A Comparison Of Carbon Emissions From International Trade--- A Case Of Japan And China

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Abstract:

Trade between countries is one of the factors in the process of economic growth. However, the effects of trade movements from an industrialized country to less industrialized countries create externalities such as pollutant emissions. The focus of this paper is the trade movement between China and Japan and its effects on the embodied carbon emissions generated from the transfer. The carbon emission model formulated is based on the hybrid input-output framework. A structural decomposition analysis is done to identify the sources of change in the carbon emissions for China and Japan. After the SDA is done, a carbon emission quotient is proposed which is based on the ratio of the carbon emissions emitted by an industry in the studied region and that of the host region. The empirical analysis was done based on the inter-country input –output tables of Japan and China for 1985 and 1990. Results show that a tremendous amount of emissions has been generated through the export of products from China to Japan. The emissions transferred from these exports were also calculated and it shows that emissions from iron & steel, cement, chemical products and rubber products were the highest though their quotients were not the largest.

Keywords: Carbon emissions, International Trade, Hybrid Input-Output, China, Japan

1. Introduction

Industrialization affects the environment adversely. International trade between countries is crucial in the growth of a nation. However, trade movements between countries generally create emissions and these embodied emissions can increase This paper will

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focus on the trade movements of industries as part of the technology transfer between China and Japan and the effects on carbon emissions.

Carbon emissions discharged from industries for the production of goods and services can be modeled using the input-output model. The conventional Input-Output model has been employed to estimate environmental loads due to the production processes of the entire economic system. Leontief (1970), Hayami, *et al.* (1993), Gale (1995), Weir (1998), Gerilla and Inamura (2000) employed the static input-output model to estimate environmental loads in relation to some aspect of the economy. These studies failed to consider the changing energy prices in the world, which more or less affects the values of the estimated emissions. Bullard and Herendeen (1975), Piantanakulchai, *et al.* (1999), resolved the problem of changing energy prices by the use of physical units for energy sectors. This present paper estimates carbon emissions from the non-construction industries of China and Japan. The difference between this present study and the previous studies regarding carbon emission modeling is that the interdependencies of the sectors are incorporated in the model. It decomposes the sectors in the economy. The complex interactions and interdependencies of the industries and sectors in the economy contribute to the changes in emissions. Sonis and Hewings (1990), Weber and Schnabl (1998) showed a method to display the paths of direct and indirect dependencies in the economy by partitioning or decomposing the economic structure. Fritz, et al. (1998) applied the method in partitioning the input-output matrix into polluting and non-polluting industries.

This paper also compares the changes in structure of the carbon emissions between China and Japan using the structural decomposition analysis (SDA). SDA represents a way of distinguishing major sources of change in an economy. Several researches had been made in this area using the SDA methodology like Carter (1970); Rose & Chen (1991); Fujimagari (1989); Skolka (1989); Gale (1995); Weir (1998) and others. Dietzenbacher and Los (1998), moreover, showed a detailed sensitivity analyses of the decomposition.

A third purpose of the paper is to compare the carbon emissions of China and Japan and to measure the share of carbon emissions from China as compared to Japan. It will also measure the emissions caused by the trade between the two countries. To be able to make an inter-country comparison, an index is generally made in macroeconomics. Several macroeconomic indices are available from literature like the Fisher index, Laspeyres and Paasche indices (SNA,1993). These indices were developed to measure the changes in prices and volumes over time or among regions or countries. The comparison of carbon emissions between or among countries can not use the Laspeyres or Paasche indices since it is difficult to give a price to the emissions generated. The proposed model is inspired by the export base theory in regional economics. The export base theory basically divides industries into basic industries which export their products and industries which cater to purely local market for their products. Some articles which use the Location Quotient as an analysis tool is presented. Hildebrand and Mace (1950) developed an approach that classifies industries in Los Angeles County into localized or non-localized industries. Issermann (1977) presented a theoretical rationale for the use of location quotients in estimating regional impacts. Recently, Juleff (1993) examined the trading relationships of several cities in the UK that sell significant proportions of the advanced producer services in the United Kingdom using the location quotient analysis. Mack & Jacobson (1996) applied the location quotient –based methodology to analyze the core-periphery dualism. They modified the location quotient formula to obtain the industries which import or export products from the core to the periphery.

