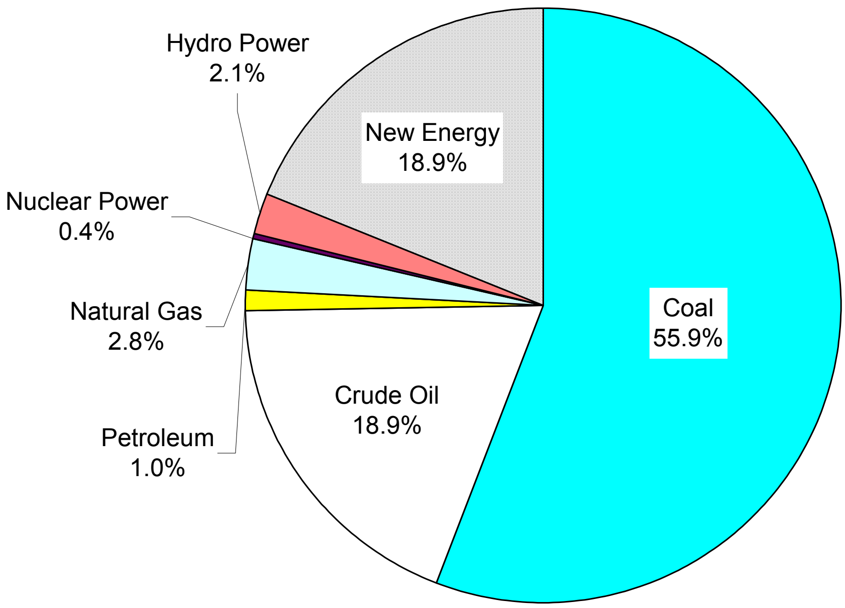
Table 3-10 Impact of 1% World Oil Inflation

EBM Version 03.1: (Simulation 4 - Baseline)/Baseline

	2002	2003	2004	2005	2006	2007	2008	2009	2010	'10/'01(%)
(1) Final Energy Consumption										
Coal	0.0	-0.1	-0.2	-0.4	-0.6	-0.8	-1.1	-1.5	-1.8	-0.2
Oil	0.0	-0.1	-0.1	-0.3	-0.4	-0.6	-0.9	-1.2	-1.6	-0.2
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
New Energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-0.9	-0.1
Share (%)*										
Coal*	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	
Oil*	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	
Natural Gas*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Electricity*	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	
New Energy*	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	
Electricity excluding renewable products*	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	
Heat*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(2) Industry										
Coal	0.0	-0.1	-0.2	-0.4	-0.6	-0.8	-1.1	-1.4	-1.7	-0.2
Oil	0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.0	-1.2	-1.5	-0.2
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.7	-0.9	-1.1	-0.1
Share (%)*										
Coal*	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	
Oil*	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	
Natural Gas*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Electricity*	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	
Heat*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	
Total*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(3) Residential										
Coal	0.0	-0.1	-0.3	-0.6	-1.0	-1.5	-2.2	-3.0	-4.0	-0.4
Petroleum	0.0	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	0.0
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.3	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.1
(4) Transport										
Road	0.0	-0.1	-0.2	-0.4	-0.7	-1.1	-1.6	-2.1	-2.8	-0.3
Total	0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.2	-1.7	-2.3	-0.3
(5) Primary Energy										
Coal	0.0	0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.7	-0.1
Oil	0.0	0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.0	-1.4	-0.2
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-0.1
Share (%)*										
Coal*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Oil*	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	
Natural Gas*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Nuclear*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Hydro*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Heat*	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	
Total*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(6) Trade										
Imports of Mineral Fuel	1.2	2.2	3.2	4.1	4.9	5.6	6.2	6.7	7.1	0.8
Exports of Mineral Fuel	1.1	2.3	3.6	4.9	6.3	7.8	9.5	11.4	13.5	1.5
Trade Balance (M$)*	-93.2	-202.9	-335.7	-495.3	-679.5	-889.2	-1,125.5	-1,387.8	-1,673.0	0.7
Trade Balance vs. GDP (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	
(7) Vehicle										
Vehicles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Passenger Cars	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(8) Emission: 1000t-c										
CO2* (1000t-c)	-62.2	-260.8	-650.5	-1,279.8	-2,191.9	-3,436.0	-5,068.0	-7,155.0	-9,778.0	-0.1
CO2	0.0	0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-0.9	
SO2* (1000t)	-1.4	-6.6	-16.7	-33.0	-56.5	-88.2	-129.2	-180.9	-244.6	-0.1
SO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

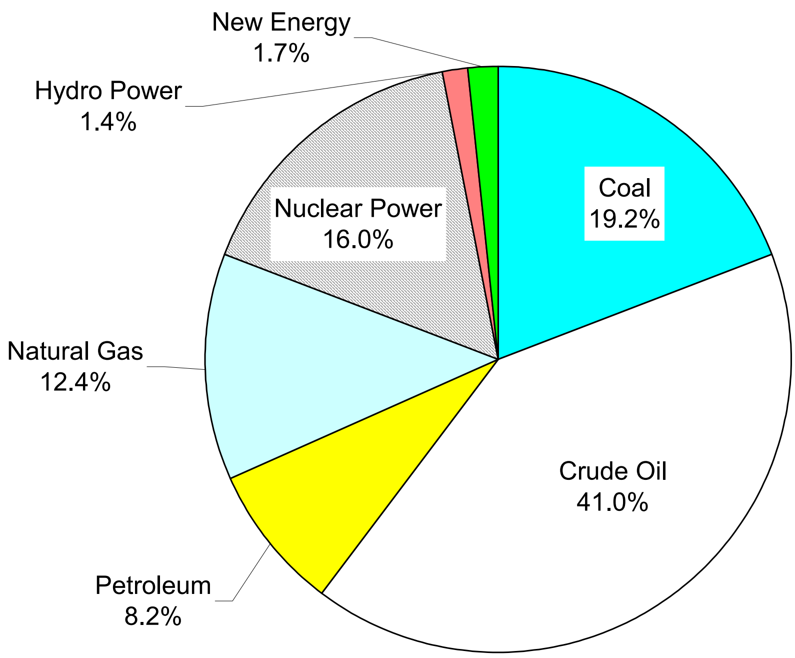
Note: * denotes difference from the baseline, otherwise % difference.

