An Input-Output Analysis on Japan-China Environmental Problem: Compilation of the Input-Output Table for the Analysis of Energy and Air Pollutants[1]

By
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Abstract

When viewed from a worldwide perspective, issues involving energy resources and the environment are undoubtedly important. We compiled the Japan-China Input-Output Tables with common industrial classifications for energy sources and air pollutants. It provides the first really accurate information with respect to energy and the generation and emission of air pollutants. Our analysis has shown that the emission of CO_2 in China is twice as high as that in Japan, and 20 times higher in the case of SOx.

1. Introduction

Nowadays, new environmental problems on a worldwide scale, such as the effects of global warming and deforestation due to acid rain, have been raised. These new environmental issues, unlike pollution problems pertaining to specified areas, such as Minamata disease, Itai-Itai disease, or Yokkaichi Asthma, which Japan has experienced in the past, are problems which threaten the global environment. As their effects spread across national borders, these environmental problems cannot be solved by the efforts of a single country. Furthermore, as these are resource issues closely related to production activities and energy consumption which are indispensable to everyday life, if these problems are not dealt with soon, they may lead to consequences that endanger economic development and in turn, endanger the lives of human beings.

In Japan, emissions of CO_2, NOx and SOx, as a proportion of the GNP, are the

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[1] This study is a joint research comprising the Ministry of International Trade and Industry in Japan, State Statistical Bureau (China), Environmental Protection Bureau (China) and Keio Economic Observatory of Keio University, headed by Professor Masahiro Kuroda (former Director of the Keio Economic Observatory, Faculty of Business and Commerce, Keio University). The authors are grateful to Miss Wong Yu Ching (Japan Center for International Finance) for her English translation. However, the authors remain responsible for the errors in this paper.

lowest in the developed world. However, in contrast to Japan or the western industrialised nations, Russia, East Europe and the Asian developing economies countries lag behind in environmental policies. In particular, they are responsible for a large share of SOx emissions. For the Asian region, China is the source of 70% of the SOx emissions, and 40% of the CO_2 emissions in the region. Therefore, efforts taken by China to improve the environment are of critical importance to Asia and the rest of the world.

At the Earth Summit held in Brazil between 3-24 June 1992, 155 nations, including Japan, signed the Framework Convention on Climate Change; the signatories from the developed countries agreeing to reduce, by the end of the 1990s, the emission of greenhouse gases such as CO_2 to those of 1990 levels.

However, the Earth's environment is faced with the dilemma that a certain level of economic growth is necessary for the maintenance and improvement of its environment; while at the same time acknowledging that economic growth may hasten environmental destruction. Consequently, the usual point of contention during discussion of energy and environmental issues at the international level, lies in who should bear the costs or whether it is feasible to treat all countries as equal, regardless of differences in national income. Hence, if we were to formulate energy saving and environmental policies in which international agreements, including the developing countries, are likely, we have to search for the 'solution' from the perspective of combining the three issues: namely, energy supply, the maintenance and improvement of the Earth's environment and economic growth together.

2. Compilation of the Japan-China Input-Output Table; with Common Classification for the Analysis of Energy and Air Pollutants

In 1970, the International Pollution Symposium, organized by the International Social Science Council, was held in Tokyo. In a speech given by Professor Wasilly W. Leontief, ('Environmental Repercussions and the Economic Structure: An Input-output Approach'[2]), the Professor proposed make explicit reference to pollutants in the input-output table, which is generally understood as those products (or by-products or waste products, etc.) with no market value. This allows us to analyze the relationship between production activities and pollution generation; the cost of preventing pollution, and the effects of pollution preventing activities on production activities or industrial structure. The main purpose of the models proposed by Leontief was to measure the social costs involved in achieving an environmentally acceptable standard.

The Input-Output Table for Pollution Analysis for the year 1968 was compiled by the Research and Statistics Department of the Ministry of International Trade and

[2] Leontief, W.W. (1970), 'Environmental Repercussions and the Economic Structure: An Input-output Approach', *Review of Economics and Statistics*, Vol.52, No.3, pp.262-271.

Basic Transaction (Monetary Value Table) Intermediate Transaction Section 45×45	Same as L.H.S Final Demand Section 45×6
Value-added Section 4×45	
Energy Related Material (Physical Unit Table) Japan: 37×45 China: 17×45	Same as L.H.S Final Demand Japan: 37×6 China: 17×6
Energy Consumption (Physical Unit Table) Japan: 31×45 China: 16×45	Same as L.H.S Final Demand Japan: 31×2 China: 16×2
Calorie Table Japan: 31×45 China: 16×45	Same as L.H.S Final Demand Japan: 31×2 China: 16×2
Atmospheric Pollutant Substance's Contents and Emission Table CO_2, SO_x, (NO_x), Soot & Dust Japan: 5×45 China: 5×45	Same as L.H.S Final Demand Japan: 5×2 China: 5×2

Note: L.H.S: Left-hand side

Figure 1: Conceptual Diagram of the Japan-China Input-Output Table for Energy and Atmospheric Pollution Analysis

Industry (MITI), the Industrial Location & Environmental Protection Bureau and the Kanton Bureau of International Trade and Industry in 1971. The Input-Output Table for Pollution Analysis for 1973 at a national level was later compiled in 1976.

The table compiled by MITI was an expanded version of Leontief's, and it contained the following features,

(1) Polluting agents comprise the oxides of sulphur, water pollution, suspended solids and industrial waste. The above selection of polluting agents was due to the fact that the main pollution problems at that time were Itai-Itai disease and Minamata disease, both caused by water and soil pollution; and Yokkaichi Asthma and photochemical smog caused by SOx and NOx.

(2) Sources of pollution are limited to the industrial sectors: pollution generated in households (waste gas from vehicles and rubbish, etc.) is not considered.

(3) In Leontief's framework, it is assumed that the cost of anti-pollution is the same regardless of whether it is performed by the public sector or the industrial sectors. On the other hand, in MITI's table, the cost of anti-pollution activity varies according to industries. Hence, this allows us to analyze the relations between pollution and changes in industrial structure, as well as economic development.

(4) Besides the input coefficients, investment is also divided into various components. This makes possible the construction of a dynamic model on pollution prevention.

MITI's table showed that the rate of removal of polluting agents in the manufacturing industries was very low, being 7.9% for sulphur oxides, 16.8% for water pollution and 30.0% for suspended solids.

China has, until recently, compiled an input-output table based on a system of material products balances (MPS), which differs from the system adopted by Japan or western countries. Two years ago, the input-output table (1987) based on SNA was first compiled, thus making comparison with Japan possible. From this, the Japan-China Input-output Table for the Analysis of Energy and Air Pollutants is compiled, with the co-operation of the Ministry of International Trade and Industry in Japan, State Statistical Bureau (China), Environmental Protection Bureau (China) and Keio Economic Observatory (KEO) of Keio University. This compilation of a two-country input-output table for environmental analysis is the first attempt in the world.