This paper is organized as follows: following this introduction is the presentation of the carbon emission model followed by the structural decomposition analysis done on the model. Also included in the second section is the carbon emission index proposed to compare the emissions from China and Japan. The third section comprises the empirical application of the models presented while the fourth section completes the paper.

2. Carbon Dioxide Emission Model

The carbon emission model formulated in this section is based on the hierarchical decomposition of the technological matrix, A. It identifies the interdependencies of decomposed economic subsystems whether it is forward, or backward linkages by means of the hierarchical decomposition of the industries (Gerilla, *et al.*, 2000). The economy in this model is subdivided into 3 subsystems namely: the carbon producing industries (es), the non-construction industries (nc) and the construction industries, (cs). The carbon producing industry is defined as the sectors which are the primary sources of carbon emissions, non-construction industries, meanwhile, are sectors not included in the construction and carbon-producing industries. The division can be explained using the decomposition of the matrices. The decomposition is shown below:

$$\begin{array}{cc} & \begin{array}{ccc} \text{es} & \text{nc} & \text{cs} \end{array} \\ \begin{array}{c} \text{es} \\ \text{nc} \\ \text{cs} \end{array} & \underbrace{\left[\begin{array}{c:c:c} A_{11} & A_{12} & A_{13} \\ \hdashline A_{21} & A_{22} & A_{23} \\ \hdashline A_{31} & A_{32} & A_{33} \end{array}\right]}_{A_h} \end{array} = \underbrace{\left[\begin{array}{c:c:c} A_{11} & A_{12} & A_{13} \\ \hdashline A_{21} & O & O \\ \hdashline A_{31} & O & O \end{array}\right]}_{A_{es}} + \underbrace{\left[\begin{array}{c:c:c} O & O & O \\ \hdashline O & A_{22} & A_{23} \\ \hdashline O & A_{32} & O \end{array}\right]}_{A_{nc}} + \underbrace{\left[\begin{array}{c:c:c} O & O & O \\ \hdashline O & O & O \\ \hdashline O & O & A_{33} \end{array}\right]}_{A_{cs}} \tag{1}$$

A_{es} is a block matrix consisting of the input coefficient sub-matrices of carbon-producing industries, A_{nc} is a block matrix of input coefficient sub-matrices of non-construction industries and A_{cs} is a block matrix consisting of input coefficient sub-matrices of construction industries. This decomposition shows the interdependency of the three subsystems in the economy. The units of elements of the block matrices are in hybrid units meaning that the carbon producing industries units are in ton-carbon (ton-C) while the other sectors, non-construction and construction sectors, retain their monetary units which are in thousand of US Dollars ('000 US$).

The subdivision of the matrices is also done to be able show the hierarchy of forward linkages, backward linkages versus the isolated sub-system which in this case is the construction industry. The production function for the input-output analysis, $X = (I-A)^{-1}f$ is decomposed according to the structure of the A_h as shown in equation (1).

Letting:
$A = A_{es} + A_{nc} + A_{cs}$
$A = A_{es} + A_a$
$A_a = A_{nc} + A_{cs}$
we have,

$$\begin{aligned} X_1 &= (I - A)^{-1}\{(I-A_a)(I-A_a)^{-1}\}f \\ &= [(I-A)^{-1}(I-A_a)(I-A_a)^{-1}]f \\ &= [(I-A)^{-1}(I-(A-A_{es}))(I-A_a)^{-1}]f \\ &= (I-A)^{-1}[(I-A)+A_{es}](I-A_a)^{-1}f \\ &= [I + (I-A)^{-1}A_{es}(I-A_a)^{-1}]f \\ &= (I + M_oA_{es})\{(I-A_a)^{-1}[(I-A_{nc})(I-A_{nc})^{-1}]\}f \\ &= (I + M_oA_{es})[(I- A_a)^{-1}\{(I-A_a)+A_{cs}]\ (I-A_{nc})^{-1}\}f \\ &= (I + M_oA_{es})(I + M_1A_{cs})\ (I-A_{nc})^{-1}f \end{aligned} \tag{2}$$

where:

$M_0 = (I - A)^{-1}$
$M_1 = (I - A_a)^{-1}$

The identity on the right hand side of the equation can be explained by reading it from right to left.