Figure 3-1 Total Primary Energy Share in China in 2001 (%)



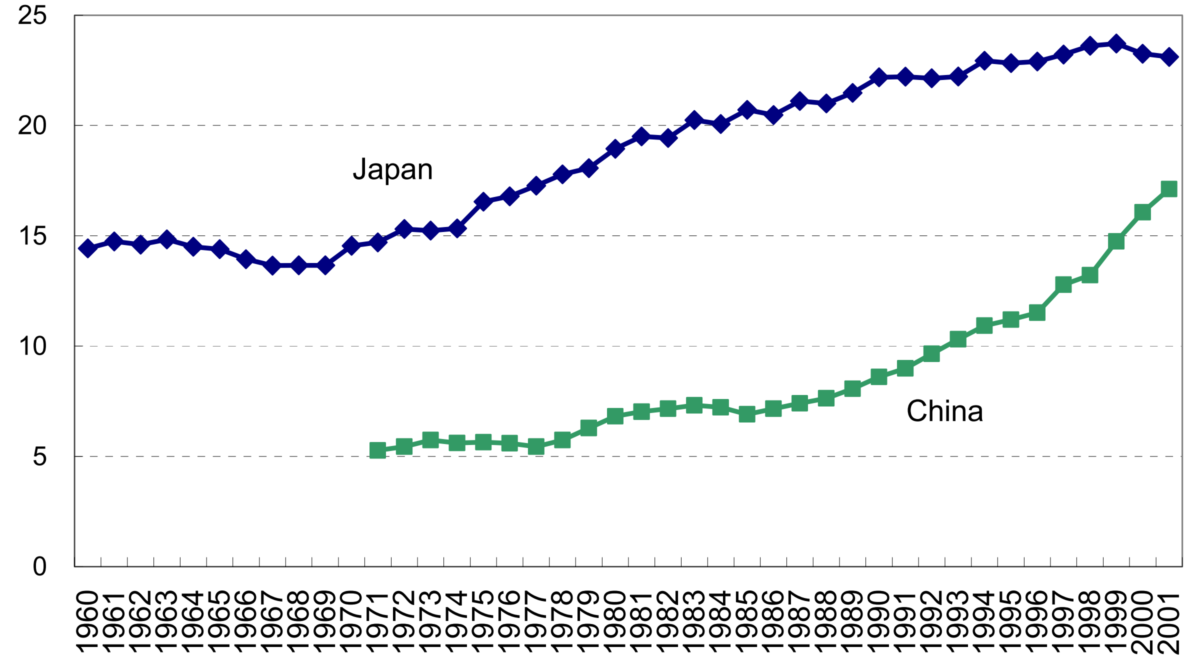
Source: Energy Balances of Non-OECD Countries, 2003 Edition

Figure 3-2 Total Primary Energy Share in Japan in 2001 (%)



Source: Energy Balances of OECD Countries, 2003 Edition

Figure 3-3 Electricity Share in Final Consumption: %



Source: Energy Balances of OECD and Non-OECD Countries, 2003 Edition

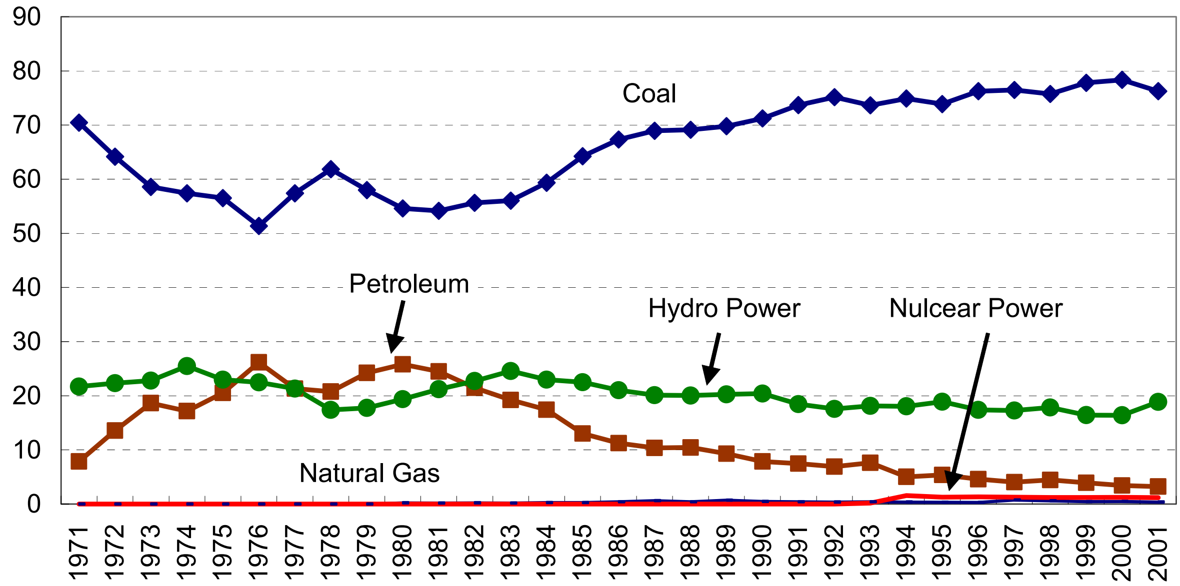
Figure 3-4 Block diagram for the energy balance model

	Coal	Crude Oil	Petroleum	Natural Gas	Nuclear	Hydro	Electricity	Total
Production	IP_CO	IP_CR		IP_NG	IP_NC	IP_HY		IP_TO
Imports	IM_CO	IM_CR	IM_PP				IM_EL	IM_TO
Exports	EX_CO	EX_CR	EX_PP				EX_EL	EX_TO
Total Primary Energy Supply	PE_CO	PE_CR	PE_PP	PE_NG	PE_NC	PE_HY	PE_EL	PE_TO
Electricity Plants	EG_CO	EG_CR	EG_PP	EG_NG	EG_NC	EG_HY	EG_EL	EG_TO
Petroleum Refineries		PR_CR	PR_PP					PR_TO
Own Use	OU_CO	OU_CR	OU_PP	OU_NG			OU_EL	OU_TO
Distribution Losses	DL_CO		DL_PP	DL_NG			DL_EL	DL_TO
Total Final Consumption	FC_CO	FC_CR	FC_PP	FC_NG			FC_EL	FC_TO
Industry	ID_CO	ID_CR	ID_PP	ID_NG			ID_EL	ID_TO
Transport	TR_CO		TR_PP	TR_NG	Vehicle		TR_EL	TR_TO
Residential	RE_CO		RE_PP	RE_NG			RE_EL	RE_TO
Commercial and Public Services	CP_CO		CP_PP	CP_NG			CP_EL	CP_TO
Other								