The Japan-China Input-output Table for the analysis of energy and air pollutants consisted of five parts. As shown in Figure 1, the Japan-China Input-Output Table follows the format of the Japan Input-output Table for Environmental Analysis compiled by KEO. While the analyses by the KEO group focus on cases in which pollutants such as CO_2 are not being eliminated, the Japan-China Input-Output Table also takes into consideration the generation and emission of soot and dust, and SOx [3].

[3] See Yoshioka, Hayami and Wong (1995).

The process of compilation is summarized as follows:

Firstly, 45 sectors are included in the basic transaction table. As the dummy sectors and private transport sector of Japan are not found in the Chinese input-output table, their values are distributed in intermediate transactions. Although the initial Chinese input-output table is not divided into exports and imports, they are disaggregated into exports and imports with the help of the State Statistical Bureau.

Secondly, the physical unit table for energy is compiled for energy related materials and other SOx and CO_2 generating materials (limestone, iron ore and copper ore, etc.). For Japan, aggregation is based on the energy physical unit table compiled by the KEO group and new estimations of the inputs of briquettes and oval briquettes are made. For China, in addition to the data compiled by the State Statistical Bureau, we compiled, by ourselves, the figures for limestone and the treatment of waste fluid pulp.

Thirdly, as the physical unit table for energy consumption consists of raw materials used in the manufacturing of products such as crude oil or raw material coal, and materials used in combustion in the respective sectors, they are converted into a combustion base. We estimated the emission of air pollutants by multiplying energy inputs in combustion base with the emission coefficients.

However, as for the estimation of SOx in Japan, an estimation is made separately for mobile and fixed sources of generation. For China, in sectors like oil refining, chemical, gas and coal products and coke, estimates of SOx from raw material usage and from consumption are made separately.

Fourthly, the calorie table is obtained by converting energy consumption into calorific values. Emission quantity is estimated by the method whereby calorie consumption is multiplied by calorie equipment emission coefficient[4].

3. Estimating the Emission of Air Pollutants

Air pollutants focused on this paper include CO_2, SOx, soot and dust, and NOx. For CO_2 and Sox, they are estimated separately for each country, as the fuels used in the respective countries contain different levels of carbon and sulphur. The generation of CO_2 is estimated based on carbon content, whereas for Sox, both generation and emission quantities are estimated. For soot and dust, only the emission quantity is estimated for Japan; whereas generation, removal and emission quantities are estimated for China. However, emission coefficients of NOx are not available for China; estimation is based on America emission coefficient figures provided by the

[4] In estimations done by the KEO group and the Science and Technology Agency, the following method is used in principle, calorie consumption × calorie equivalent emission coefficient = emission quantity. See Yoshioka, K., Tonooka, Y., Hayami, H., Ikeda, A. and Suga, M., 'Compilation of the Input-Output Table for Environmental Analysis', KEO Occasional Paper, No. 26, October 1992; and Science and Technology Agency (ed.), *Energy Usage in Asia and the Earth's Environment*, Ministry of Finance Publishing Bureau, April 1992.

Environmental Protection Bureau. For the estimation of soot and dust in both countries, we only estimate the generation from fixed generation sources, thus omitting mobile generation sources such as motor vehicles.

3.1. Estimation of Air Pollutants in Japan

For the generation of CO_2 in Japan, the estimation results obtained by the KEO group are used. However, for CO_2 emission from briquettes, oval briquettes and gases, a new estimation is made based on the carbon balance table drawn up from information gathered from interviews.

For the estimation of SOx, energy is divided into that used in fixed generation sources and that used in mobile production sources. As for fixed generation sources, the sulphur content is classified by use and type of energy; the SOx generation then being estimated accordingly. Emissions from fixed generation sources are then estimated by multiplying the quantity generated with the rates of removal obtained from the 'Survey on Air Pollutants Emission'; jointly carried out by the Environmental Agency and MITI. SO_2 emissions from, for instance, the heating systems in buildings, are distributed using energy input coefficients of head offices based on data from the Tokyo Metropolitan Input-Output Table. With regard to mobile generation sources, the respective energy consumption rates are multiplied by the emission coefficient for automobiles, and the emission coefficient for airplanes, respectively. As for SOx from ships, this is estimated from the sulphur content of the various kinds of petroleum used in ships. Reduction rates in each sector are the ratios of SOx emissions to the aggregation of sulphur content.

The sulphur content and emissions from cement, coke, briquettes and oval briquettes are estimated from the sulphur balance table drawn up from information gathered in interviews.

As for the estimation of soot and dusts emissions, we combined the information obtained from the survey on air pollutants and energy consumption in the input-output table.

Finally, the estimation for NOx is obtained by aggregation and refinement of the KEO group's estimation results.

3.2. Estimation of Air Pollutants in China

For the estimation of CO_2 in China, carbon content data for coal provided by the Environmental Protection Bureau in China possibly do not co-ordinate with coal consumption as recorded in energy statistics[5]. Hence, the estimate is based on the Science and Technology Agency's study of the relation between carbon content and heat generation per kilogram. Further, lower calorific values are revised to higher

5 Regarding this point, and the coal and sulphur content in briquettes are kindly provided by Mr. Nagasawa, Director of the Kasukabe Laboratory, Institute of Coal Technology, and Mr. Araki, Plant Manager of Hashimoto Shiogama Pte. Ltd.

calorific values, based on Japanese information. For petroleum and gases, estimations are made on the basis of data provided by the Environmental Protection Bureau in China, with a part of the estimation being supplemented with carbon content data in Japan. As statistical data on the input of limestone are not available in China, SOx from limestone is estimated on the basis of cement production. As for pulp fluid waste, the estimation is made from the output of pulp, based on China's disposal rate data. The output figures of briquettes and oval briquettes are estimated from raw material inputs, and their consumption is made equal to output. Accordingly, a part of the coal input in the coal product sector is assumed to be used as raw materials for processed coal, and the estimation made by including the mass of limestone used as adhesive.

With regard to SOx, the quantity generated is estimated separately from the sulphur content in different fuel types and different uses. As for sulphur generated from the smelting of non-ferrous metal, we made use of data supplied by the Environmental Protection Bureau. For sulphur that is absorbed in the production process of cement, the estimation is made based on data from a Japanese company which uses a rotary kiln. In the case of cement, even without having removal activity carried out, the sulphur element is taken in by the products, and hence our estimations are based on the sulphur balance table compiled from information obtained from interviews. A similar procedure also applied to coke[6].

In the other sectors, the sulphur elements contained in fuels may be combusted or left intact. The latter case refers to sulphur elements contained in ashes, slag, or soot and dust. In this analysis, our estimation of SOx emissions exclude the non-combusted portion. In more concrete terms, in the case of Japan, SOx emitted from chimneys and exhaust fumes from automobiles are estimated from an actual investigation, and the ratio of emission to generation is taken as the reduction rate. A similar technique is used in the case of China, and reduction rates by sector are set up based on data provided by the Environmental Protection Bureau. However, for briquettes and oval briquettes, the generated quantity is reduced due to the high content of non-combusted sulphur elements.

