Environmental Simulation for China*
:Effects of 'Bio-coal Briquettes'

Nakano, Satoshi† and Asakura, Keiichiro‡

† *Keio Economic Observatory, Keio University, Japan,*
‡ *Institute of Economic Research, Hitotsubashi University, Japan*
E-mail: satona@yellow.plala.or.jp

July 2002

Abstract

The purpose of this research is to clear the possibility for sustainable development in China, which would have a big impact on the economic and environmental situation in east Asian countries. To this end we have created the economic-environmental regional database to elucidate the regional characteristics of China, and then constructed an econometric model to simulate the various effects of installing the environmental protection technology in China.

The regional database of China is based mainly on 'Statistical Yearbook', 'Regional Statistical Yearbook', 'Input-Output Table', 'Labor Statistical Yearbook', 'Environment Yearbook', 'Coal Industry Yearbook', 'Population Statistics', 'Energy Statistical Yearbook', 'Industry Economic Statistical Yearbook', etc. The database shows that the CO_2 and SOx emissions as well as the economic activities are largely different among regions, our Chinese econometric model allows for these differences.

Next, we have constructed a multi-sectoral econometric model based on Keynesian economics for environmental policy simulation, which can calculate domestic production, value added, household consumption, CO_2 and SOx emissions by region.

The environmental issues have factors in wide research fields such as engineering, medical science, politics and economics. Therefore we have included technological information from engineering and agricultural experiments in our econometric model. In our report we show the simulated effects of installing 'Bio-coal briquette' in China. The 'Bio-coal briquette' is a substitution good for coal and one of the low-cost desulfurization technologies. The 'Bio-coal briquette' is made from coal, biomass and lime put under high compression pressure.

The results of our simulation show that the economic effects of installing the Bio-coal briquettes have inflationary pressure by changing the demand structure and the input coefficients. However the CO_2 and SOx emissions show significant improvement, and are reduced by 11.8 % and 30.5 %, respectively.

1 Introduction

According to 'World Development Indicators' [3] by the World Bank, the CO_2 emissions from industries in China increased from 2.8 billion tons(CO_2 conversion) in 1992 to 3.6 billion tons in 1997. The percentage of world emissions increased from 12.8 % to 15.1 % and ballooned from 2.4 to 3 times Japan's level. In addition, according to 'China Environmental Yearbook' [4], the

*We acknowledge financial support from "Research for the Future Program," under the Japan Society for the Promotion of Science. This research has been done in cooperation with Prof.Takanobu Nakajima(Faculty of Business and Commerce, Keio University). And we would like to thank Mr.Yuji Sakai(Graduate School of Engineering, The University of Tokyo) for telling us precious information about the improved effect of soil by the ashes of bio-coal briquettes. We are solely responsible for any errors.

SOx emissions from industries in China increased from 13.2 million tons in 1992 to 13.6 million tons(SOx conversion) in 1997. The situation of air pollution in China becomes serious year by year.

In China, the area of alkali soil is approximately 400,000 km^2[5], and the alkali soil area where the precipitation is more than 500 mm/year, is 200,000 km^2. The alkali soil area where sodium carbonate and sodium hydrogen carbonate in groundwater have accumulated in the surface layer of soil, and crystals of clay have changed into fine particles. These fine particles are mobilized by rain. They become compacted and form hard soil when they dry. Therefore planted seeds cannot sprout and root, and agricultural output decreases sharply, and eventually becomes impossible. Because a food shortage due to population increase is predicted, it is necessary to improve low-productivity soil[6].

With respect to global warming, it is important to reduce CO_2 emissions in China. Similarly, Japan must reduce greenhouse gas emissions to 6 % less than the 1990s level. However, it will be difficult for Japan to achieve this level purely through energy-saving measures. The clean development mechanism (CDM), a flexible mechanism answered the needs of both countries. Under the CDM an advanced country contributes to the reduction of greenhouse gases in a developing country and thereby obtains carbon credits. Bio-coal briquettes, as discussed in this paper, are ideally suited to use under CDM. Bio-coal briquettes have a higher combustion efficiency than coal. In addition, the ashes of the briquettes improves saline-alkali soil and growing trees becomes possible. An additional result is that CO_2 emissions are reduced.

The purpose of this paper is to clarify the potential for sustainable development in China. To this end we have constructed a regional economic and environmental database, and built an econometric model to simulate the various effects of installing environmental protection technologies in China. There are several examples of simulations for the improvement of air pollution([34]∼[36]). In this research, we examine the installation of bio-coal briquettes in China and the increase in food production due to the improvement of saline-alkali soil, as well as the fluctuation of economic variables and the reduction of CO_2/SOx. This research is interdisciplinary and includes aspects of economics, engineering, and agricultural science.

2 The Model

The basic frame of our model is the same as that in Yoshioka and Mizoshita[39]. Please refer to that paper for a detailed description of the model. In this paper we briefly outline the model's characteristics. (Please see Figure 1. We have printed the equation system and the economic/environmental variables as chart 1-3).

The economic model is a short-run Keynesian model in which management policies on the demand side operate effectively. In other words, this model is different from the Neoclassical model in that it focuses on allocation of production mediated by reserved factors. However, we assume that supply does not always increase ad infinitum with increase of demand, and that the supply function equals the short-run marginal cost. For raw materials, the price of goods rises to equilibrium if demand increases. Because there is still unlimited labor supply in China, we treat labor as different from raw materials. Initially, agricultural sector labor is defined as the remainder when the labor absorbed to non-agricultural sectors from the labor force population. The agricultural sector wages are determined by dividing the distribution to labor of the income of the agricultural sector by the number of laborers. Furthermore, we assume that the non-agricultural sector wage is equal to the wage of the agricultural sector multiplied by a high fixed rate. If demand for labor increases in the non-agricultural sector, the sector can always absorb more labor from the agricultural sector. These assumptions are proper if the labor market has unlimited supply and the potential labor supplier works for minimum wage in non-agriculutural sectors. This characteristic of the labor market is the first feature of this model.

The second character of this model is that we calculate the CO_2 and SOx emissions by region in China. '1992 China Input-Output Table' is the primary source for the model, and is national rather than regional data. However, we can partially differentiate the regional industrial structure by utilizing the 'China Statistical Yearbook'. We assume that the technological structure of each industry is common to all regions, and that the CO_2 and SOx emissions from regions where the industrial structure is distinct, can be calculated by utilizing the regional information. In addition, we specify the regional consumption vector of final demand and measure direct regional CO_2 and SOx emissions from household consumption. As shown in Asakura, Nakajima and Washizu [7], the economic power differentials and the regional differences in geographical environment in China greatly influence environmental variables. It is important that we account for these geographical differences.

The third characteristic is that the economic model makes environmental simulation possible. For example, installation of new technology for environmental protection requires new investment and it increases the investment item of final demand. On the other hand, the input coefficients of energy fall, and the short-run marginal cost decreases and it may decrease the product price. Furthermore, if all of the new investment is provided by a domestic fund, the interest rate rises and it suppresses crowding out. Because all influences are processed in the model, a cost-benefit analysis for installation of new technology is possible.

The basic form of this model is simple as shown in Figure 1. Therefore we can use various technical information and draw focussed conclusions by varying the inputs.

3 The Economic and Environmental Statistics and the Reservation of the Model

We used the Chinese statistics([16]~[27]) e.g. '1992 Input-Output Table' and made the data base for input to the economic model. In the input-output table, the 1997 table had already been published, but we used the 1992 table in this model. Because of this the total society production, which is required in order to grasp the correlation of the industrial structure and the CO_2/SOx emissions in each region, is not available by shifting from the MPS system to the SNA system. In addition, the model is based on the cross-section data because procurement of detailed time series information is difficult. And various parameters of the consumption function, in the vestment function and the supply and demand function of money are estimated, but the parameter of the consumption demand function utilizes the value in Kuroda[12] and other parameters are decided by calibration to the input-output table and the statistical yearbook. Because this model is static and not a completely closed model, we assume that money supply, price of agricultural goods, import price of goods, exchange rate, captital stock, government expenditure, and export are the exogenous variables.

4 The Environmental Simulation

As a part of "Research for the Future Program," under the Japan Society for the Promotion of Science, we installed experimental bio-coal briquette production machines which are simple desulphurization technologies into Chengdu, Sichuan province and Shenyang, Liaoning province in China. Bio-coal briquette is an oval briquette that can be substituted for coal. Chengdu Research Group for Bio-coal Briquettes[15] demonstrated that the bio-coal briquette is produced by mixing coal, biomass and desulfurizer (powdered limestone) under high pressure of 3-5t /cm^2 and measured raw material composition provided by the experiment. Accordingly, in this simulation, we utilized this technical information and calculated the SOx and CO_2 reduction effect for bio-coal briquette substituted for coal.