heat rate

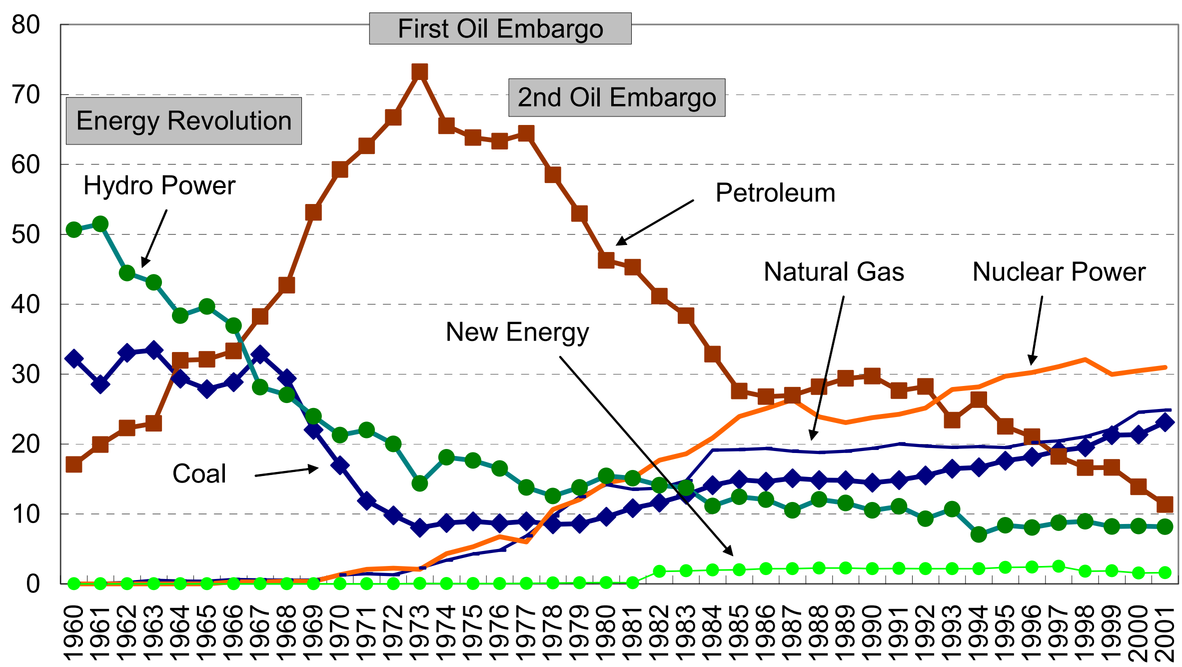
GDP

Figure 3-5 Share of Electricity Generation in China: %



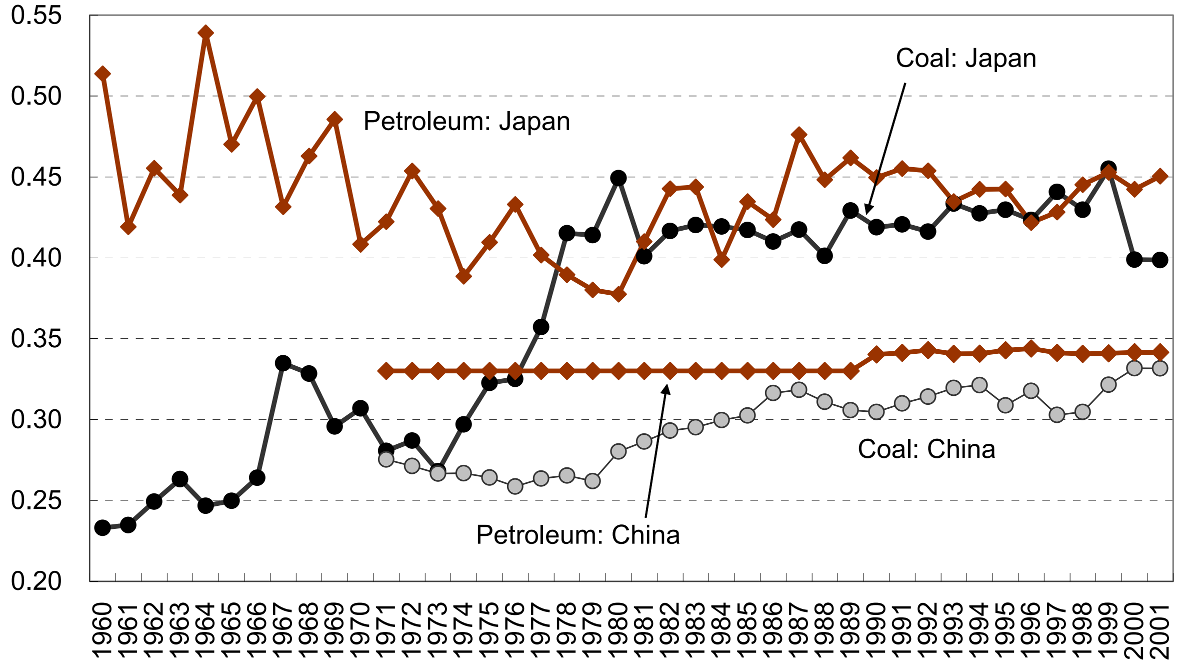
Source: Energy Balances of Non-OECD Countries, 2003 Edition

Figure 3-6 Share of Electricity Generation in Japan: %



Source: Energy Balances of OECD Countries, 2003 Edition

Figure 3-7 Heat Rate in Japan and China: Generated Electricity / Fuel Input



Source: Energy Balances of OECD and Non-OECD Countries, 2003 Edition

Sulfur Emissions Control in China: Domestic or Regional Cooperative Strategies*

Introduction

In this paper, we examine the trend of acid rain in Northeast Asia, specifically in Japan and China. Nakada and Pearce (1999) extended and updated data for abatement costs, damage costs and source-receptor matrices in this region. They compared the estimated optimal level of sulfur dioxide (SO_2) reduction in 1990 with that in 1995, and contrasted those estimates with the actual emission charge in China. Although in China the system of charge on SO_2 emissions was introduced and updated for several years, the negative effects resulted from sulfur deposition has grown into a serious problem not only in China but also in the neighboring region.

Our analysis demonstrates that the domestic optimal level of SO_2 reduction in China has increased during this decade. In line with an increase in domestic optimal level, willingness to pay of Japan for reducing sulfur deposition emitted in China also has risen because the proportion of SO_2 emitted in Northeast China has dramatically spread to Japan. According to our analysis, although the rate of emission charge in China was raised in 1998, that rate is still less than the estimated domestic optimum excluding the damage costs caused by acid rain. If the damage costs is considered, the optimal rate of emission charge increases. These analytical results indicate that not only domestically, but also regionally optimal policy framework will effectively mitigate the damages caused by SO_2 emissions in Northeast Asia.

4-1 Acid Rain: Sulfur Deposition as a Regional Problem in Northeast Asia

Sulfur dioxides emitted from production process have raised domestic pollution problems in China because they are deposited in a gaseous form called “dry deposition,” falling to the ground within about 300 km of the source and directly damaging human health or buildings. In addition, sulfur dioxide emissions also bring about regional or trans-boundary pollution problems such as acid rain because sulfate travels about 1000 km deposited to land via cloud droplets. Such droplets increase the acidity of precipitation, develop into acid rain and indirectly damage ecosystems. This phenomenon is called “wet deposition.” Although acid rain has been taken as a serious political agenda in Europe and North America during the last decades, the problem is also emerging in Northeast Asia. In China, for instance, primary energy demand is still dominated by coal, not only for electricity generation but also for industry, in addition to the rapid GDP growth (Foell, W. K. et. al., 1995). Therefore, subsequent sulfur emissions will increase in the next decades, although the speed is decreasing. The negative impacts as a consequence of the growth of emissions levels have drawn increasing attention of researchers and several simulation models have been developed for analyzing the acid rain problem in this region.

Table 4-1 displays the projected percent contribution to sulfur deposition in Japan by each model. In the model developed by Carmichael et. al. (1995), for instance, 38 % of sulfur deposition in Japan is emitted by themselves, 45 % by non-anthropocentric sources such as volcanoes, 10 % by China and 7 % by the Korean Peninsula. Each model estimates quite different figures from others. The contribution of China to Japanese sulfur deposition is estimated as only 2 % in the model developed by Huang et. al. (1994), compared to 25 % in the Ikeda’s (1995) estimation. The international project for comparing such simulation models called MICS-Asia Phase II has just started.