As for the estimation of soot and dust, we have relied entirely on data provided by the Environmental Protection Bureau.

Finally, in the case of NOx, we use American estimates supplied by the Environmental Protection Bureau.

4. An Overview of the Japan-China Input-Output Table with Common Classification for the Analysis of Energy and Air Pollutants

Both Tables 1 and 2 show the original 45-sector table aggregated into three sectors in

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6 We received valuable information from Mr. Tsuru of Tokyo Gas on sulphur and carbon content in coke production.

Table 1: Input-Output Table for Energy and Atmospheric Pollution Analysis: Japan (3-Sector, 1985)

	1:Primary Industry	2:Secondary Industry	3:Others	4:Endogeneous Total	5:Domestic Final Demand	Total Domestic Demand	6:Exports	7:Imports
01:Primary Industry(1 mil yen)	1534563	27850404	2153502	31538469	4557422	36095891	94841	-17095917
02:Secondary Industry(1 mil yen)	4166825	133133532	55237343	192537700	87253794	279791494	38691134	-15337091
03:Others(1 mil yen)	2853438	40968091	68715632	112537161	228468254	341005415	8758677	-5185181
04:Intermediate Inputs(1 mil yen)	8554826	201952027	126106477	666819263	320279470	987098733	47544652	-37618189
05:Value-added(1 mil yen)	10539989	101193510	218472434	330205933				
06:Total(1 mil yen)	19094815	303145537	344578911	997025196	320279470	1317304666	47544652	-37618189
07:Coal(10,000t)	318	843675	22365	866358	704	867062		
08:Crude Oil and Petroleum(kl)	8673752	59642784	68550080	136866616	26470504	163337120		
09:Electricity(mil.kWh)	4160	233804	162611	400575	135002	535577		
10:Coal(Tcal)	209	570200	14836	585257	424	585681		
11:Crude Oil and Petroleum(Tcal)	79633	577231	626027	1282890	226692	1509582		
12:Electricity(Tcal)	3578	201071	139844	344493	116102	460595		
13:Energy Inputs(Tcal)	87092	2192120	949513	3226214	463279	3692004		
14:CO_2 Contents(CO_2:10^3t)	23373	623909	246055	893337	93174	986511		
15:SO_X Contents(SO_2:t)	68992	2609547	812323	3490862	4836	3495698		
16:SO_X Emission(SO_2:t)	40986	669070	440181	1150236	2868	1153104		
17:Soot and Dust Emission(t)	1369	77128	21983	100648				

Table 2: Input-Output Table of Energy and Atmospheric Pollution Analysis: China (3-Sector, 1987)

	1:Primary Industry	2:Secondary Industry	3:Others	4:Endogeneous Total	5:Domestic Final Demand	Total Domestic Demand	6:Exports	7:Imports
01:Primary Industry(10 thousand yuan)	7257776	19287304	2734419	29279499	244379810	53659309	2788781	-1549757
02:Secondary Industry(10 thousand yuan)	8218039	56868979	25653824	90740842	42610955	133351797	12357462	-16012518
03:Others(10 thousand yuan)	2115365	11739794	8512125	22367284	49423161	71790445	568454	-325630
04:Intermediate Inputs(10 thousand yuan)	17591180	87896077	36900368	142387625	116413926	258801551	15714697	-17887905
05:Value-added(10 thousand yuan)	37307153	41800664	35132901	114240718				
06:Total(10 thousand yuan)	54898333	129696741	72033269	256628343	116413926	373042269	15714697	-17887905
07:Coal(10^4t)	6693	63605	7318	77616	17186	94803		
08:Petroleum(10^4t)	1337	4235	2765	8337	274	8611		
09:Electricity(10^8kWh)	773	3571	348	4693	292	4985		
10:Coal(Tcal)	369797	3667336	400644	4437778	975796	5413574		
11:Petroleum(Tcal)	135775	425851	282288	843909	27898	871807		
12:Electricity(Tcal)	66498	307078	29934	403510	25140	428650		
13:Energy Inputs(Tcal)	611231	4579704	735632	5926567	1060544	6987111		
14:CO_2 Contents(CO_2:10^3t)	179917	1597954	235978	2013849	362199	2376048		
15:SO_X Contents(SO_2:t)	1491976	15965786	1860191	19317953	4080806	23398759		
16:SO_X Emission(SO_2:t)	1456112	13412882	1785783	16654778	3672725	20327503		
17:Soot and Dust Emission(t)	1593047	14592408	1988529	18173984	854760	19028744		

both Japan and China. Furthermore, with respect to energy in physical units, these are displayed in broad categories such as 'coal' or 'petroleum'[7]. As the Japanese basic transaction table is split to show sectors such as private transport and the dummy sectors, the values are different from figures published in the 1985 Input-Output Table. Energy consumption in Japan is based upon figures in the physical unit table attached to the 1985 Input-output Table, with the deficient parts being supplemented by data from *Statistics on Production Activities* and *The Structure Survey of Energy Consumption in Commerce, Mining and Manufacturing*.

4.1. A Comparison of Energy Structure

Firstly, Japan's dependency on coal accounted for 16% of the energy total; with the largest part being used in the secondary sector and the production of electric power and gas. In contrast, 75% of the total energy in China is supplied by coal, and the input into the secondary sector constituted 68% of the total coal consumption. In addition, households accounted for 18% of the total coal consumption. Following coal are petroleum and electric power, each constituting only about 6% of the total energy. On the other hand, 40% of the total energy consumption in Japan is supplied by petroleum. Other than petroleum, supplies from coal and electric power constitute 15% and 12.5%, respectively.

Next, in terms of energy consumption structure, about 60% of the total energy consumption in Japan is in the secondary sector, which is lower than the 65% in China. In contrast, whereas 26% of the total energy is consumed by the tertiary sector in Japan, the corresponding is only 11% for China. On the contrary, energy consumption in China is high in both households and the primary sector.

For the types of energy consumed in the respective sectors, whereas coal and petroleum occupy about same portions in the secondary sector in Japan, coal constitutes the greatest share in China. In Japan, the use of electric power is greater in households and the tertiary sector.

Japan's dependency on petroleum is high in all sectors, including households. On the other hand, in the case of China, instead of petroleum, both the secondary sector and households depend more on electric power. The above differences between Japan and China could be attributed to the difference in the increase in automobiles in both countries.

4.2. A Comparison of the Relative Composition of Air Pollutants

The total CO_2 generated in China is estimated to reach 2.376 billion tons (in molecular mass of CO_2; or 0.648 billion tons in molecular mass of carbon), as compared to the total emission of 0.987 billion tons in Japan (in molecular mass of CO_2; or 0.300 billion tons in molecular mass of carbon). In China, 70% of CO_2 is produced by coal, with the

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[7] Detailed tables will be published from Tsusho-sangyo-chosakai as 'Japanese and Chinese Input-Output Tables for Energy Consumption and Atomospheric Environments Analysis' on June 1994.

secondary sector (67%) and households (15%) generating 83% of the total; while the tertiary sector generates 10% of the total CO_2. In Japan, generation rates by the secondary sector and households are 63% and 10%, respectively, but the share contributed by the tertiary sector can reach 25%, which is higher than that in China. In the case of Japan, as a large amount of coal is used in the secondary sector, this results in the high generation of CO_2.