We reduced the input coefficient of coal to correspond to the material composition of the popular-type bio-coal briquettes as shown in Figure 2. We then increased the input coefficients of agriculture, coal, electric power and the ceramic industry rise. The method is as follows.

1. According to Chengdu Research Group for Bio-coal Briquettes[15], the raw material composition of the popular-type bio-coal briquettes in Chengdu is shown in Table 1. If we ignore calorific value and combustion efficiency and suppose that 1 ton of coal is replaced by 1 ton of bio briquette, then since 1 ton of bio-coal briquette contains 664kg of coal, we can consider the coal input factor to be 0.664.

$$a_{bcoal,j} = 0.664 a_{coal,j} \tag{1}$$

Where,

$a_{bcoal,j}$	: Coal input coefficient for bio briquettes production by the jth sector
$a_{coal,j}$	: Original coal input coefficient of the jth sector

2. For other raw materials, we factor in the materials cost necessary for 1 ton of bio-coal briquette, multiply $a_{bcoal,j}$ by the ratio of other raw materials cost to coal cost and add the result to the original input coefficient of each raw material. In other words we calculate the additional input value of these raw materials by using the ratio multiplied by the value of coal input. In the case of powdered limestone, for example, UC^{other} equals 25.50 and we change the ceramic input coefficients of the sectors consuming bio-coal briquettes. Also, we classify saw dust and straw as agricultural sector materials.

$$a_{i,j}^{bother} = a_{i,j}^{other} + \frac{UC_i^{other}}{UC^{coal}} a_{bcoal,j} \tag{2}$$

Where,

$a_{i,j}^{bother}$	: The ith raw material input coefficient which is spent for bio briquettes production by the jth sector(except coal)
$a_{i,j}^{other}$	: The ith raw material original input coefficient of the jth sector(except coal)
UC^{coal}	: The cost of coal which is necessary for 1 ton of bio briquettes($= 63.08$)
UC_i^{other}	: The ith raw material cost which is necessary for 1 ton of bio briquettes (except coal)

3. We also consider the difference in calorific value and combustion efficiency between bio-coal briquettes and coal, and multiply $a_{bcoal,j}$ and $a_{i,j}^{bother}$ by the ratio of the calorific values and combustion efficiency between bio-coal briquette and coal.

$$\begin{aligned} a_{nbcoal,j} &= \tfrac{Heat_{coal}}{Heat_{bio}} \tfrac{Ef_{coal}}{Ef_{bio}} a_{bcoal,j} \\ a_{i,j}^{nbother} &= \tfrac{Heat_{coal}}{Heat_{bio}} \tfrac{Ef_{coal}}{Ef_{bio}} a_{i,j}^{bother} \end{aligned} \tag{3}$$

Where,

$a_{nbcoal,j}$	: The jth sector$'$s coal input coefficient for bio briquettes production which accounts for calorific value and combustion efficiency
$a_{i,j}^{nbother}$	: The jth sector$'$s ith raw material input coefficient for bio briquettes production including calorific value and combustion efficiency (except coal)
$Heat_{coal}$	: Calorific value of coal($= 20,188$kJ/kg)
$Heat_{bio}$	: Calorific value of bio briquettes($= 16,207$kJ/kg)
$\frac{Ef_{coal}}{Ef_{bio}}$	: Ratio of combustion efficiency of coal to bio briquettes($= 1.0/1.29$)

There is a technical constraint such that calorific value and bio-coal briquettes cannnot be applied to industries having large-sized boilers(e.g. iron/steel and electric power sector). In addition, we assume that the coal mining sector and the coal product sector that produce bio-coal briquettes do not consume them. We further assume that all industries besides these consume bio-coal briquettes. However, bio-coal briquettes are not used in household sector.[1] We decrease CO_2 emission coefficients to correspond the decrease in coal input, and the desulfurization rate is 67 % following the Chengdu Rsearch Group [15].

In this simulation, we include the capital cost of the bio-coal briquette machine. In other words, we assume that the environmental protection technology is produced in China as opposed to foreign production and installation.

We determine the optimum size and number of machines for bio-coal briquette demand by using the cost function of the economic model(Equation (4).[2]

The cost function of this bio-coal briquette machine was estimated by Yoshioka, Nakajima and Nakano[37] using Japanese data. We calculate the total cost of machines according to the size and number, and add this to the final demand investment of the machinery manufacturing sector. In addition, the cost of bio-coal briquette machines increases the price of goods in the sector installed, and we add the cost of machines over durable years and domestic production to the price equation.[3]

$$\begin{gathered} C(q,n) = aq^b + n^\alpha \exp\left(c + d\ln q + \tfrac{e}{2}\ln q^2\right) \\ a = 0.26,\ b = 0.71,\ c = -1.62,\ d = 0.34,\ e = 0.25,\ \alpha = 0.6 \end{gathered} \tag{4}$$

Where,

$C(q,n)$	: Production cost of bio briquette machines
q	: Production capacity of bio briquette machine(t/hour)
n	: Number of bio briquette machines

Furthermore, we can calculate the quantity of the ashes from bio-coal briquette consumption and the increase of food production from the improvement of soil utilizing the ashes of bio-coal briquettes.[4] And Yang et.al.[28] reports the results of a soil improvement experiment in Shenyang, Liaoning and shows the change of corn production according to applied quantity of the desulfurization gypsum or the ashes of bio-coal briquettes. We utilize the conclusion that 3.16 ton/ha of corn was produced for 23 ton/ha of the bio-coal briquette ashes[28] and caluculate

[1] After the consumption demand of 5 account description of household has been decided in the model, we convert 5 account description to item classification of input-output table by account description and item converter. Therefore modification of the converter is requirement to simulate subsitution bio-coal briquette for coal. However, It is as reservation in this simulation because re-mensuration of value share of goods to occupy in account descriptions is very difficult.

[2] we consider that all bio-coal briquette machines are not produced in one place, and assume that these machines are produced in 30 footholds.

[3] We assume that the durable years of the machines are 10 years.

[4] We assume that the ashes equal to 15 % of bio briquette with weight.

the corn production from the area of alkali soil improved by the ashes.[5] We multiply the increase in corn production by the unit price of corn in 1992 and add it to the production of agricultural sector.[6]

5 Simulation Results

Firstly CO_2 emissions in Liaoning province are the highest at 240 million tons(CO_2 conversion) according to the regional CO_2 emissions measured as a theoretical value in this model(Figure 3). Shangdong province(230 million tons), Heilongjiang province(230 million tons), Hebei province(230 million tons), Jiangsu province(210 million tons) are also high-rank provinces. The cold northeast area and the coastal area which has robust economic activity also show high output. When we examine the emissionsa structure by sector(Figure 4), the highest is the electric power sector with 860 million tons, second is household consumption with 410 million tons, third is the iron and steel industry with 410 million tons and fourth is the ceramic industry with 320 million tons. Particularly, CO_2 emissions from the power generation sector is approximately 30 % of the total. In addition, CO_2 emissions from industries are 2.76 billion tons (Table 2), and exceed the World Bank value([3]) which we referred to above. And the CO_2 from coal is approximately 80 % of the total and greatly exceeds CO_2 emissions from other fuel sources.

Next, Let us look at SOx. Figure 5 shows regional SOx emissions. Shangdong province(29 million tons(SO_2 conversion)), Sichuan province(26.9 million tons), Jiangsu province(25.1 million tons), Hebei province(15.1 million tons) and Shaanxi province(13 million tons) are high output provinces. The geographical distribution is quite distinct between the SOx and CO_2 emissions as shown in Figure 3. Due to data constraints, the carbon content of coal is same value in all regions, but the sulfur content is regional distinct(National Institute of Science and Technology Policy[11]). In particular, coals consumed in Sichuan and Shaanxi are high in sulfur content. It is the main factor causing the SOx emissions of these provinces to be high.

The electric power industry is the highest sector(86.8 million tons(SO_2 conversion)) for both SOx and CO_2(Figure 6). And second is household consumption, third is the ceramic industry and fourth is the iron and steel industry. Furthermore, SOx emissions from coal are the highest and account for over 90 % of the total.

Next, we will see the result of the simulation as reported in Figure 7 and Table 3.

The rate of change of CO_2 and SOx due to utilization of bio-coal briquettes is -30.5 % and -11.8 %, respectively. We can confirm that the sectors in which we would install bio-coal briquettes show high reduction, while the sectors without briquettes show low reduction. Figure 7 shows that the price of goods rises due to changing the sectorial input coefficients and the sectorial marginal cost and causes an inflationary effect. As a result, real GDP rises by 0.11 %.

The highest regional reduction of CO_2 occurs in Jiangsu province(30.2 million tons(CO_2 conversion))(Figure 8). Other regions with high CO_2 reductions are Shangdong province(28.7 million tons), Hebei province(23.5 million tons), Heilongjiang province(19.1 million tons) and Henan province(18.9 million tons). Big reductions are found in the provinces where the CO_2 emissions as shown in Figure 3 are high. In addition, Table 4 shows the optimum size and number of bio-coal briquette machines industry should install. We found that it was best to make many small machines even in sectors where bio-coal briquette demand is great, as Yoshioka, Nakajima and Nakano [37] pointed out.