In our analysis, the source-receptor matrix projected by Calori, et. al. (2001) are applied since the estimate is the most updated one, and it is the revised version of Carmichael’s (1995) which is somewhere between extremes, although the applicability of this model is open to debate. These estimates are investigated into a simulation model called Regional Acidification Information and Simulation (RAINS-ASIA) ver. 7.52, which is developed by World Bank (WB), Asian Development Bank (ADB) and International Institute for Applied Systems Analysis (IIASA). According to Calori, et. al. (2001), Japanese anthropogenic emissions contributed almost 50% to the total sulfur deposition in 1990, where the contribution from China was 21%, volcanic sources 13% and South Korea 13%. After 1990, the increase in Chinese emissions offsets decreasing effect of Japanese emissions. In 1995, while the Japanese contribution to its deposition declining from 50% to 38%, the contribution from China is increasing from 26% to 40%. What could cause such transboundary pollution problem? According to Jinnan, W. et. al. (2000), the emission charge for reducing SO_2 emissions, of which rate is 0.2 RMB per kg-SO_2 or $24.15 per t-$SO_2$ in 1998 value, has been implemented in China for several years. Is that sufficient to reduce SO_2 emissions for solving not only domestic but also regional sulfur deposition problems?

Damages attributed to sulfur emissions are resulted from external effects of economic activities. If the emission of one country damages the environment of other nations across borders due to acid rain, such "transboundary" pollution problem can be characterized as an "international externality." The international externality is mainly due to the lack of relevant property rights. There is no property right assigned to the atmosphere, which is often referred to as the "global commons." If the polluting country and victims co-operated, the "regional" optimal level of abatement could be achieved. However, lack of property rights makes a nation state free to pollute the atmosphere so as to minimize its own social costs, and to achieve its optimal "domestic" level of abatement, while it damages the environment of its neighbors.

According to Nakada and Pearce (1999), from a viewpoint of regional collective social welfare, the minimization of total social costs of all countries in a region will lead to an efficient level of abatement. Suppose that there is one upstream polluter and several downstream recipients. Marginal damage cost for all neighboring countries and marginal abatement cost for the polluter are assumed to be known. Provided that the reduction of emissions is a pure public good, minimization of the total social costs in the region will lead to the cooperative solution QR in Figure 4-1. The point is called regionally optimum where the sum of marginal damage costs in all countries affected by the emissions is equal to the marginal abatement cost of the polluting country. The regionally optimal level of abatement, QR, will not be an optimum level of abatement for each individual state because a polluter could decrease its own social cost if it did not sign up for the agreement. The domestic optimum QD can be interpreted as the point where the marginal damage cost from domestic emissions is equal to the marginal damage cost from sulfur depositions multiplied by the proportion of the sulfate deposited in its country that originates from domestic sources.

Moreover, a lack of information of damage caused by acid rain would make the nation state reduce its abatement level to a sub-optimal level QH, in which the damage costs only for human health attributed to dry deposition is internalized, while the damage resulted from wet deposition is entirely ignored. An efficient strategy for China to reduce the damage attributed by sulfur deposition will be to disseminate information on damages caused by wet deposition and it could be regionally Pareto efficient for Japan to assist China to reduce sulfur emissions.

4-2 Empirical Analysis

We examine the Potential Benefits of Cooperation between China and Japan. The MAC curve of China is substantially below the MAC curve of Japan. Figure 4-2 indicates that there is a considerable amount of cost-efficient options in China for Japan to reduce its SO_2 deposition. This is because a considerable percentage of sulfur emitted in those countries is transferred to Japan; additionally, abatement costs in China are less expensive than the costs in Japan.

For the estimates of marginal abatement cost, the data in RAINS-ASIA ver.7.52 is employed. With regard to the source-receptor matrix, Calori, et. al.. (2001) are referred, which is also incorporated into the same model. With regard to marginal damage cost, Li (1999) shows that there exist several estimates for damages due to sulfur deposition shown in Table 4-2.

As for the estimates of damage costs, Xu (1998) is employed concerning damages caused by wet deposition as well as by dry deposition because the estimate is somewhere between extremes, although, as in the case of source-receptor matrix, the applicability of this estimate is open to debate. The estimated damages in this analysis are those on human health, on buildings, on crops and on forest. These damages are estimated in terms of market prices excluding disutility of environmental degradation or consumer surplus. Damage costs within benefit-cost analysis should include the value of consumer surplus. In Ostro and Chestnut (1998), the values without utilities, i.e. costs of illness, are multiplied by a factor of 2.0. Following their analysis, the values obtained in Xu (1998) are multiplied by the same factor.

There are two assumptions for the estimation of damage costs. The first one is that damages to the environment and human health only depend on the annual deposition. No accumulative effect of sulfur deposition exists. The second one is that unit damage cost per SO_2 emission is constant. The former might be doubtful because the accumulation of sulfur deposition may have a serious effect on the environment and human health. The damage cost could be more if the accumulation of sulfur deposition is also considered. The second assumption is purely for the simplicity of the model. The damage values in China can be shown in Table 4-3.

According to Xu (1998), the total damage costs for human health is estimated as 13,800 mil. RMB in 1993 value. Because the unit damage cost per SO_2 emission is assumed to be constant, the figure, divided by the sulfur deposited in China and multiplied by the rate of self-deposition in China, generates marginal damage cost per unit of SO_2 emission. By using the GDP deflator, the marginal damage cost in the above table is obtained. Additionally, willingness to pay of Japan for reducing a unit of sulfur deposited by China is \$199.19 per ton of SO_2 emission.

Firstly, the domestic optimal level of SO_2 abatement in China is demonstrated. Figure 4-3 shows that the domestic optimal level of SO_2 abatement in China is 102.64 kt of sulfur dioxide in 1990, only 0.5% of total emissions in China in the same year. However, the domestic optimal level of SO_2 abatement is increased because the marginal abatement cost curve (MAC) shifts downward over time due to reduction in abatement costs, and the marginal damage cost curve (MDC) shits upward over time, resulted from the fact that willingness to pay (WTP) for damage caused by SO_2 emissions increases in proportion to the level of income. Hence, the same figure in 1995 increases up to 1014.77 kt, about 5% of China's emissions.

Next, the regional optima in Northeast Asia are examined. Although detailed estimates of damages resulted from acid rain for Japan are not readily available, it is possible to estimate WTP to reduce one ton of sulfur dioxide by using the benefit transfer method. There are several ways in which we can adjust the damage cost which has already been calculated in one particular area to be used in another, one feasible assumption of WTP differences is that the WTP varies between countries reflecting disparities in relative income levels because people who have different incomes will have different WTP for environmental improvement under their different budget constrain. In this section, the values estimated in Xu (1998) are transferred to estimates in Japan, adjusted with income levels. Figure 4-4 demonstrates that the regional optimal level of SO_2 abatement in China is 131.94 kt of sulfur dioxide in 1990, 0.6% of total emissions; however, the same figure in 1995 increases up to 3311.61 kt, which amounts to 10% of total emissions. The incremental SO_2 emission reduction resulted from side-payment from Japan to China has dramatically increased from 29.3 kt to 2394.29 kt since the damage caused by the transboundary sulfate pollution is intensified. The reason of this fact is that the proportion of SO_2 emitted from northeast China[ix] is dramatically increased, which is comparably nearer to Japan.

The following two figures show the level of sulfur emissions of each province. Figure 4-5 shows the emissions in 1990, where the most polluting areas are Sichuan and Jiangsu provinces.

Figure 4-6 demonstrates that, since 1990, a number of large point sources such as power plants have been built in Northeast China. As a result, the most sulfur-emitting province in 1995 is Shandong, as it can be seen in Figure 4-7. Sichuan and Jiangsu provinces are reducing emissions and the most polluting areas are moving eastwards and northwards, respectively. Consequently, as Figure 4-8 shows, percent contribution to deposition by northeast China is substantially increased, from 15.8 % of sulfur deposited in Japan in 1990 to 36.7 % in 1995, while Japanese own contribution decreases from 46.2 % in 1990 to 30.2 % in 1995. This is one of the main reasons that damage costs attributed to sulfur deposition in Japan is increased; hence, the incremental SO_2 emission reduction resulted from side-payment from Japan to China has considerably increased, from \$100.87 per t-SO_2 emitted in China to \$199.19.