Generation of SOx in China amounted to 23.4 million tons (in molecular mass of SOx), which is in sharp contrast to the 3.5 million tons in Japan. The greater the amount of coal with a high sulphur content used, the higher the generation of SOx. In Japan, the share of SOx is high in the secondary sector (75%), which together with the tertiary sector, constitutes 97% of the total generation. Contrastingly, in the case of China, the share contributed by the secondary sector is 67.3%, followed by 8% from the tertiary sector and 17% from households. As households in Japan contribute only 0.1% of the total generation, the problem of SOx in Japan is related to the industry. However, the same does not apply for China.

Emissions of SOx amounted to 20.31 million tons in China, as compared to the 1.15 million tons emitted in Japan. Of the total 1.15 million tons emitted, 38% is from the tertiary sector. With removal measures being carried out in the secondary sector, emissions are lower than the quantity generated.

As for soot and dust, emissions from the secondary sector constitute 77% of the total in both Japan and China. Although there is no analysis of emissions of soot and dust from households, about 4% of the emission is from households in the case of China. Emissions from the tertiary sector are as high as 22% in Japan, which is relatively higher than the corresponding 10% in China. As measures on the reduction of soot and dust have for long focused on the secondary sector, the above estimates suggest that we should also focus on the tertiary sector in the future.

5. A Comparison of Generation and Emission Coefficients of Air Pollutants in Japan and China

The differences in the emission quantities of air pollutants in Japan and China could be attributed to the following three factors. The first factor concerns whether removal activity is being carried out. This has a great effect on the emission of SOx, soot and dust. The second factor lies in the differences in the type of energy consumed. The main source of energy in China is coal, which contains high levels of both sulphur and carbon, in contrast to Japan, which mainly relies on petroleum. The third factor is in the difference in energy consumption per unit of product. With equipment that is low in heat efficiency, a greater quantity of energy input will be required for the same output. Hence, using production methods that are naturally energy saving should result in a simultaneous rise in heat efficiency and environmental protection.

5.1. A Comparison of SOx Reduction Rates

The SOx reduction rate is found to be on average 67% in Japan, as compared to 14% in China. Desulfurization equipment for removing SOx is almost non-existent in China. The quantity of SOx reduced in China consists mainly of ashes left in boilers of low efficiency. In Japan, the desulhurization rates of electricity, chemical, iron and steel, non-ferrous metal and metallic products range between 75-90%. In the case of China, the reduction rate remains low at 4% even in the case of electricity.

5.2. The Calculation Method of the CO_2 Emission Coefficient Per Calorie of Energy Consumption

The operation of desulfurization equipment may have the effect of increasing energy needs. To examine this effect, we can compare the emission per calorie of energy consumption. The rate of emission from energy consumption per calorie, is usually the emission coefficients defined by energy type or boiler type. However, in this paper, we compare the emission coefficients per calorie consumed aggregated by sector. The differences will basically reflect the composition of fuels used. In other words, using coal which contains high levels of carbon and sulphur will increase the quantity of emission. In comparison, using gas containing a high level of hydrogen will reduce the coefficients. However, the problem here is that depending on whether electric power or heat supply is included as calorie input, the interpretation of the values will change accordingly. In the case of Japan (in which the utilization rate of electric power is high), converting the amount of electricity into calories will result in a smaller value. In this paper, the following ratio is used for comparison,

(Quantity of Emission in China / Calorie of Primary Energy Consumption) /
(Quantity of Emission in Japan / Calorie of Primary Energy Consumption)

5.3. A Comparison of CO_2 Generation Coefficients Per Calorie of Energy Consumption

Limiting the calculation of calorie consumption to the case of fossil fuels, it is found that CO_2 emission coefficient of China is 1.187 times greater than that of Japan as a whole. Industries in which large differences arise are iron and steel (1.63 times) and household consumption (1.30 times). If electric power is added to fossil fuels, then the difference becomes 1.273 times. This is especially so with wood and furniture (2.87), medical products (2.72), electrical machinery (2.40), electronics (2.64) and railways (2.69), all having differences greater than 2.30 times. As the iron and steel industry in Japan produce their own electric power, and the purchase from industrial electric power is very small, the industry utilizes energy with low CO_2 emissions.

Industries in which China has lower emission coefficients (smaller than 1.0) include gas (0.90), cement (0.68), machinery (0.97), and public enterprises (0.85). Among the above industries, the reason for lower emission in the cement industry is obvious. This is because, for cement in Japan, 64% of CO_2 is generated from limestone. As data on the input of limestone are not available in China, the generation of CO_2 is estimated from the output of cement. Since China requires double the energy level used in Japan to produce the same amount of cement, a small generation coefficient results from a small numerator and a large denominator. As for the case of gases, this is probably due to the use of blast furnace gas with low calorie but high carbon content.

5.4. A Comparison of SOx Generation and Emission Coefficients Per Calorie of Energy Consumption

For SOx, great differences arise, depending on whether desulfurization is performed or otherwise. For per CO_2 ton per calorie unit of fossil fuel energy consumption, the generation coefficient is 3.30 times; whereas the emission coefficient is 8.68 times higher in China. In addition, the difference between both countries in terms of coefficients in household consumption is as high as 300 times. This is caused by the difference in sulphur content in coal, -1.2%, as compared to 0.003% in gasoline or kerosene. For the paper and pulp industry, while Japan is found to have a higher content of sulphur in the generation stage, emissions in Japan are 4.7 times smaller than in China, which emphasises the importance of desulfurization. In Japan, transport is the only industry which has a high emission as well as generation coefficient. This is due to the large number of vehicles in Japan, and crude petroleum has a high sulphur content. On the other hand, as the number of automobiles is large and the ratio of vehicles using gasoline is high, the difference in road freight transport is smaller than other industries.

5.5. A Comparison of the CO_2 Emission Coefficients Per Calorie of Energy Consumption for Soot and Dust

Soot and dust are pollutants that produce the greatest difference, showing a difference of 94 times. This is due mainly to the difference in whether an electronic precipitator is used. While we have seen an electronic precipitator on one of the factory floors which we visited, it did not seem to be operating at full capacity, due to an insufficiency in electric power.