Because SOx directly influences the health of residents, let us examine the regional reduction(Figure 9). the highest is 810,000 tons(SO_2 conversion) in Shangdong province and second

[5]The data of bio-coal briquettes in this research is based on Chengdu Research Group for Bio-Coal Briquettes[15]. Therefore the properties of soil in [15] are diffrent from ones in Yang et.al.[28]. And we do not consider regional differences of pH and components of alkali soil.

[6]According to 'China Price 50 Years(1949-1998)'[29], the price of middle class corn is 812 yuan/ton in 1992.

is Jiangsu province(773,000 tons). Sichuan(707,000 tons), Guizhou(537,000 tons) and Yunnan(437,000 tons) also have high SOx reductions. We observe a big reduction in the provinces where SOx emissions are high as shown in Figure 5.

55,100 *ha* of alkali soil is improved by the ashes of bio-coal briquettes and 17400 tons of corn can be harvested from the area afresh. This quantity of corn is less than 1 % of total corn production in 1992, but can provide food for approximately 1.48 million persons when according to grain consumption per capita. This equals approximately 0.1 % of China's population.[7]

Because this model is static, we can only measure the effect one year after bio-coal briquettes installation, but with one application of the bio-coal briquette ashes corn can be harvested for at least five years according to Yang et.al.[28]. Accordingly, roughly 870,000 tons of corn can be harvested from the same area over five years. Furthermore, if alkali soil is improved by 50,000 *ha* afresh annually in five years, approximately 26.1 million tons of corn is produced. This is equivalent to food for 22.1 million persons, approximately 1.9 % of the population in China.

6 Concluding Remarks

In this paper we outlined the basic structure of the environmental/economic model and showed the mensuration effect of installing bio-coal briquettes. We will now summerize the environmental information provided from the model.

The CO_2 and SOx emissions are quite distinct regionally, CO_2 emissions in Liaoning province are about 50 times those of Hainan province, and SOx emissions in Shangdong province are approximately 90 times those of Hainan.[8] Accordingly, we suggest that it is necessary to acknowledge that the environmental situation is greatly different among regions before conservation measures are taken.

We found that negative effect upon the economy is relatively slight as compared with large reduction of CO_2 and SOx emissions. And Figures 8 and 9 show that geographical distribution of CO_2 and SOx reduction is regionally different. This is one of the effective indexes to determine installation with respect to CDM, as well as the optimum size of bio-coal briquette machines. Furthermore, judging from the vast Chinese population, the effect of increased food production due to soil improvement is slight, but since the effect is cumulative, it is promising as a measure against predicted food shortages.

In the research simulation we measured the economic and environmental effects as a result of installing the popular-type bio-coal briquette machines in China and substituting briquettes for coal, and the effect on increased food production by applying the ash of briquettes to improve the saline-alkali soil.

However, the flue gas desulfurization(FGD) system should be installed on large-sized boilers and it is desirable to apply desulfurization gypsum which is a byproduct in the saline-alkali soil to attain more desulfurzation and further reduce alkali soil effects. Accordingly, in the future, we should collect cost information for desulphurization technologies and consider running simulations including these technologies. In addition, we can determine the effects of installing bio-coal briquette machines and desulphurization technologies generally by adding the medical information available correlating SOx emissions and negative health effects to the economic model. This may be our next research project.

[7] According to 'China Statistical Yearbook' [19], the corn production is 95.4 million tons, the grain consumption per capita is 117.96*kg*, the total population is 1.17 billion in 1992.

[8] The CO_2 and SOx emissions from Tibet province is minimum, but there is defect value of data. We compared among 29 provinces.

References

[1] Ezaki,Mitsuo and Sun,Lin(2000) "Trade Liberalization and the Economy of China:A Dynamic CGE Analysis(1997-2010)" *APEC Discussion Paper Series*, Apec Study Center, Graduate School of International Development, Nagoya University & IDE-JETRO, no.29.

[2] Sweet,William and Hood,Marlowe (1999) "Can China consume less coal ?", *IEEE Spectrum November* .

[3] The World Bank(each year) 'World Development Indicators'.

[4] Editorial Board of China Environment Yearbook ed.(2000) 'China Environment Yearbook(2000)'(in Chinese),China Environment Yearbook Press.

[5] Nitta,Yoshitaka, Ishikawa,Haruo, Sadakata,Masayoshi, Matsumoto,Satoshi and Wang,Kezhen(2001) 'Utilization of desulfurization by-product'(in Japanese),Yamada,Tatsuo ed.(2001)'An Experiment of Sustainable Development in China: Case Study of De-sulfurized Bio-Coal Briquette in Shenyang and Chengdu' Keio University Press, Chapter 8, pp.153-174.

[6] Matsumoto,Satoshi and Chun,So ul(1998) 'Improvement of Bad Soil and Increase of Food Production by Applying Desulfurization Gypsum'(in Japanese), Keio Economic Observatory Discussion Paper, no.G-28, Keio University, "Research for the Future Program," the Japan Society for the Promotion of Science.

[7] Asakura,Keiichiro, Nakajima,Takanobu and Washizu,Ayu(1998) 'Construction of Chinese Regional Database and Rough Estimation of CO_2 Emissions'(in Japanese) ,Keio Economic Observatory Discussion Paper, no.G-27, Keio University, "Research for the Future Program," the Japan Society for the Promotion of Science.

[8] Inada,Yoshihisa, Fujikawa,Kiyoshi, Murota,Koju and Adachi,Naoki(1997) "An Analysis of China's Economic Development and Environmental Problems"(in Japanese),*Keizai Bunseki* no.154, pp.10-86.

[9] Ezaki,Mitsuo(1977) 'Model Analysis of the Japanese Economy'(in Japanese) Sobunsha.

[10] Ezaki,Mitsuo and Sun,Lin(1998) "Growth Accounting of the Chinese Economy:1981-1995"(in Japanese),*Forum of International Development Studies*,Nagoya University,no.10, pp.1-15.

[11] National Institute of Science and Technology Policy(1992) 'Energy Utilization in Asia and the Global Environment'(in Japanese) Printing Bureau, Ministry of Finance.

[12] Kuroda,Masahiro(1989) 'Quantitative Analysis of General Equilibrium' (in Japanese) *Modern Economics 19*, Iwanami Shoten.

[13] Kuroda,Masahiro, Kiji,Takayuki, Yoshioka,Kanji, Hayami,Hitoshi and Wada,Yoshikazu(1996) 'Energy Consumption and Environmental Issues in China'(in Japanese) Ministry of Economy, Trade and Industry/Research Institute, Research Series 27.

[14] Kojima,Reiitsu(1989) 'Explanatory Material of Economic Statistics and Economic Law in China'(in Japanese),Institute of Developing Economies.

[15] Chengdu Research Group for Bio-coal Briquettes(2000) 'Report of Follow-up Survey of Bio-Coal Briquettes in Chengdu(1999)'(in Japanese) Keio Economic Observatory Discussion Paper, no.G-68, Keio University, "Research for the Future Program," the Japan Society for the Promotion of Science.

[16] Soken/State Statistical Bureau, People's Republic of China(1997) 'Chinese Wealth and Power'(in Japanese),NEC Creative.

[17] Development Research Center of the State Council of P.D. China and Editorial Board of China Economic Yearbook(1992-1997) 'China Economic Yearbook(1992-1997)'(in Chinese),Economic Management Press(China Economic Yearbook Press from 1994).

[18] State Statistical Bureau, People's Republic of China(1995)'China Input-Output Table(1992) '(in Chinese),China Statistics Publishing House.

[19] State Statistical Bureau, People's Republic of China(1992-1997) 'China Statistical Yearbook(1992-1997)'(in Chinese),China Statistics Publishing House.

[20] Statistical Bureau by Region, People's Republic of China(1993) 'Statistical Yearbook by Region(1993), 30 provinces'(in Chinese),China Statistics Publishing House.

[21] State Statistical Bureau, People's Republic of China(1993) 'China Rural Area Statistical Yearbook(1993)'(in Chinese),China Statistics Publishing House.

[22] State Statistical Bureau, People's Republic of China(1993) 'China Labor Statistical Yearbook(1993)'(in Chinese),China Statistics Publishing House.

[23] State Statistical Bureau, People's Republic of China(1993) 'China Industry Economic Statistical Yearbook(1993)'(in Chinese),China Statistics Publishing House.

[24] Tertiary Industry Census Office(1995) 'China's First Census of Tertiary Industry(1991-1992)'(in Chinese),China Statistics Publishing House.

[25] State Statistical Bureau, People's Republic of China(1996) 'China Population Statistics(1996)'(in Chinese),China Statistics Publishing House.