4-3Integration of Domestic and Regional Issues

As it was mentioned earlier, the domestic and regional optimal levels of SO_2 emission reduction have been estimated. Now, let us consider the issue of emission charge in China again. As it was mentioned earlier, Jinnan, W. et. al. (2000) mention that the rate of emission charge in China is 0.2 RMB per kg-SO_2 in 1998, which is equivalent to \$24.15 per t-SO_2 in 1998 value as shown in Table 4-4. However, in 1998, the State Council approves the increase in its rate up to 1.2 RMB per kg- SO_2, i.e., \$144.93 per t-SO_2. In the previous sections, the domestic optimal rate of damage costs in China is \$221.24 per t-SO_2, i.e., 1.85 RMB per kg-SO_2 only for health damage and \$349.5 per t-SO_2, i.e., 2.92 RMB per kg-SO_2 for both damages on health and on ecosystems. The current rate of emission charge is obviously less than the domestic optimum; however, it can be considered that the rate is increased towards the domestic optima. With regard to the regional optimum, the marginal damage cost for Japan is estimated as \$199.19 per t- SO_2 emitted from China, i.e., 1.66 RMB per kg- SO_2. Therefore, the regional optimal rate of SO_2 emission charge in China is \$548.69 per t-SO_2, that is, 4.58 RMB per kg-SO_2.

These estimates above indicate that, although the actual rate of emission charge in China is increased, that rate is still less than the domestic optimum excluding the damage costs caused by acid rain. If the damage costs attributed to acid rain is considered, the optimal emission charge is increased. The estimates also show that Japan is willing to pay for achieving regional optimal solution.

Although in China the system of charge on SO_2 emissions has been implemented for several years, the negative effects resulted from sulfur deposition has become a serious issue in this region as well as in China. Our analysis has shown that the domestic optimal level of SO_2 reduction in China has been increased during this decade. Additionally, willingness to pay of Japan for reducing sulfur deposition emitted in China also has risen. The reason of this is that the proportion of SO_2 emitted in northeast China has been substantially increased, which is nearer to Japan. According to our analysis, although the rate of emission charge in China has been increased, that rate is still less than the estimated domestic optimum excluding the damage costs caused by acid rain. If the damage costs attributed to acid rain is considered, the optimal rate of emission charge is increased. Regionally as well as domestically optimal policy framework could effectively mitigate the damages caused by SO_2 emissions in Northeast Asia.

4-4 How Regional Cooperation Can Be Realized?

The above analysis suggests that it is essential for China to impose more strict pollution control if it realizes the regional optimal level of emission. However, China has little, if any, incentive to enhance pollution control level above the domestic optimal one. Regional cooperation is required to give China incentive to do more activities for controlling air pollution.

To encourage environmental policy in China, Japan has employed Official Development Assistance (ODA) and has provided huge amount of ODA for the environmental area. According to the data of Development Assistance Committee, Japan has provided China with US\$ 6.3 billion, or 77% of ODA for the environmental area during 1995-2000 (Figure 4-9)[x]. The share of ODA for the environment becomes higher to 27.2% during 1996-2000, and to over 60% during 2000-2001. By sector, Japan has focused mostly on activities in the transportation and energy sectors[xi], followed by water and sanitation and flood protection. This sectoral allocation shows sharp contrast to the other donors, for they emphasized more on environmental policy and administration and biosphere protection as well as transportation sector in the assistance (Table 4-5). This implies that Japan has provided more ODA on the sustainable energy use and the reduction of pollutants emission, especially that of sulfur dioxide.

There is a good reason that Japan has provided much amount of ODA for the environment area in China. As China enjoys rapid economic growth, its economic and political influence becomes stronger, which makes Japanese feel that it threatens Japan's existing interests and influence in Asia. It raises an argument in Japan that Japan does not have to provide economic assistance any more, because China can manage economic growth financially by itself. On the other hand, the advocates are convinced that China still needs international assistance to manage the degrading environment. Influenced partly by this opinion, Japan has shifted its focus on ODA from economic infrastructure to environmental preservation.

The major activities in the biosphere protection and cleaner energy production were consisted of fuel-gas desulfurization (FGD), rehabilitation of thermal power plants and environmental soft loan by the mid-1990s. FGD can reduce sulfur dioxide emission more than 90%, though the installation as well as operation is expensive when compared to other technical measures. Japan provided financial assistance to install FGD at the same time it provided ODA for investing new coal-fired power plants. Environmental soft loan was to be provided with number of plants so that they could reduce the financial burden for installing end-of-pipe and/or process technologies to reduce emission of sulfur dioxide.

However, it becomes clear that the above activities have made too small impact on the improvement of local air pollution problem in China. Financial assistances for FGD might help power plant to expand the production without increasing sulfur emission, but assistances were provided exclusively to large coal-fired power plants that were the only one of the major pollution sources in the area. Also, environmental soft loan program was not worked so effectively in financing subsidized loans to plants in China as in Japan, for the central government, not the handling banks decided the plants that should obtain financial assistances without any consideration to the company's financial status such as ability to repay, collateral and cash flow.

In late 1990s, Japan changed its environmental ODA strategy for China to pay more attention to pollution at specific areas. After close consultations, Japan selected some specific areas such as Dalian, Chongquin and Guiyang, which had been suffering from serious emission of sulfur dioxide and acid rain, to take a comprehensive approach for managing air pollution at the local level. Japan also assisted to make a master plan for air quality improvement, and helped them to develop infrastructure that is required for fuel conversion from coal to natural gas in the household as well as industries. The same type of comprehensive approach has also been taken in Liuzhou and Lanzhou.

However, it becomes financially infeasible to apply comprehensive approach to all cites and areas that are suffering air pollution in China. Japan has spent part of ODA for water management and water pollution control because many areas have also been suffering from water pollution and water shortage in lakes and rivers in China. Also, the ODA budget has been decreasing rapidly because of the serious fiscal deficit and tight budget constraint in Japan.

In addition, it can be argued that ODA is no more suitable instrument to help reduce sulfur emission in China when we count on the physical and health benefit from the reduction in acid rain. By definition, ODA should be an instrument to help developing countries to improve their welfare, well-being, and sustainable development. On the other hand, Japan can expect to enjoy, benefits from ODA when it provides ODA for helping China to reduce local air pollution. It is because air pollution has a nature of local as well as regional public bads. Thus, it is argued that new financial instruments should be applied when providing regional/global goods and tackling with regional/global public bads (Kaul, et.al., 2003).

Clean Development Mechanism, or CDM, can be an instrument for cooperation in reducing air pollution in China. Developed countries including Japan aim to implement CDM projects so that they can obtain Certificated Emission Reductions, or CERs to comply with their quantified emission limitation of GHGs. CDM projects needs new sources of technical and financial cooperation because international community has decided in the Marrakech Accords that ODA should not be used for CDM.