5.6. A Comparison of Generation and Emission Coefficients Per Physical Unit

The difference in the quantity of pollutants generated or emitted depends largely on energy efficiency in the production process. Figures 2 to 6 show the above differences expressed in terms of multiplying factors. For instance, for plate glass, China requires 4.9 times calorie of fuel consumption as compared to Japan, in producing a similar 1 weight case of stake glass. Consequently, the amount of CO_2 generated is 6.75 times greater, and the amounts of SOx generated and emitted are 12.0 times and 25.3 times greater, respectively. However, we are still in the process of checking if the measurement unit of one weight case is the same in both countries. In the case of pulp,

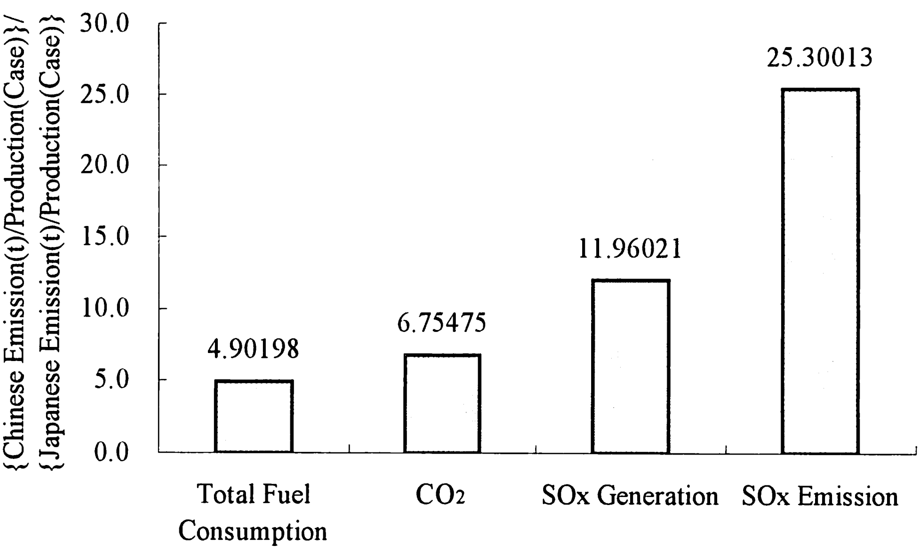

Figure 2: Emission Coefficients Per Weight Case of Plate Glass Production —A Japan-China Comparison

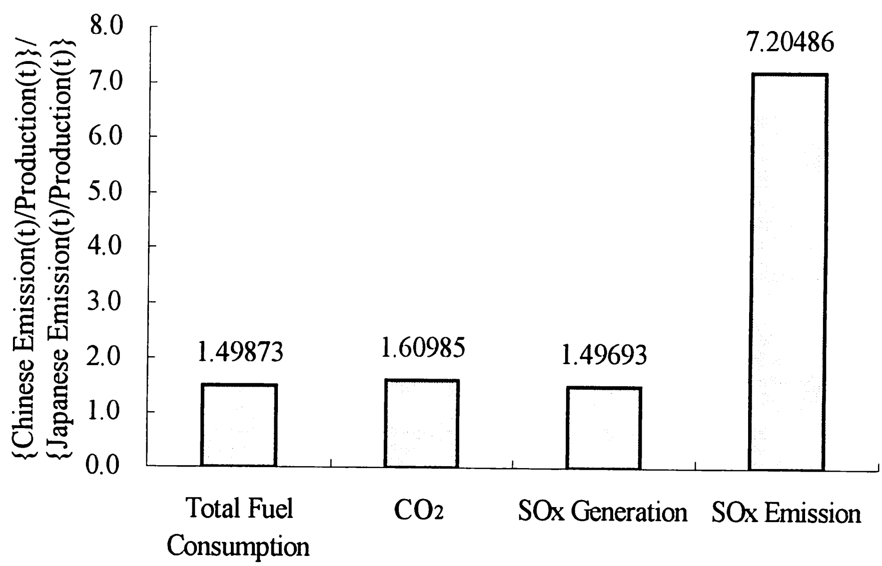

Figure 3: Emission Coefficients of One Ton Pulp Production —A Japan-China Comparison

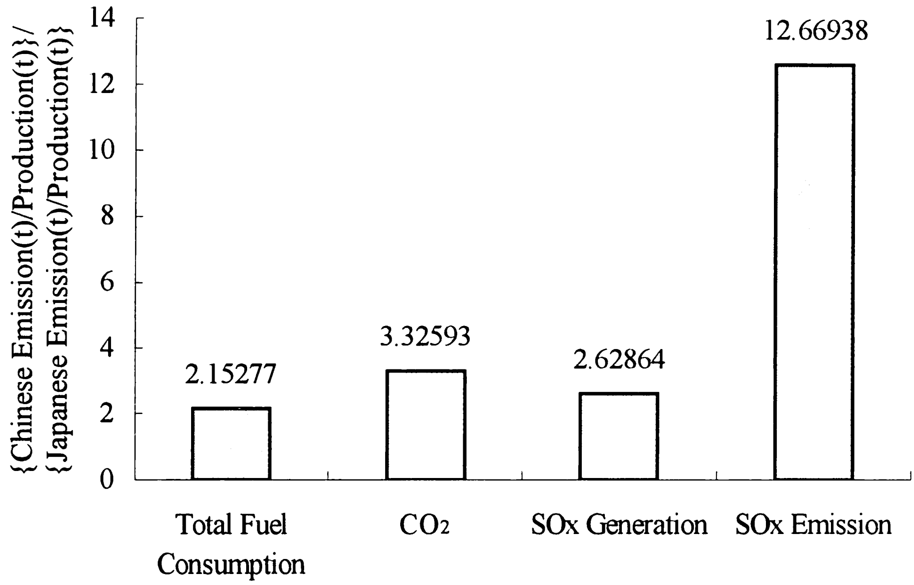

Figure 4: Emission Coefficients of One Ton Crude Steel Production —A Japan-China Comparison

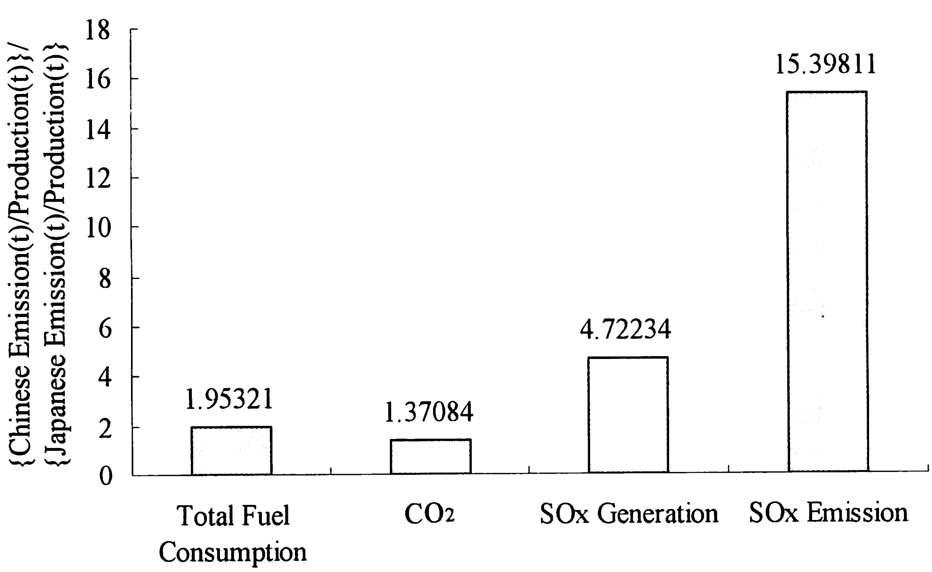

Figure 5: Emission Coefficients of One Ton Cement Production —A Japan-China Comparison