[26] State Statistical Bureau, People's Republic of China(1994) 'Chinese Family Income and Expenditure Survey in Urban Areas(1994)'(in Chinese),China Statistics Publishing House.

[27] State Statistical Bureau, People's Republic of China(1997) 'Survey of Price and Family Income and Expenditure in Urban Areas(1997)'(in Chinese),China Statistics Publishing House.

[28] Yang,Hong, Kong,Dejun, Yao,Yuchen, Li,Cuixia, Liu,Jianping, Li,Yangpu and Lu,Zhiping(2001) 'Research of Improvement Effect of Alkali Soil by Desulfurization Gypsum and Ashes of Bio-Coal Briquette'(in Chinese), 'Examination Meeting of Japanese and Chinese Experts for the Repression of Air Pollution and Improvement of Alkali Soil by Appling Bio-coal Briquette Technology' (in Shengyang at 27/28 August 2001).

[29] Cheng,Zhiping ed.(1998) 'China Price 50 years(1949-1998)'(in Chinese),China Price Press.

[30] Ministry of Economy, Trade and Industry/Research Institute(1994) 'Input-Output Table for Analisis of Energy Consumption and Air Pollution'(in Japanese), Tsusho Sangyo Chosakai.

[31] Ministry of Economy, Trade and Industry, Keio University and Sosiety ofInput-Output Analysis of Chinese Environmental Problem(1995) 'Common Classification between Japan and China: Input-Output Table for Analysis of Energy Consumption and Air Pollution'(in Japanese).

[32] Tsujimura, Kotaro and Kuroda,Masahiro(1973) 'General Equilibrium Analysis of Japanese Economy'(in Japanese) Chikuma Shobo.

[33] Tsujimura,Kotaro(1981) 'Econometrics' (in Japanese) Iwanami Shoten.

[34] Nakajiama,Takanobu, Asakura,Keiichiro, Washizu,Ayu, Nakano,Satoshi, Kito,Hirofumi and Ohira,Sumihiko(2000) 'Environmental Simulation by Chinese Regional Model'(in Japanese) Keio Economic Observatory Discussion Paper, no.G-71, Keio University, "Research for the Future Program," the Japan Society for the Promotion of Science.

[35] Keiichro,Asakura, Nakano,Satoshi, Washizu,Ayu and Nakajiam,Takanobu(2000) 'Environmental Simulation by Chinese Economic Model'(in Japanese) Keio Economic Observatory Discussion Paper, no.G-117, Keio University, "Research for the Future Program," the Japan Society for the Promotion of Science.

[36] Nakajima,Takanobu, Yoshioka,Kanji, Keiichro,Asakura, Nakano,Satoshi and Washizu,Ayu(2001) 'Simulation of Bio-coal Briquette Diffusion'(in Japanese),Yamada,Tatsuo ed.(2001)'An Experiment of Sustainable Development in China: Case Study of De-sulfurized Bio-Coal Briquette in Shenyang and Chengdu' Keio University Press, Chapter 6, pp.113-132.

[37] Yoshioka,Kanji, Nakajima,Takanobu and Nakano,Satoshi(2001)'An Optimum Scale of Popular-type Bio-coal Briquettes Machine'(in Japanese),Yamada,Tatsuo ed.(2001) 'An Experiment of Sustainable Development in China: Case Study of De-sulfurized Bio-Coal Briquette in Shenyang and Chengdu' Keio University Press, Chapter 7, pp.133-151.

[38] Statistics Bureau, Management and Coordination Agency, Japan(1998) 'Annual Report on the Family Income and Expenditure Survey'(in Japanese),Japan Statistical Association.

[39] Yoshioka,Kanji and Mizoshita,Masako(1998) 'A Plan for the Chinese Environmental and Economic Model'(in Japanese) Keio Economic Observatory Discussion Paper, no.G-10, Keio University, "Research for the Future Program," the Japan Society for the Promotion of Science.

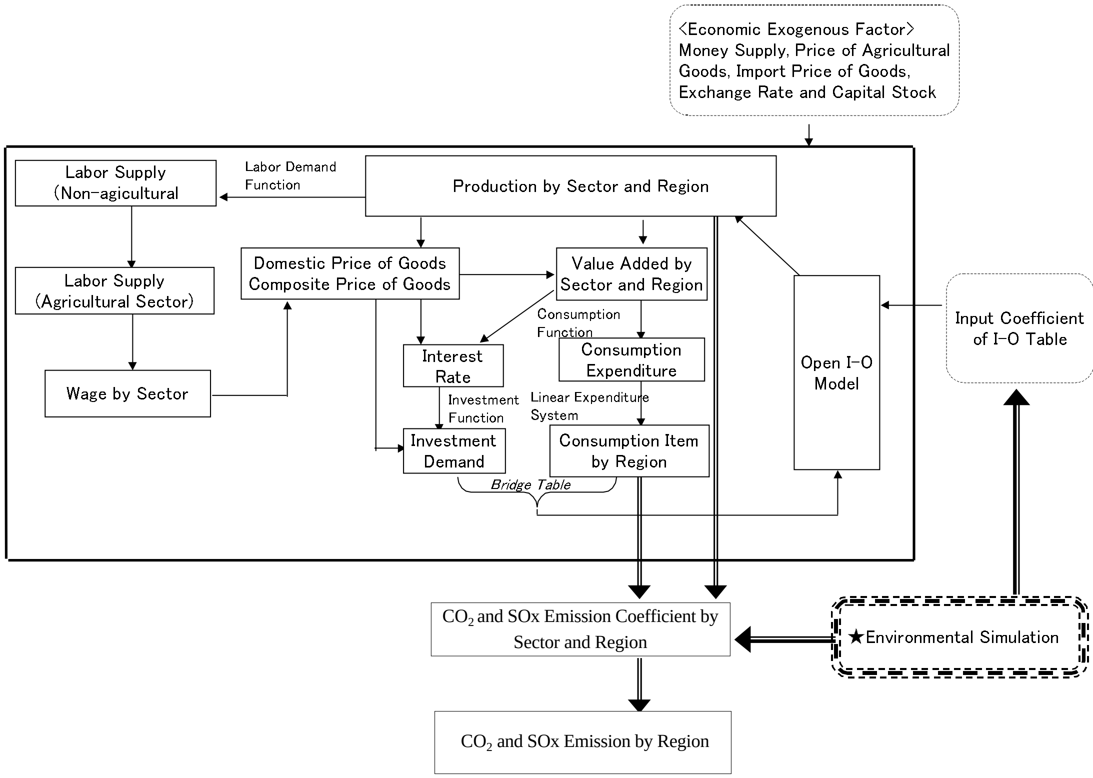

Figure 1: Flow Chart of the China Model

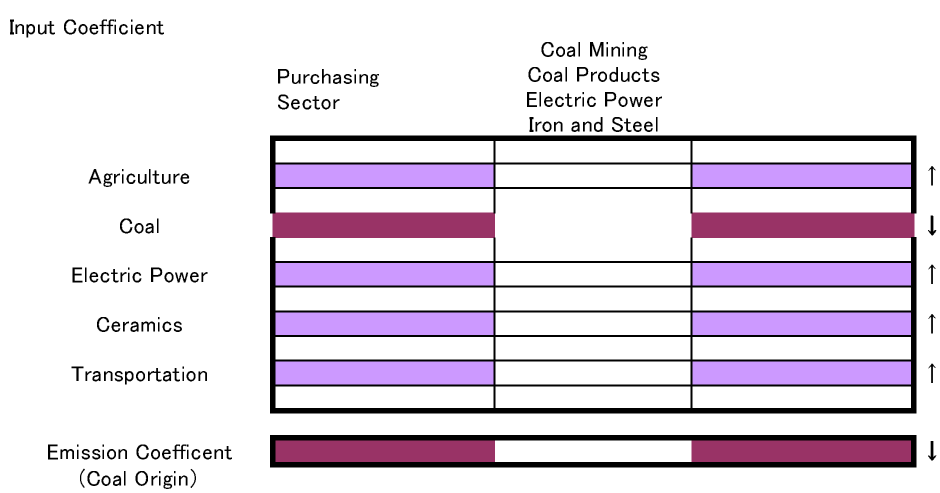

Figure 2: Change of Input Coefficients due to Bio-coal Briquette Installation

Table 1: Raw Material Composition per 1 ton of Popular Type Bio-coal Briquette in Chengdu *

Raw Material	Unit	Quantity	Unit Price (Yuan /Unit)	Inputs (Yuan)
Coking Coal	kg	664	0.095	63.08
Powdered limestone	kg	170	0.15	25.50
Sawdust	kg	124.5	0.15	18.68
Straw	kg	41.5	0.05	2.08
Electricity	kWh	30.0	0.57	17.10
Transportation				10.00

* Source: Chengdu Research Group for Bio-coal Briquette[15].
However, maintainance cost and wage are not extracted.