Most of the CDM projects that are under consideration or certificated by the CDM Board correspond to the following categories: rehabilitation of power plants, development of renewable energy, recovery of methane gas and power generation from waste landfill site, and reforestation. Except recovery of methane gas and reforestation, these activities can reduce sulfur dioxide as well as carbon dioxide emission at the project site, thus can reduce negative local impact of sulfur dioxide in China as well as regional impact of acid rain. In this sense, CDM can be an additional activity to enhance domestic environmental instruments for sustainable development in China.

References

Barrett, S. (1994), "Self-Enforcing International Environmental Agreements," Oxford Economic Papers 46, pp.878-894.

Calori, G. et. al. (2001), "Interannual Variability in Sulfur Deposition in Asia," Journal of Global Environmental Engineering, vol.7, p.p.1-16.

Development Assistance Committee (DAC), 2002. *International Development Statistics 2002*. Paris: OECD.

Ostro B. and L. Chestnut (1998), "Assessing the Health Benefits of Reducing Particulate Matter Air Pollution in the United States," Environmental Research, v.76, p.p. 94-106.

Hayami, H. and Y. Ichikawa (1995), "Development of hybrid LRT model to estimate sulfur deposition in Japan," Water, Air, and Soil Pollution, 85, pp.2015-2020.

Huang, L., et. al. (1994), "Acidic Deposition in East Asia – International Workshop on Acidic Deposition in East Asia," CRIEPI Report ET93002.

Ikeda, Y. et. al. (1995), "Estimates of atmospheric pollution for East Asia – Estimates of sulphur dioxide emissions in China," Journal of Japan Society for Atmospheric Environment, Vol.30, No.6, pp.374-390.

Jinnan, W. et. al. eds.(2000), *SO_2 Emissions Trading Program: US Experience and China's Perspective*, China Environmental Science Press.

Kaul, Inge et. al. (eds.), *Providing Global Public Goods: Managing Globalization. Oxford*: Oxford University Press.

Kochi, I. et. al. (2001), "Cost Benefit Analysis of the Sulfur Dioxide Emissions Control Policy in Japan," Environmental Economics and Policy Studies, vol.4, p.p.219-233.

Li, S. (1999), *The System for Environmental Protection in China*, Toyo Keizai Shimpo sha, (in Japanese).

Nakada, M. and D. Pearce (1999), "Acid Rain in East Asia, an Analysis of Side-Payments," Energy and Environment, 1999, Vol.10, Issue 6, p.p.705-720.

Park, C. C. (1990), *Acid Rain, Rhetoric and Reality*, Routledge.

WB, ADB and IIASA (2001), *Rains-Asia CD-ROM ver.7.52,* Institute for International Applied Systems Analysis (IIASA).

Takahashi, W. (2002), "Problems of Environmental Cooperation in Northeast Asia: The Case of Acid Rain," in Harris, P. (eds.), *International Environmental Cooperation: Politics and Diplomacy in Pacific Asia*, University Press of Colorado, p.p.221-247.

Xu, et. al. (1998), *Economic Damage of Environmental Pollution in China*, China Environmental Science Press.

Table4-1 Projected Percent Contribution to Sulfur Deposition in Japan (%) (1990)

Model	Sources of Deposition			
	Japan	Volcanoes	China	Korean Peninsula
Ichikawa et.al. (1995)	40	18	25	16
Ikeda et.al. (1995)	37	28	25	10
Carmichael et.al. (1995)	38	45	10	7
Huang et.al. (1994)	94		3	2
Chinese Academy of Science (1995)	85		10	4
Calori et. al. (2001)[xii]	38	9	40	13

Figure 4-2 Regional optimal and domestic optimal solutions

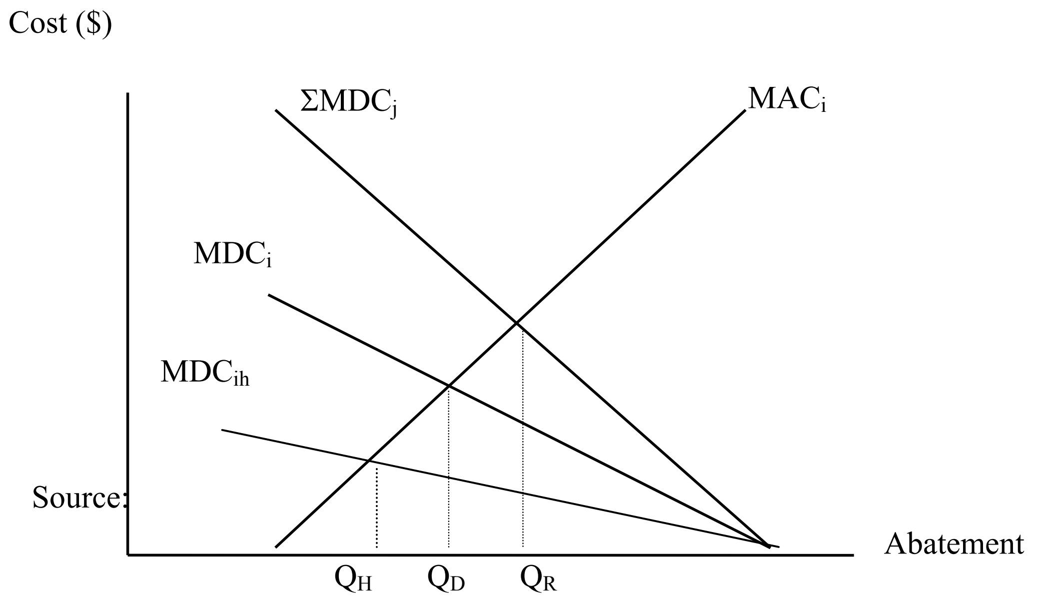
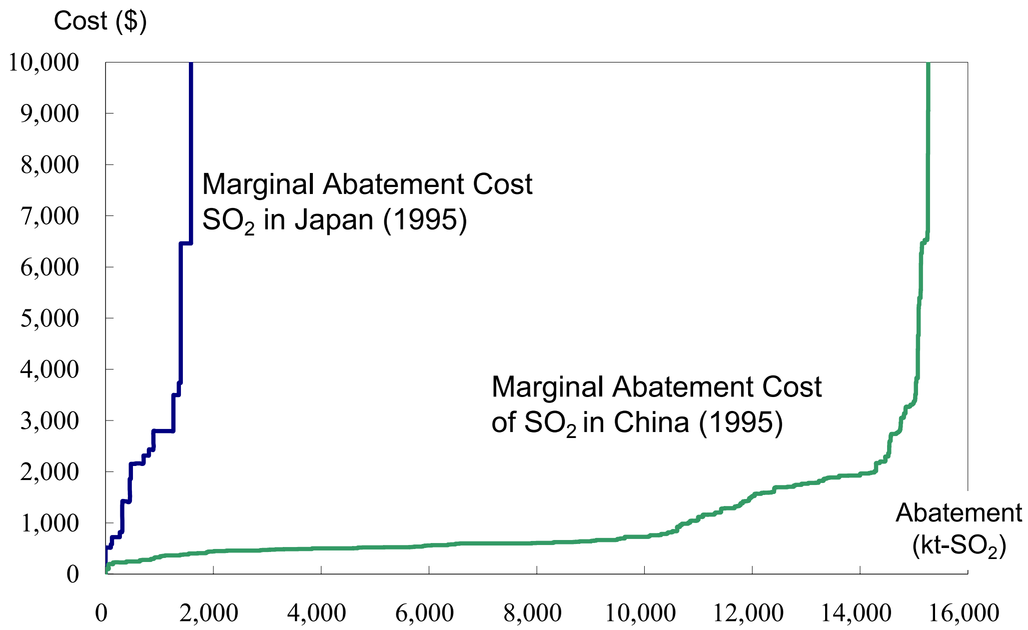