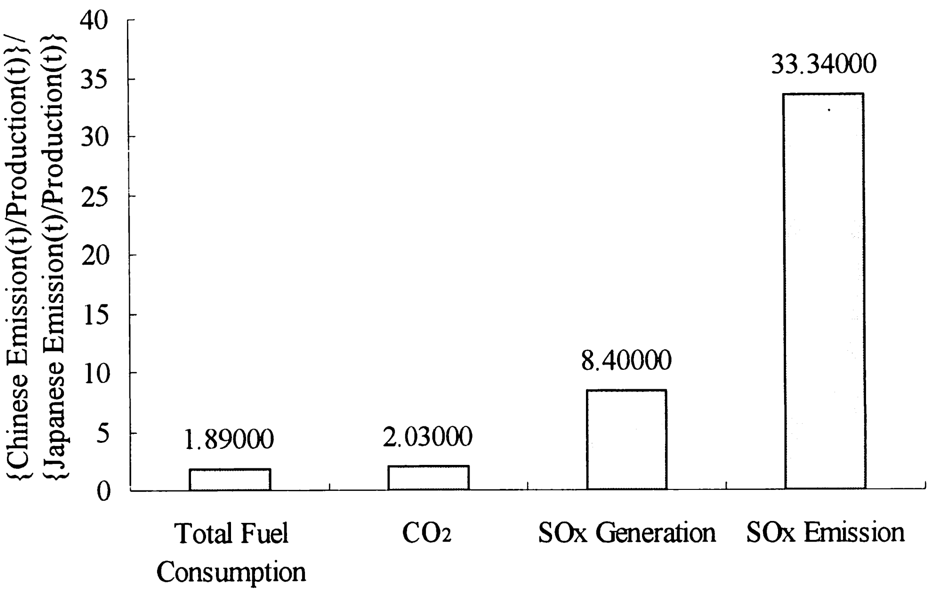

Figure 6: Emission Coefficients of One Million kWh Electricity Production (Coal and Oil) —A Japan-China Comparison

the difference in energy usage is 1.5 times per ton, and this directly affect the generation of CO_2 and SOx. As for iron and steel, fuel consumption is 2.15 times higher, and the generation of CO_2 and SOx are 3.3 times and 2.6 times greater, respectively; indicating the importance of not only energy efficiency but also the differences in energy types and recycling methods. In addition, the 12.7 times difference in the emission stage is due to the availability, or otherwise, of desulfurization equipment.

There are about twice energy productivity differences between Japan and China in cement production. But the differences of CO_2 emission per energy consumption are less than twice, since cement production induces CO_2 emission by limestone calcination other than fuels combustion. Finally, for electric power, there is a 2 times difference in CO_2 as well as fuel consumption efficiency, which is mainly affected by the rates of nuclear power generation in Japan and hydro-power in China. The difference in SOx is again due to the different in the type of energy and the existence, or otherwise, of desulfurization equipment.

6. A Comparison of Induced Generation and Emission Quantity Based on Repercussion Calculation

6.1. Power of Dispersion and Sensibility of Dispersion: A Comparison

We calculated the power of dispersion and the sensibility of dispersion to examine the characteristics of the 45-sector table aggregated from the basic tables of Japan and China[8]. Plots are revealed in Figures 7 to 8 with the power of dispersion on the X-axis and the sensibility of dispersion on the Y-axis.

A large difference in the sensibility of dispersion between Japan and China is observed. While China has high sensibility of dispersion in agriculture and forestry, and the chemical industries, Japan has relatively high sensibility of dispersion for oil refinery and public enterprises. The industries that show a high sensibility of dispersion in both Japan and China are commerce, finance and insurance. Furthermore, while in China, iron and steel and machinery have about the same sensibility of dispersion at an average level, electricity and oil refinery exhibit a high sensibility of dispersion. On the other hand, the power of dispersion are high for coke, cement and transport equipment in Japan; whereas they are high in the gas and construction sectors in China. As for cement, coke, communication and the administrative sector, both countries have similar magnitudes. These differences are basically due to the fact that Japan is dependent on petroleum and electric power, whereas China has an economic structure that depends on agriculture. Nevertheless, it should be noted that there may be effects caused by the inclusion of subsidiary sectors of Chinese agriculture.

[8] See Yoshioka, Hayami and Wong (1995).