Table 2: Main Theoretical Values of Economic and Environmental Model

Main Economic Variables	Theoretical Value	Unit
Wage per capita (Agriculture)	1909	Yuan
Labor Supply (Total)	5.2	100 million person
Labor Supply (Agriculture)	2.6	100 million person
Labor Supply (Non-agriculture)	2.6	100 million person
Nominal Real Production	68.5	100 billion Yuan
Nominal/ Real Import	5.2	100 billion Yuan
Nominal/ Real Consumption	12.5	100 billion Yuan
Nominal/ Real Investment	8.3	100 billion Yuan
Nominal/ Real GDP	26.6	100 billion Yuan
Interest Rate	8.64	%
GDP Deflator	100	
Domestic Price of Goods/ Composite Price of Goods	1.00	
Main Environmental Variables	**Theoretical Value**	**Unit**
CO_2 Emission (CO_2 conversion)		
Industry	27.6	100 million ton
Household	4.1	100 million ton
Total	31.7	100 million ton
SOx Emission (SO_2 conversion)		
Industry	24.2	million ton
Household	3.5	million ton
Total	27.7	million ton

Table 3: Simulated Rate of Change of CO_2 and SOx by Sector*

unit:%

Sector	CO_2	SOx
Agriculture	-14.75	-81.16
Coal Mining and Dressing	-12.34	-12.34
Petroleum and Natural Gas Extraction	-3.23	-22.85
Other Mining	-35.02	-101.07
Food, Beverage and Tobacco Production and Processing	-44.20	-112.36
Textile, Garments and Leather Products	-44.13	-111.92
Paper and Paper Products	-45.47	-112.56
Electric Power, Steam and Hot Water Production and Supply	2.66	2.66
Petroleum Refining	-12.90	-24.16
Coking, Gas and Coal Products	0.34	0.34
Chemical Industry	-29.50	-86.64
Medical and Pharmaceutical Products	-44.19	-109.73
Chemical Fiber	-16.19	-72.66
Ceramic and Nonmetal Mineral Products	-40.41	-104.89
Iron and Steel Industry	-0.13	-0.13
Nonferrous Metal	-34.87	-92.13
Machinery and Electric and Telecommunications Equipment	-33.59	-96.79
Other Manufacturing	-39.05	-105.56
Construction	-18.50	-72.52
Transportation, Storage, Postal and Telecommunications Services	-16.30	-68.55
Commerce	-38.24	-108.31
Other Service	-25.02	-100.24
Industry (CO_2)	-13.79	
Household (CO_2)	0.47	-
Total (CO_2)	-11.84	
Industry (SOx)		-35.84
Household (SOx)	-	0.39
Total (SOx)		-30.49
Wage	1.47	
Labor Supply (Agriculture)	-0.45	
Labor Supply (Non-agriculture)	0.44	
Real Production	0.34	
Real Import	2.20	
Nominal Consumption	1.81	
Real Consumption	0.52	
Real Investment	0.96	
Real Interest Rate	-0.35	
Nominal Interest Rate	1.72	
Nominal GDP	2.30	
Real GDP	0.11	
GDP Deflator	102.21	
Composite Price of Goods	2.11	
Domestic Price of Goods	2.28	

*The interest rate figure represents a difference between the theoretical value and calculation.

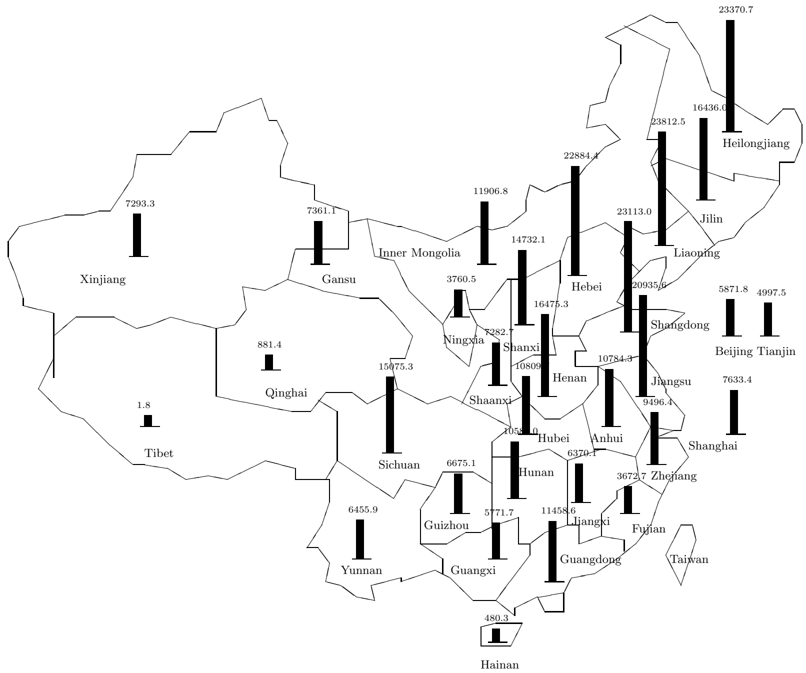

Figure 3: CO_2 Emissions in 1992(10000 t-CO_2)

1

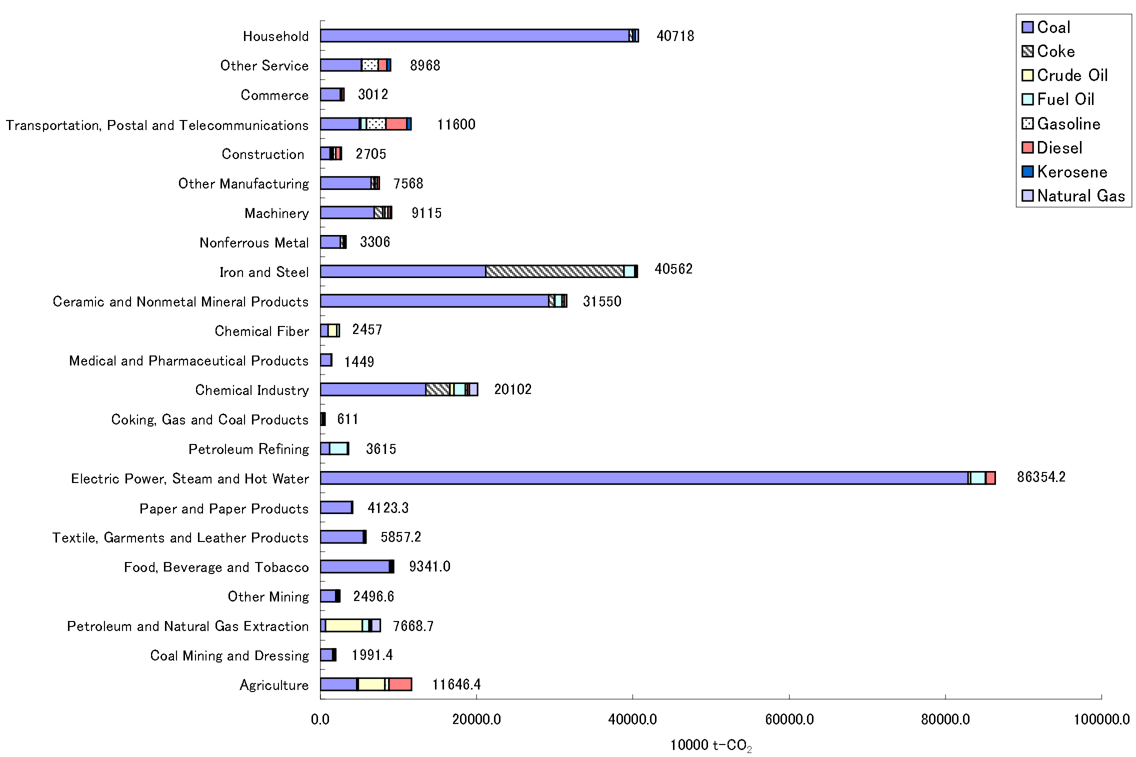

Figure 4: CO_2 Emissions by Sector in 1992(10000 t-CO_2)