Figure 4-3 Marginal Abatement Cost Curves for SO_2, Japan and China



Source of data: IIASA, *Rains-Asia CD-ROM ver.7.52*

Table 4-1 Damage Cost Estimates in China (mil. RMB, nominal)

Type of Damage	Guo and Zhang (1990)	Academy of Social Sciences (1998)	Sun (1997)	Smil (1996)	World Bank (1997)	Xu (1998)	Xia (1998)
Health	3,760	7,800	26,030	5,150	352,530	13,800	20,160
Acid Rain	4,610	28,850	17,900	4,250	41,380	16,000	14,000

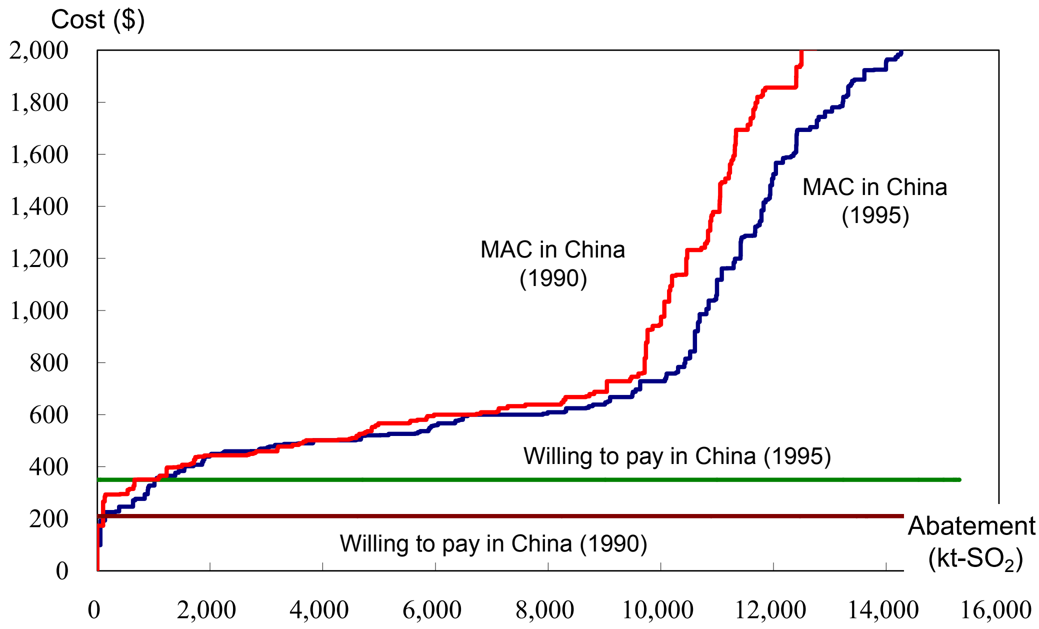
Source: Li (1999), Xu (1998)

Table 4-2 Total Damage Costs and Marginal Damage Costs in China

		Total Damage Costs	Marginal Damage Cost
		1993 (mil. RMB)	1995 ($/t-$SO_2$)
Health		13,800	221.24
Acid Rain	Forest	10,600	128.26
	Crops	2,200	
	Building	3,200	

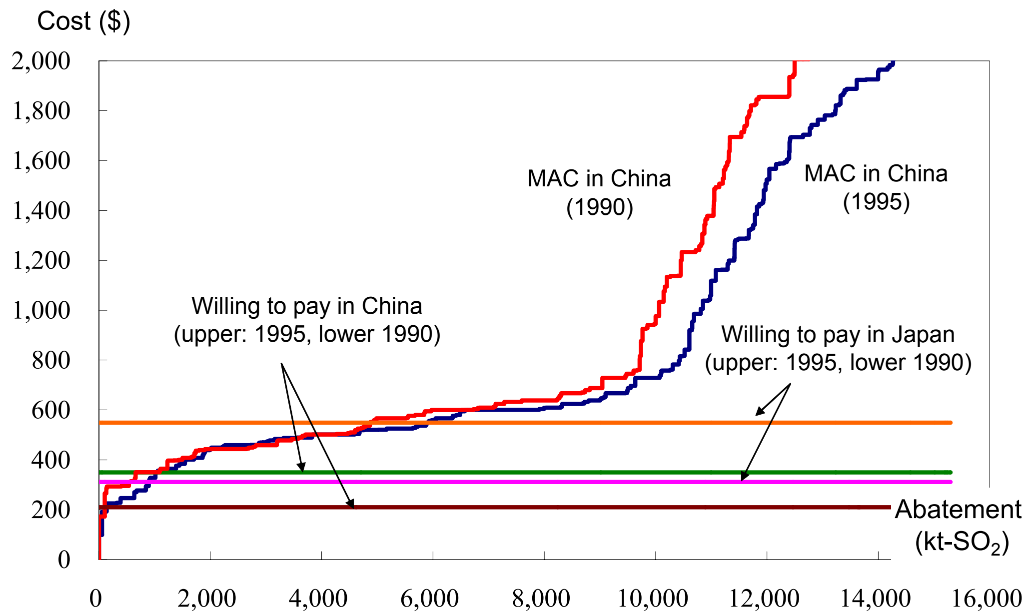
Source: Xu (1998)

Figure 4-4 Domestic Optima for China in 1990 and 1995



Source of data: IIASA, *Rains-Asia CD-ROM ver.7.52*

Figure 4-4 Domestic and Regional Optima for China in 1990 and 1995



Source of data: IIASA, *Rains-Asia CD-ROM ver.7.52*

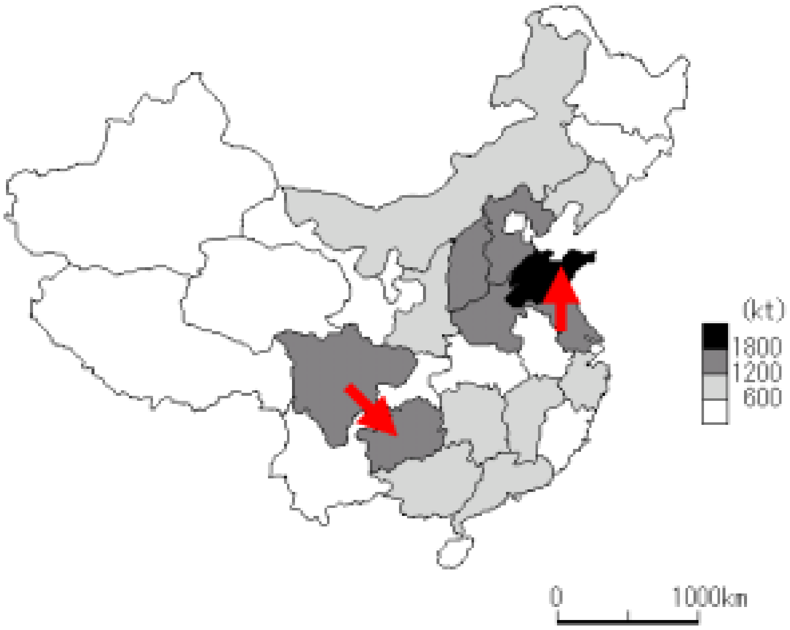
Figure 4-5 Sulfur Emissions of Each Province in China 1990