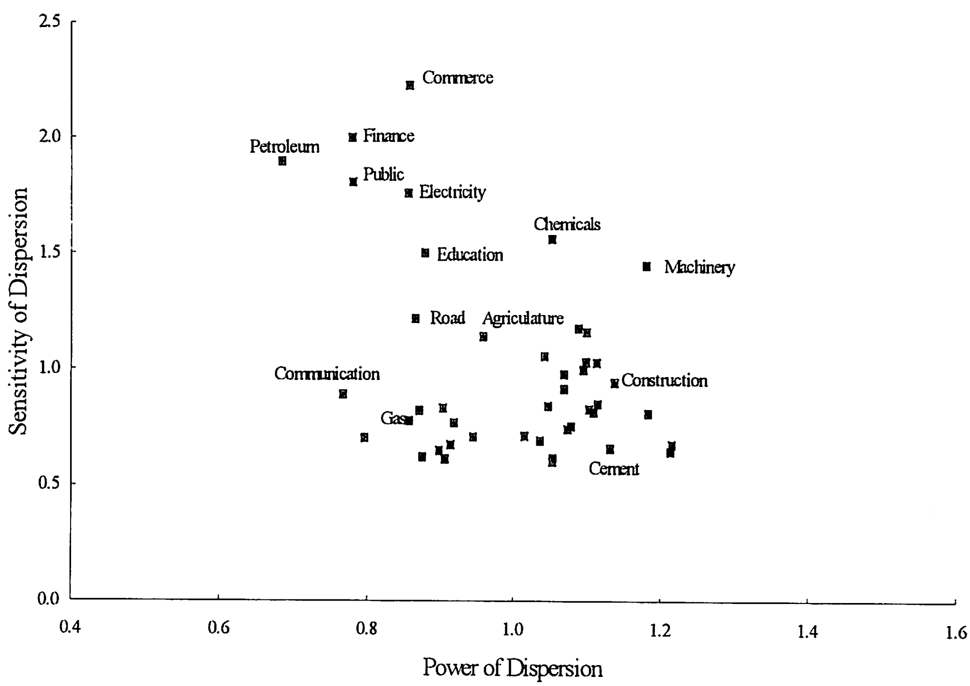

Figure 7: Power of Dispersion and Sensibility of Dispersion in Japan

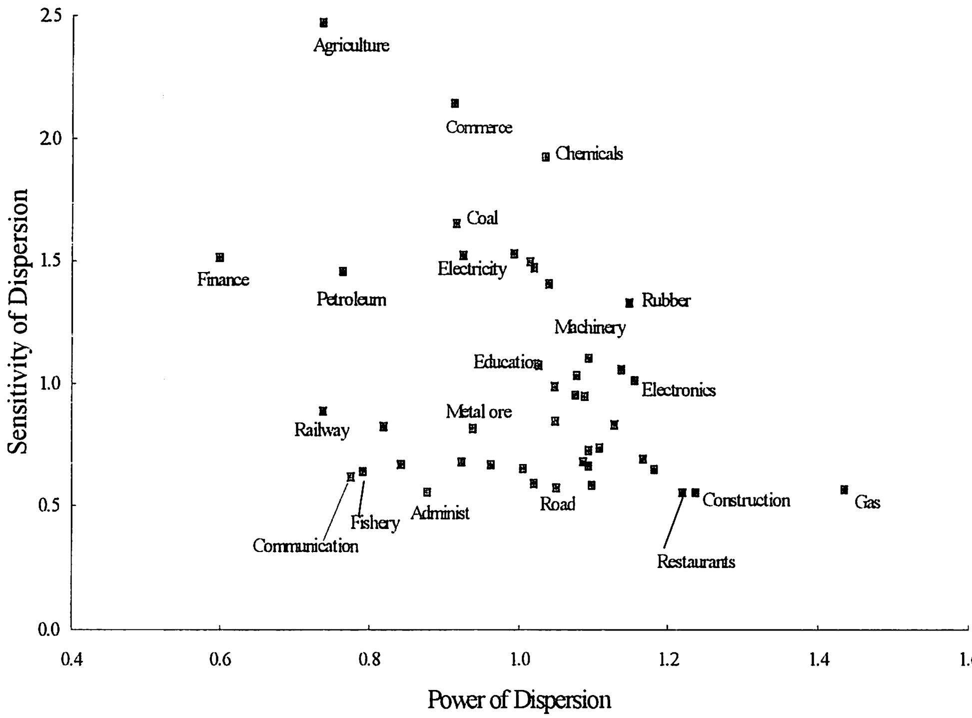

Figure 8: Power of Dispersion and Sensibility of Dispersion in China

6.2. Generation and Emission of Air Pollutants Induced by Production Activities

Next, we estimated the direct and indirect emission from the production of one unit of output in both Japan and China, respectively. In Figures 9 to 11, emissions from China are plotted on the Y-axis and emission from Japan are plotted on the X-axis of the same graph. One unit of output taken as 1 million yen in Japan and 10 thousand yuan in China. In order to have a common physical unit between the two countries, they have to be converted using a certain parity. In this paper, we do not use any PPP, so that the figures simply show relative differences of emission coefficients between countries.

As for CO_2, the induced emission from cement is higher in Japan. On the other hand, the corresponding induced emission is greater in the case of electric power in China. Together with cement, oil refining, finance and insurance, and "other transport" are industries with relatively high induced CO_2 emissions in Japan. In contrast, electric power, coal mining, iron and steel, chemicals, ceramics, agriculture and forestry are all industries with relatively high induced emissions in China.

As for the generation of SOx, China has a high emission coefficient in electricity. Other than electricity, industries such as coal mining, iron and steel, ceramics and chemicals in China also have relatively large emission coefficients. On the other hand, for the emission of SOx, sectors such as transport and oil refining have high emissions.