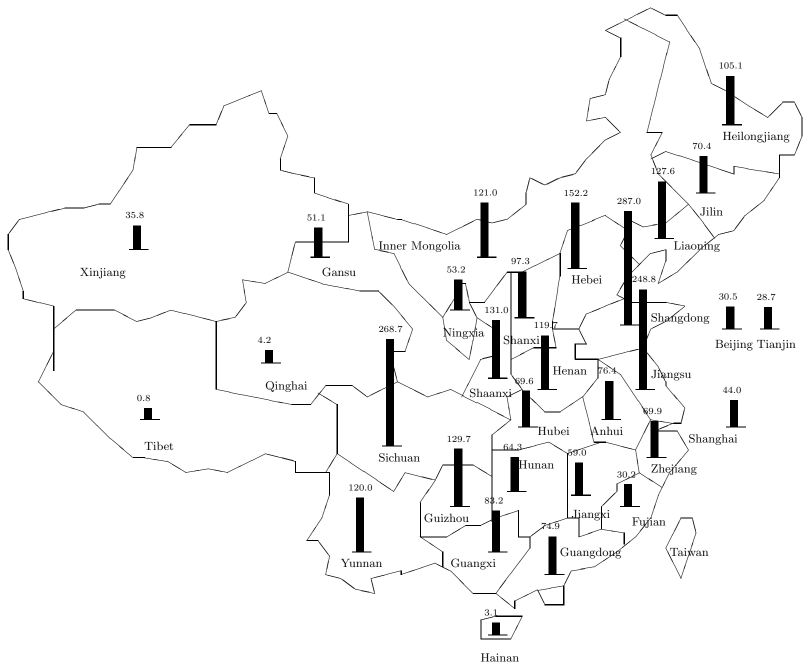

Figure 5: SOx Emissions in 1992(10000 t-SO_2)

1

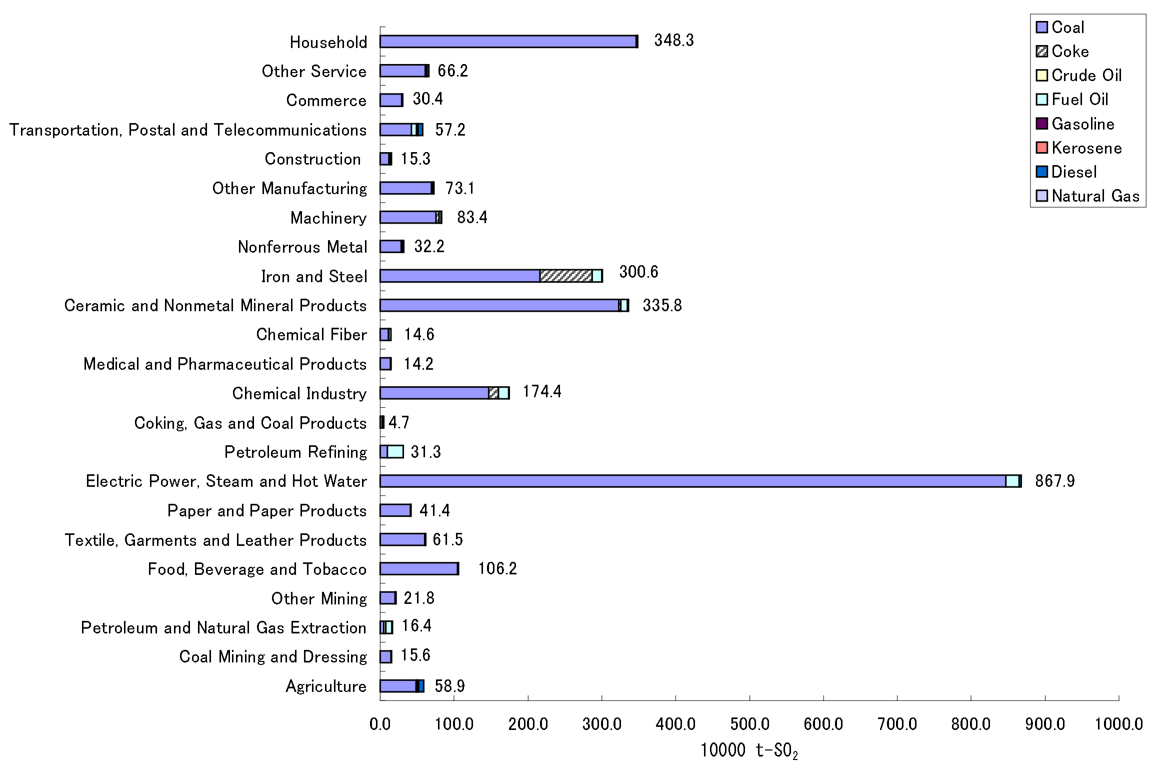

Figure 6: SOx Emissions by Sector in 1992 (10000 t-SO_2)

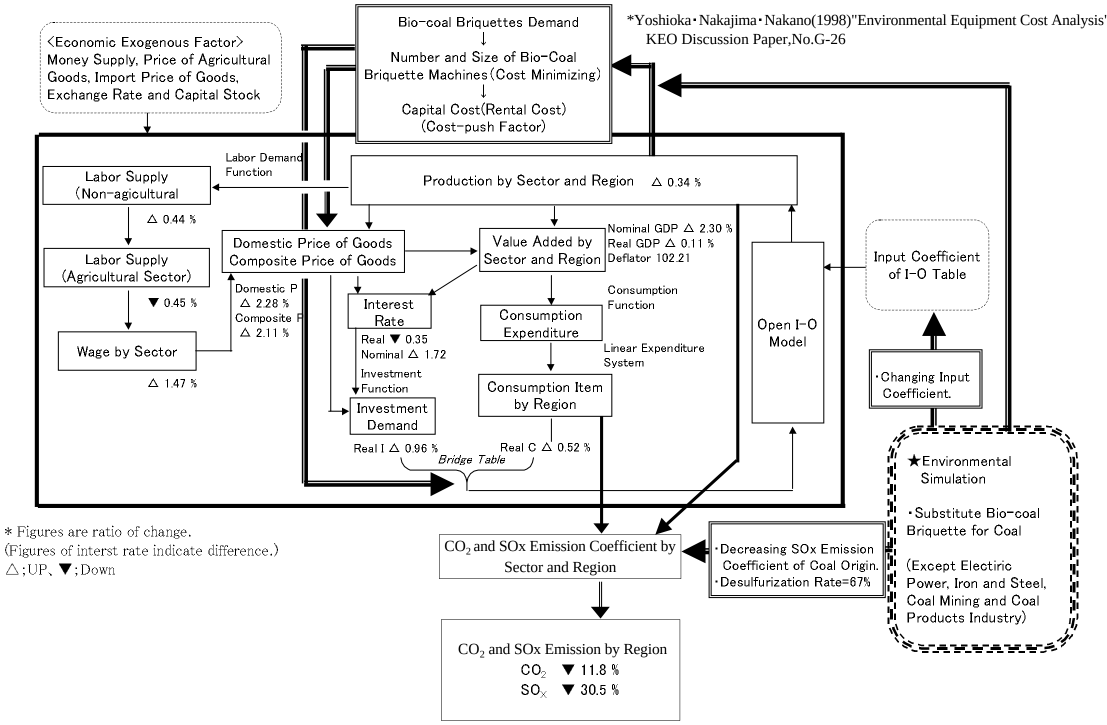

Figure 7: Installation of Bio-coal Briquettes

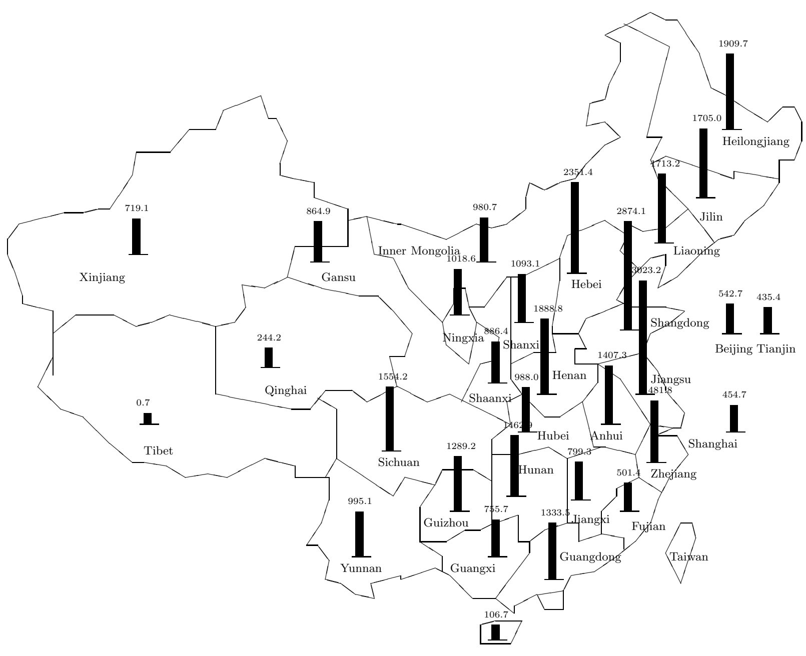

Figure 8: CO_2 Reduction Due to Installation of Bio-coal Briquettes(10000 t-CO_2)

Table 4: Manufacturing Number and Optimum Size of Bio-coal Briquette Machine per Foothold*

Sector	Optimum size ($t/hour$)	Number
Agriculture	1.83	43
Coal Mining and Dressing	-	-
Petroleum and Natural Gas Extraction	1.09	10
Other Mining	1.49	22
Food, Beverage and Tobacco Production and Processing	2.06	72
Textile, Garments and Leather Products	1.89	49
Paper and Paper Products	1.77	38
Electric Power, Steam and Hot Water Production and Supply	-	-
Petroleum Refining	1.31	16
Coking, Gas and Coal Products	-	-
Chemical Industry	2.19	102
Medical and Pharmaceutical Products	1.36	17
Chemical Fiber	1.23	13
Ceramic and Nonmetal Mineral Products	2.42	206
Iron and Steel Industry	-	-
Nonferrous Metal	1.59	27
Machinery and Electric and Telecommunications Equipment	1.97	58
Other Manufacturing	1.95	55
Construction	1.32	16
Transportation, Storage, Postal and Telecommunications Services	1.85	45
Commerce	1.59	27
Other Service	1.87	47

*We assume that bio briquette machines are produced in 30 places. This table shows value per foothold.