Source of data: IIASA, *Rains-Asia CD-ROM ver.7.52*

Figure 4-6 SO_2 Emissions from New Large Point Sources (1995)

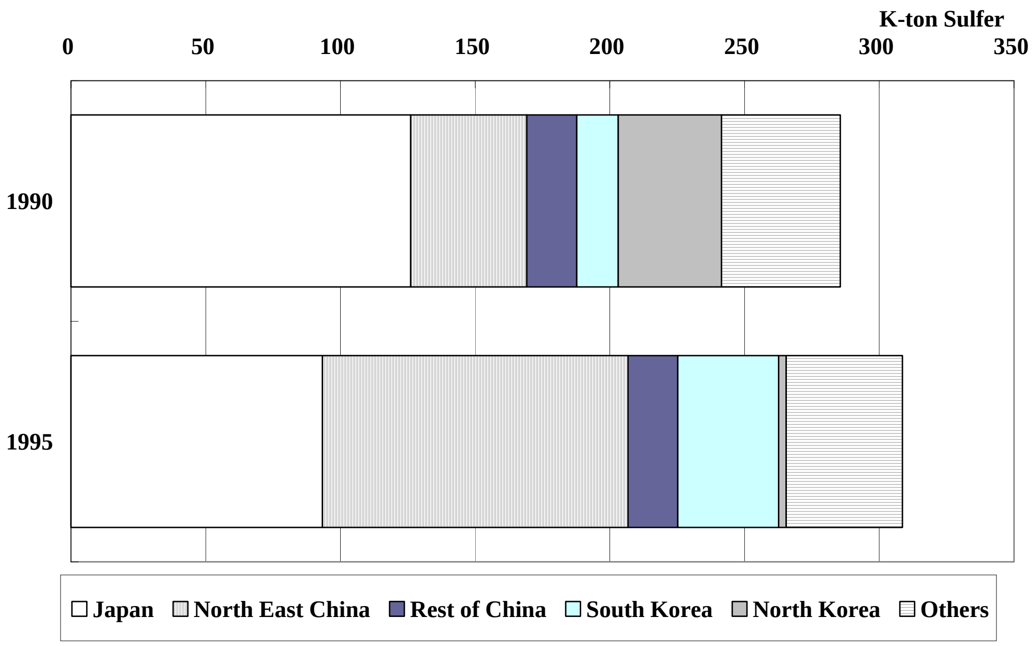
Source of data: IIASA, *Rains-Asia CD-ROM ver.7.52*

Figure 4-7 SO_2 Emissions of Each Province in China 1995



Source of data: IIASA, *Rains-Asia CD-ROM ver.7.52*

Figure 4-8 Sulfur Deposition in Japan Contributed by Sources in 1990 and 1995



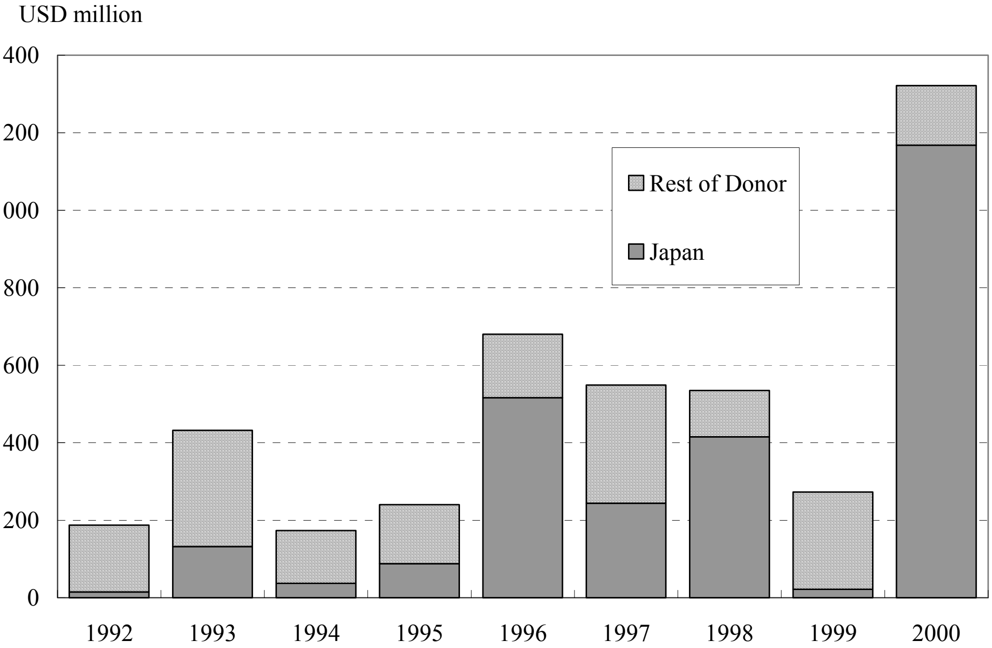
Source of data: IIASA, *Rains-Asia CD-ROM ver.7.52*

Table 4-3 Emission Charge and Domestic and Regional Optima (per t-SO_2) (1995)

	Actual Rate	Domestic Optimum		Regional Optimum
		Health	Health and Acid Rain	
Emission Charge	\$ 24.15 (-1998) \$ 144.93 (1998-)	\$ 221.24	\$ 349.5	\$ 548.69

Source of data: IIASA, *Rains-Asia CD-ROM ver.7.52*

Figure 4-9 Environmental ODA in China by Donor 1992-2000 (%)



Source of data: DAC, *International Development Statistics 2002*

Table 4-5 Environmental ODA in China by Sector During 1995-2000 (%)

	Japan	Rest of Donors
Water and Sanitation	22.11	3.75
Waste Management	0.00	2.68
Transportation	25.43	48.70
Communication	3.42	1.29
Energy	25.52	9.61
Forest	0.16	3.39
Agriculture and Fishery	4.20	3.42
Industry	0.10	6.31
Economic Development Policy	1.95	1.17
Environmental Policy and Administration	6.90	11.49
Biosphere Protection	3.13	7.51
Flood Prevention	7.07	0.66
Sum	100.00	100.00

Source: Author calculated based on DAC (2002)

[*] This chapter is partly based on Nakada and Ueta(2004).The authors are grateful to Yoichi Ichikawa, Jusen Asuka, ZhiDong Li, Ikuho Kochi and Wakana Takahashi for informative advice.

[ix] Northeast China in this paper includes: Anhui, Beijing, Hebei, Heilongjiang, Henan, Jilin, Jiangsu, Liaodong, Nei Mongol, Shanghai, Shenyang, Shandong, Shanxi, Taiyuan, Tianjin, and Zhejiang.

[x] DAC defines an activity as environmental-oriented, thus environment ODA if an activity is intended to produce an improvement, or something that is diagnosed as an improvement in the physical and/or biological environment of the recipient country, area or target group concerned, or if it includes specific action to integrate environmental concern with a range of development objectives through institutional building and/or capacity development (DCD/DAC/ENV96(14)). According to this definition, economic infrastructure and service such as activities promoting sustainable use of energy resources as well as social one and sustainable natural resource management are classified as environmental-oriented activity.

[xi] Activities in the energy sector include rehabilitation of thermal power plant, and transmission and distribution system, and investment on small hydropower plant and renewable energy.

[xii] This estimation is for the year 1995.