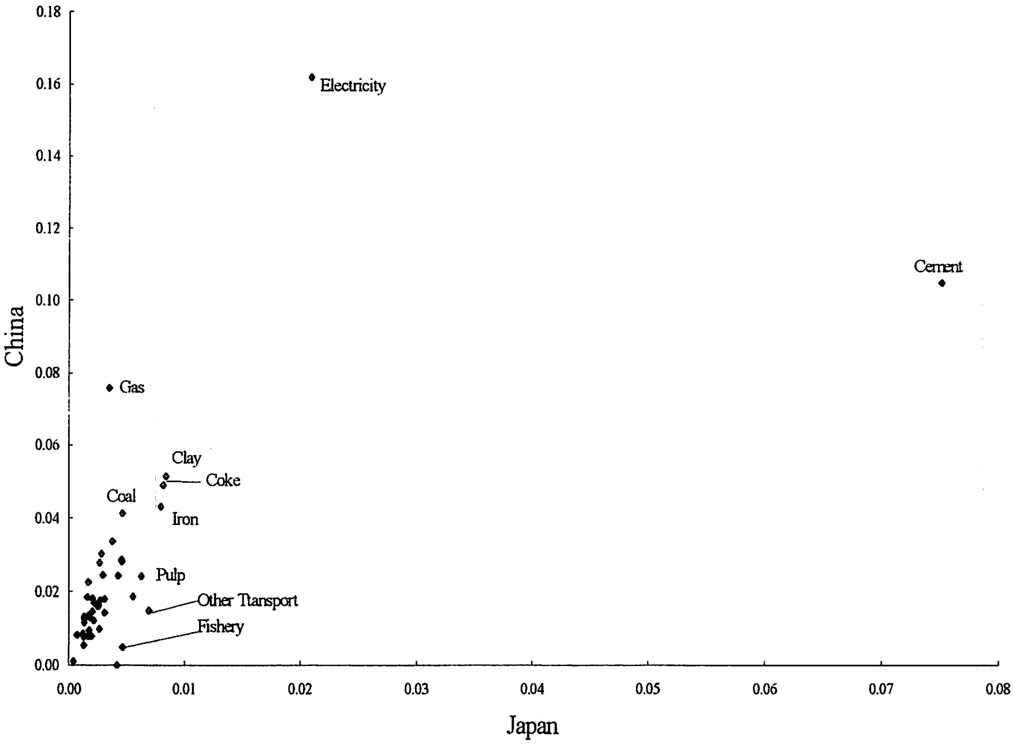

Figure 9: Induced CO_2 Generation Coefficients

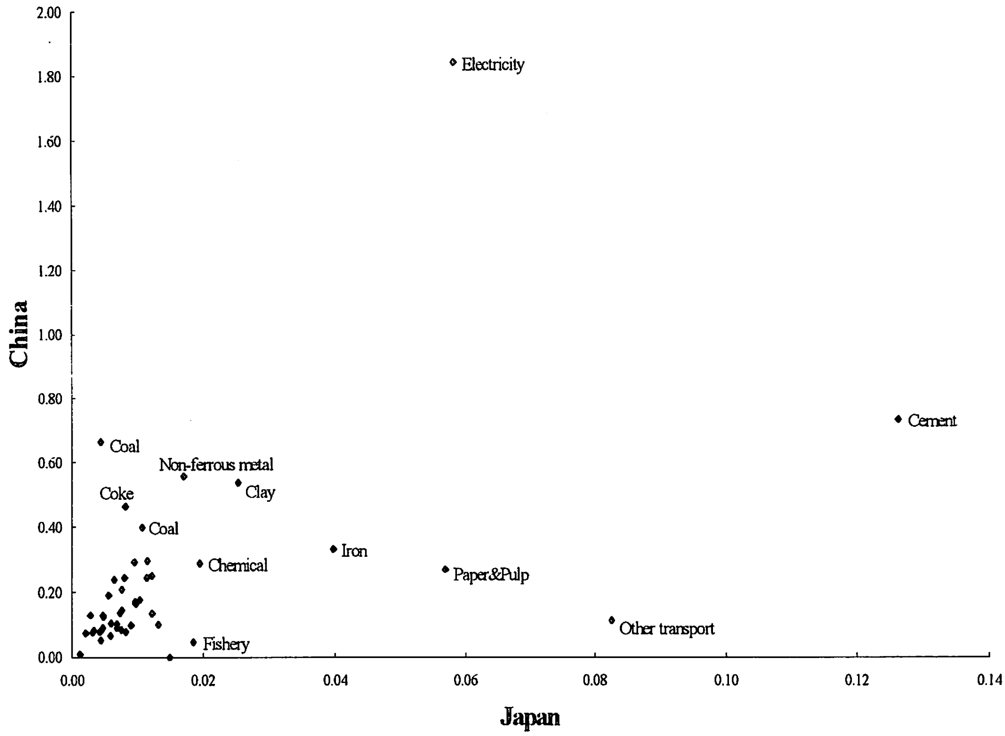

Figure 10: Induced SO_2 Generation Coefficients

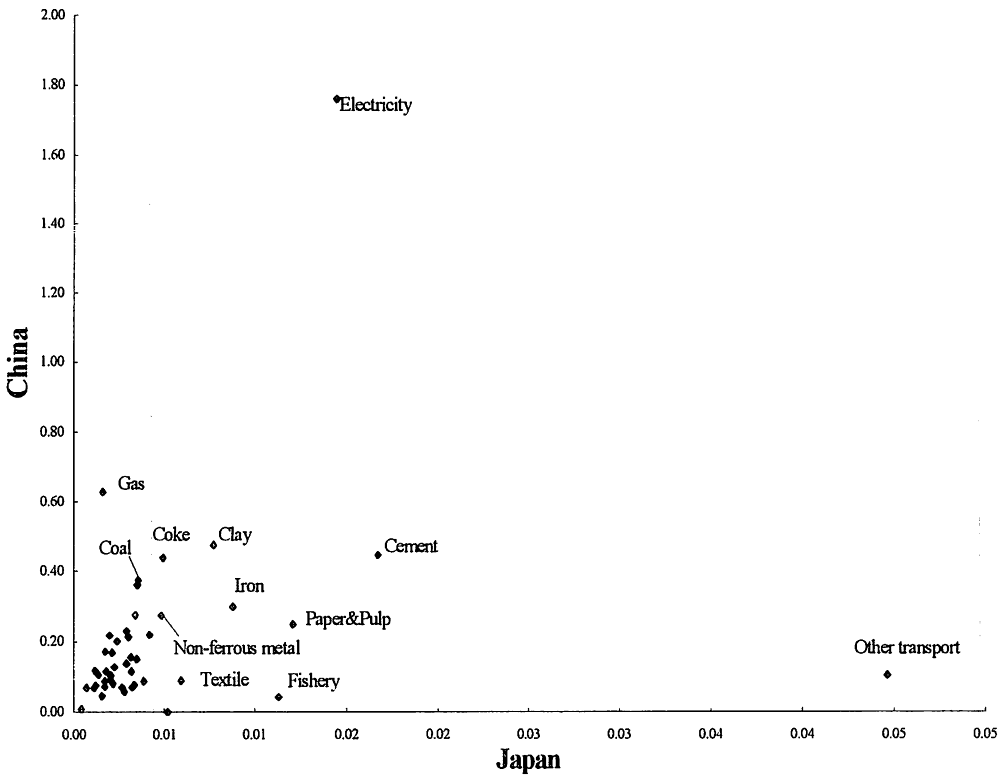

Figure 11: Induced SO_2 Emission Coefficients

7. Conclusions

Although we have just started our analysis of environmental problems in China, the issues involved are no doubt important. From the point of view of neighbouring countries like Japan, and from the perspective of the whole world, issues involving energy resources are those beyond conjecture. We have compiled the Japan-China input-output table, with common industrial classification for energy and air pollutant analysis. Although it may not be sufficiently detailed, applying only to 45 sectors, it provides the first most accurate information with respect to energy, or the generation and emission of air pollutants.

Our analysis has shown that the emission of CO_2 in China is twice as high as that in Japan, and 20 times higher in the case of SOx, which is a large difference when compared with the scale of per capita income. China is very much behind Japan, in both the removal of pollutants and energy efficiency; and this has been made clear by comparison of quantity units. However, the crucial issue is: what is the difference in emission quantities when the same amount of economic value is produced in both countries? In the final section, the 45-degree line is drawn equating 1 yuan to 100 yen. As this does not reflect purchasing power, and if 1 yuan is to be equivalent to 10-20 yen, then it is obvious that in producing the same economic value, China emits 1000 times greater the amount of air pollutants when compared to Japan.

Instead of using the exchange rate, based upon data on quantity and data from the input-output table, we found that the exchange parity is 75 yen/yuan for coal, whereas electric power is 286 yen/yuan, paper and pulp: 184 yen/yuan and iron and steel: 149 yen/yuan. In addition, the induced emission of CO_2 from one million yen of cement in Japan is found to be slightly more than 70 tons, which is quite similar to the 76 tons recorded in the more accurate basic table[9].

Our results of analysis obtained so far show that although the Japan-China input-output for the analysis of energy and air pollutants comprises only 45 sectors, it is able to stand the test of repercussion calculation. If we are to reduce the world's total emission of CO_2 (while it is necessary for Japan to raise its energy efficiency and promote environmental protection), the target could be more easily achieved by promoting environmental protection policies in other Asian countries, such as China, which have fallen behind implementing environmental measures.

References

[1] Hayami, H., Ikeda, A., Suga, M. and Yoshioka, K. (1993), "Estimation of Air Pollutions

[9] On the other hand, this could also be interpreted as the 70 tons obtained from the (I-A) type of repercussion is after all smaller than the 76 tons from (I-(I-M)A) type of repercussion. Yoshioka, Hayami, Ikeda, Suga (1992), 'An Application of the Input-Output Table for Environmental Analysis: Emission of CO_2 in Production Activities' (in Japanese), *Innovation and I-O Techniques*, Vol.3, No.4, pp.31-47.

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[6] Yoshioka, K., Hayami, H. and Wong, Y.C. (1995), "An Input-Output Analysis on Japan-China Environmental Problem (3): Why Sox Emissions are high in China?" *KEO Discussion Paper*, No. 41.