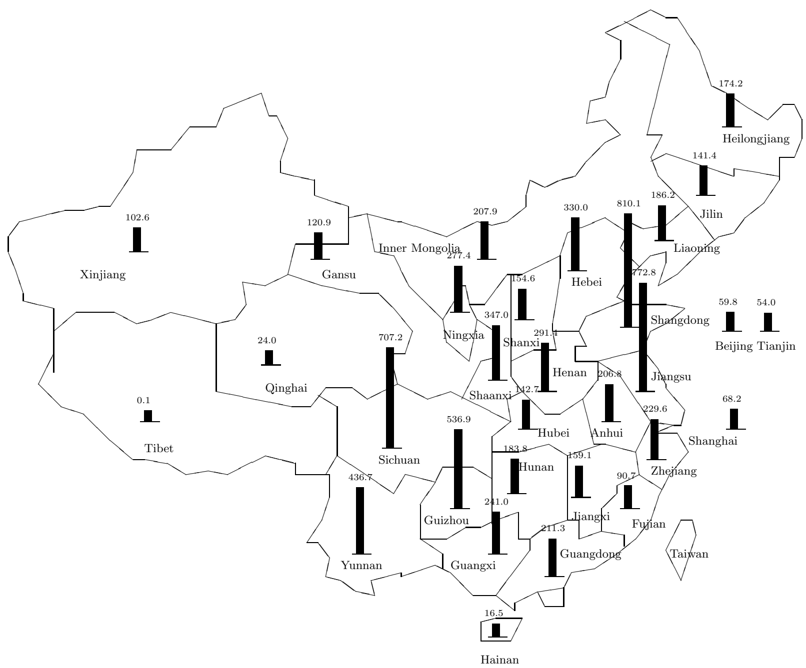

Figure 9: SOx Reduction Due to Installation of Bio-coal Briquettes(1000 t-SO_2)

Chart 1:Equation System for the Economic and Environmental Model for China

< Economic Variables >

Composite Price of Goods	$\ln p_{oi} = [s_i, (1 - s_i)] \begin{bmatrix} \ln p_i \\ \ln p_{\bar{M}i} \end{bmatrix}$	$i = 1, \cdots, 43$
Short − term Supply Function	$p_j = \sum_i p_{oi} a_{ij} + \frac{\partial L_j}{\partial x_j} w_j$	$j = 2, \cdots, 43$
Domestic Supply	$\mathbf{x} = [\mathbf{P} - \mathbf{P_o}(\mathbf{I} - \mathbf{\Delta})\mathbf{A}]^{-\mathbf{1}}[(\mathbf{I} - \mathbf{\Delta})\mathbf{P_o}(\mathbf{C} + \mathbf{I} + \bar{\mathbf{G}}) + \mathbf{P} \cdot \mathbf{E}\bar{\mathbf{X}}]$	43×1 *Vector*
Induced Import	$\mathbf{IM} = \mathbf{P_M^{-1}} \mathbf{\Delta} \mathbf{P_o}[\mathbf{Ax} + \mathbf{C} + \mathbf{I} + \bar{\mathbf{G}}]$	43×1 *Vector*
Allocation by Region of Macroeconomic Production by Sector	$x_j^k = o_j^k x_j$	$k = 1, \cdots, 30$ $j = 1, \cdots, 43$
Value Added by Region and Sector	$v_j^k = p_j x_j^k - \sum_i p_{oi} a_{ij} x_j^k$	$j = 1, \cdots, 43$
Value Added by Region	$v^k = \sum_j v_j^k$	$k = 1, \cdots, 30$
Macroeconomic Consumption Function	$C_e^k = \alpha^c + \beta^c v^k$	$k = 1, \cdots, 30$
Account Description Aggregation of Composite Price of Goods	$p_{ohl} = \Pi_i \; Conv_{il}^h p_{oi}$	$l = 1, \cdots, 5$
Consumption Demand Function by 5 Account Descriptions	$p_{ohl} c_l^k = \alpha_l^h p_{ohl} + \beta_l^h (C_e^k - \sum_m p_{ohm} \alpha_m^h)$	$k = 1, \cdots, 30$ $l, m = 1, \cdots, 5$
Conversion between Account Description and Item	$c_{jl}^k = Conv_{jl}^c p_{ohl} c_l^k$	$l = 1, \cdots, 5$ $k = 1, \cdots, 30$ $j = 1, \cdots, 43$
Consumption Demand by Region and Account Description(for Environmental Analysis)	$c_l^k = \sum_j c_{jl}^k / p_j$	$k = 1, \cdots, 30$ $l = 1 \cdots, 5$
Aggregation of Consumption Demand	$C_j = \sum_k \sum_l c_{jl}^k / p_{oj}$	$j = 1, \cdots, 43$
Aggregation of Composite Price of Goods (for Investment Function)	$p_{oI} = \Pi_i \; Conv_i^I p_{oi}$	$i = 1, \cdots, 43$
Investment Function	$\ln I = \alpha^I + \beta^I \ln \bar{Y}_{real-1} + \gamma^I (r - \frac{\Delta p_{oI}}{p_{oI}})$	
Investment Demand by Item	$I_{nom,j} = Conv_j^I I p_{oI}$ $I_j = I_{nom,j} / p_{oj}$	$j = 1, \cdots, 43$
Supply and Demand Equation of Money	$\ln(\bar{M}/Y) = \alpha^{LM} + \beta^{LM} r$	
Labor Demand Function	$L_j = \delta_j^{-\frac{1}{\beta_j^L}} x_j^{\frac{1}{\beta_j^L}} \bar{K}_{j,-1}^{1-\frac{1}{\beta_j^L}}$	$j = 2, \cdots, 43$
Labor Supply of Agricultural Sector	$L_1 = \bar{L} - \sum_{j=2} L_j$	
Wage of Agricultural Sector	$w_1 = \frac{x_1 - \sum_i p_{oi} a_{i1} x_1 - p_{k1} \bar{K}_{1,-1}}{L_1}$	
Wage Differetials	$w_j = \alpha_j^w w_1$	$j = 2, \cdots, 43$
Nominal GDP	$Y = \sum_j \sum_k v_j^k$	
Real GDP	$Y_{real} = \sum_j (p_j x_j / p_j - \sum_i p_{oi} a_{ij} x_j / p_{oi})$	
GDP Deflator	$GDPdef = Y / Y_{real}$	

i and j indicate Industrial Sector$(i, j = 1, \cdots, 43)$
k indicates Region(Province)$(k = 1, \cdots, 30)$
l indicates Consumption Account Description$(l = 1, \cdots, 5)$

$$\Delta = \begin{bmatrix} (1 - s_1) & & \\ & \ddots & \\ & & (1 - s_n) \end{bmatrix}$$

Chart 1:Equation System for the Economic and Environmental Model for China(Cont.)

$< Environmental\ Variables >$		
$Fuel\ Input\ by\ Region\ and\ Sector$	$E^k_{ju} = coe^k_{ju} x^k_j$	$k = 1, \cdots, 30$ $j = 1, \cdots, 22$ $u = 1, \cdots, 8$
$Fuel\ Input\ of\ Household\ Consumption$ $by\ Region$	$EC^k_u = \sum_l c^k_l coec^k_u$	$k = 1, \cdots, 30$ $u = 1, \cdots, 8$
$SO_x\ Emission\ by\ Region,\ Sector\ and\ Fuel$	$SO^k_{ju} = ((1 - d^k_{ju}) so^k_{ju} E^k_{ju})(64/32)$	$k = 1, \cdots, 30$ $j = 1, \cdots, 22$ $u = 1, \cdots, 8$
$SO_x\ Emission\ from\ Households\ by\ Region$ $and\ Fuel(Direct\ Combustion)$	$SOC^k_u = ((1 - dc^k_u) soc^k_u EC^k_u)(64/32)$	$k = 1, \cdots, 30$ $u = 1, \cdots, 8$
$SO_x\ Emission\ by\ Sector$	$SO_j = \sum_k \sum_u SO^k_{ju}$	$j = 1, \cdots, 22$
$SO_x\ Emission\ from\ Household$ $Consumption(Direct\ Combustion)$	$SOC = \sum_k \sum_u SOC^k_u$	
$SO_x\ Emission\ by\ Region$	$SO^k = \sum_u \sum_j SO^k_{ju} + \sum_u SOC^k_u$	$k = 1, \cdots, 30$
$SO_x\ Emission$	$SO = \sum_k SO^k$	
$CO_2\ Emission\ by\ Region,\ Sector\ and\ Fuel$	$CO^k_{ju} = (ci^k_{ju} E^k_{ju})(44/12)$	$k = 1, \cdots, 30$ $j = 1, \cdots, 22$ $u = 1, \cdots, 8$
$CO_2\ Emission\ from\ Households\ by\ Region$ $and\ Fuel(Direct\ Combustion)$	$COC^k_u = (cc^k_u EC^k_u)(44/12)$	$k = 1, \cdots, 30$ $u = 1, \cdots, 8$
$CO_2\ Emission\ by\ Sector$	$CO_j = \sum_k \sum_u CO^k_{ju}$	$j = 1, \cdots, 22$
$CO_2\ Emission\ from\ Household$ $Consumption(Direct\ Combustion)$	$COC = \sum_k \sum_u COC^k_u$	
$CO_2\ Emission\ by\ Region$	$CO^k = \sum_u \sum_j CO^k_{ju} + \sum_u COC^k_u$	$k = 1, \cdots, 30$
$CO_2\ Emission$	$CO = \sum_k CO^k$	
	$j\ indicates\ Industrial\ Sector(j = 1, \cdots, 22)$ $k\ indicates\ Region(Province)(k = 1, \cdots, 30)$ $u\ indicates\ Energy(l = 1, \cdots, 8)$	

Chart 2 :Endogenous Variables of the Economic and Environmental Model for China

$<$ *Economic Variables* $>$

C_e^k	$k=1,\cdots,30$	*Nominal Consumption by Region*
C_j	$j=1,\cdots,43$	*Real Consumption*
c_l^k	$k=1,\cdots,30 \quad l=1\cdots,5$	*Real Consumption Demand by Region and Account Description*
c_{jl}^k	$j=1,\cdots,43 \quad k=1,\cdots,30 \quad l=1\cdots,5$	*Nominal Consumption Demand by Region, Account Description and Item*
p_{oi}	$i=1,\cdots,43$	*Composite Price of Goods*
p_{ohl}	$l=1,\cdots,5$	*Composite Price of Goods by Account Description*
p_{oI}		*Composite Price of Goods (Aggregation for Investment Function)*
p_j	$j=2,\cdots,43$	*Domestic Price of Goods*
IM	43×1 *Vector*	*Induced Import*
x_j	$j=1,\cdots,43$	*Real Production by Sector*
x_j^k	$j=1,\cdots,43 \quad k=1,\cdots,30$	*Real Production by Region and Sector*
v_j^k	$j=1,\cdots,43 \quad k=1,\cdots,30$	*Value Added by Region and Sector*
v^k	$k=1,\cdots,30$	*Value Added by Region*
v_j	$j=1,\cdots,43$	*Value Added by Sector*
I	43×1 *Vector*	*Real Investment*
r		*Nominal Interest Rate*
Y		*Nominal GDP*
Y_{real}		*Real GDP*
L_j	$j=2,\cdots,43$	*Labor Demand(Non − agricultural Sector)*
L_1		*Labor Supply(Agricultural Sector)*
w_1		*Average Wage per capita(Agricultural Sector)*
w_j	$j=2,\cdots,43$	*Wage(Non − agricultural Sector)*

$<$ *Environmental Variables* $>$

E_{ju}^k	$k=1,\cdots,30 \quad j=1,\cdots,22$ $u=1,\cdots,8$	*Fuel Input by Region and Sector*
EC_u^k	$k=1,\cdots,30 \quad u=1,\cdots,8$	*Fuel Input of Household Consumption by Region*
SO_{ju}^k	$k=1,\cdots,30 \quad j=1,\cdots,22$ $u=1,\cdots,q$	SO_x *Emission by Region, Sector and Fuel*
SOC_u^k	$k=1,\cdots,30 \quad u=1,\cdots,8$	SO_x*Emission from Households by Region and Fuel(Direct Combustion)*
SO_j	$j=1,\cdots,22$	SO_x *Emission by Sector*
SOC		SO_x *Emission from Household Consumption (Direct Combustion)*
SO^k	$k=1,\cdots,30$	SO_x *Emission by Region*
SO		SO_x *Emission*
CO_{ju}^k	$k=1,\cdots,30 \quad j=1,\cdots,22$ $u=1,\cdots,8$	CO_2 *Emission by Region, Sector and Fuel*
COC_u^k	$k=1,\cdots,30 \quad u=1,\cdots,8$	CO_2 *Emission from Households by Region and Fuel(Direct Combustion)*
CO_j	$j=1,\cdots,22$	CO_2 *Emission by Sector*
COC		CO_2 *Emission from Household Consumption (Direct Combustion)*
CO^k	$k=1,\cdots,30$	CO_2 *Emission by Region*
CO		CO_2 *Emission*

Chart 3 :Exogenous Variables and Parameters of the Economic and Environmental Model for China

$\bar{\mathrm{G}}$	43×1 *Vector*	*Real Government Consumption*
$\bar{\mathrm{EX}}$	43×1 *Vector*	*Real Import*
a_{ij}	$i, j = 1, \cdots, 43$	*Input Coefficient*(A *indicates Vector*)
$p_{\bar{M}i}$	$i = 1, \cdots, 43$	*Import Price of Goods*
$\bar{p_{o1}}$		*Price of Agricultural Goods*(*Composite Goods*)
$\bar{p}_1$		*Price of Agricultural Goods*(*Domestic Goods*)
$\bar{p}_{k1}$		*Rental Cost of Capital*(*Agricultural Sector*)
$\bar{Y}_{real-1}$		*Real GDP in the previous term* (*Predetermined Endogenous Variable*)
$\bar{L}$		*Total Labor Supply*
$\bar{K}_{j,-1}$	$j = 1, \cdots, 43$	*Capital Stock*(*Predetermined Endogenous Variable*)
$\bar{M}$		*Money Supply*
s_i	$i = 1, \cdots, 43$	*Share of Domestic and Import Goods*
o_j^k	$k = 1, \cdots, 30 \quad j = 1, \cdots, 43$	*Distribution Coefficient of Production by Region*
$Conv_{il}^h$	$i = 1, \cdots, 43 \quad l = 1, \cdots, 5$	*Converter between Account Description and Item for Composite Price of Goods*
$Conv_{jl}^c$	$j = 1, \cdots, 43 \quad l = 1, \cdots, 5$	*Converter between Account Description and Item for Consumption Demand*
$Conv_i^I$	$i = 1, \cdots, 43$	*Item Aggregation Converter of Composite Price of Goods*(*for Investment Function*)
α^c, β^c		*Parameter of Macroecnomic Consumption Function*
α^h, β^h		*Parameter of Consumption Demand Fuction by* 5 *Account Descriptions*
$\alpha^I, \beta^I, \gamma^I$		*Parameter of Investment Fuction*
α^{LM}, β^{LM}		*Parameter of Supply and Demand Equation of Money*
δ_j	$j = 1, \cdots, 43$	*Parameter of Labor Demand Function*
β_j^L	$j = 1, \cdots, 43$	*Distribution Rate of Labor*
α_j^w	$j = 1, \cdots, 43$	*Coefficient of Wage Differetials*
coe_{ju}^k	$k = 1, \cdots, 30 \quad j = 1, \cdots, 22$ $u = 1, \cdots, 8$	*Input Coefficient of Fuel by Industry* (*by Region and Sector*)
$coec_u^k$	$k = 1, \cdots, 30 \quad u = 1, \cdots, 8$	*Input Coefficient of Fuel by Household*(*by Region*)
d_{ju}^k	$k = 1, \cdots, 30 \quad j = 1, \cdots, 22$ $u = 1, \cdots, 8$	*Desulfurization Rate*(*by Region and Sector*)
dC_u^k	$k = 1, \cdots, 30 \quad u = 1, \cdots, 8$	*Desulfurization Rate of Household Consumption* (*by Region*)
so_{ju}^k	$k = 1, \cdots, 30 \quad j = 1, \cdots, 22$ $u = 1, \cdots, 8$	*Sulfur Contents*(*by Region, Sector and Fuel*)
soc_u^k	$k = 1, \cdots, 30 \quad u = 1, \cdots, 8$	*Sulfur Contents for Household Consumption* (*by Region and Fuel*)
ci_{ju}^k	$k = 1, \cdots, 30 \quad j = 1, \cdots, 30$ $u = 1, \cdots, 8$	*Carbon Contents*(*by Region, Sector and Fuel*)
cc_u^k	$k = 1, \cdots, 30 \quad u = 1, \cdots, 8$	*Carbon Contents for Household Consumption* (*by Region and Fuel*)