- $(I - A_{nc})^{-1}f$ represents the total production vector in the non-construction sector for the production of final demand f;

- $(I + M_1A_{cs})$ represents the intermediate input requirements of the construction commodity needed to produce final demand;

- $(I + M_0A_{es})$, means that the output requirements of the whole system needs commodity input requirements from the carbon producing industry.

There are 3 decomposition schemes for the production function because of the three subsystems. The 3 decomposition schemes are equivalent so one decomposed production function is used for the carbon emission intensity formulation. Using equation (2), we can extract the first 2 terms of the equation to form E_g. This is the matrix of total carbon emission coefficient of industries. It represents the interconnections of the carbon-producing industry, the non-construction industry and the construction industry, which contributes to the carbon emissions.

$$E_g = (I + M_0A_{es})(I + M_1A_{cs}) \tag{3}$$

We have E_g as the matrix of total carbon emission coefficient of industries induced by the non-construction sector for the production of final demand. Equation 4 shows the matrix form of E_g.

$$E_g = \left[\begin{array}{c:c:c} E_{g11} & E_{g12} & E_{g13} \\ \hdashline E_{g21} & E_{g22} & E_{g23} \\ \hdashline E_{g31} & E_{g32} & E_{g33} \end{array}\right] \quad (4)$$

where:

E_{g11} = carbon producing industry output submatrix of carbon producing industries induced by the final demand of the carbon-producing sector;

E_{g12} = carbon producing industry output submatrix of carbon producing industries induced by the final demand of the non-construction sector;

E_{g13} = carbon producing industry output submatrix of carbon producing industries induced by the final demand of the construction sector;

E_{g21} = non-construction output submatrix of carbon producing industries induced by the final demand of the carbon-producing sector;

E_{g22} = non-construction output submatrix of carbon producing industries induced by the final demand of the non-construction sector;

E_{g23} = non-construction output submatrix of carbon producing industries induced by the final demand of the construction sector;

E_{g31} = construction output submatrix of carbon producing industries induced by the final demand of the carbon-producing sector;

E_{g32} = construction output submatrix of carbon producing industries induced by the final demand of the non-construction sector;

E_{g33} = construction output submatrix of carbon producing industries induced by the final demand of the construction sector;

The carbon emission coefficient vector of carbon producing industries is given in the matrix below:

$$E_{ge} = \left[\begin{array}{c:c:c} E_{g11} & E_{g12} & E_{g13} \end{array}\right] \quad (5)$$

E_{ge} is defined as the direct and indirect emission output acquired as a result of the production processes of the carbon producing sectors, non-construction and the construction sectors. To be able to get the direct and indirect emission output discharged in the processes of the non-construction industry, we can decompose equation (5) to equation (6) as shown below:

$$E_{gnc} = \left[\; O \;\vdots\; E_{g12} \;\vdots\; O \;\right] \tag{6}$$

The non-construction carbon emission structure, E_{gnc}, implies the different linkages of the 3 decomposed subsystems relating to the non-construction industry. The final demand can be converted into the hybrid system as given in the vector:

$$f_i = \left[f_{es} \;\vdots\; f_{nc} \;\vdots\; f_{cs} \right]^t \tag{7}$$

where:

f_i = final demand;
f_{es} = Final demand of the carbon producing industry;
f_{nc} = Final demand of the non-construction industry;
f_{cs} = Final demand of the construction industry;

Note that the symbol (^{t}) means the transpose of the vector. The final demand, f_{nc}, used in this paper is the final demand of non-construction industries. Furthermore, f_i can be decomposed into the different components of final demand such as, imports, exports, capital formation, private consumption, and government consumption.

We can now show the carbon dioxide emission model used in the study as:

$$CO_{nc} = E_{gnc} * (I - A_{nc})^{-1} f_{nc} \tag{8}$$

where:

CO_{nc} = vector of total carbon emission intensity from the carbon producing industries induced by the non-construction sector;
E_{gnc} = matrix of carbon emission structure induced by the non-construction industry;
A_{nc} = technology coefficient matrix of the non-construction industry;
f_{nc} = vector of non-construction industry requirements;

2.1 Structural Decomposition Analysis

The sources of changes in carbon emission intensity are studied using SDA. The total change in carbon emissions intensities is decomposed into effects caused by the changes in the emission structure of carbon producing sectors, E_{gnc}, changes in non-construction technology, $(I - A_{nc})^{-1}$ as well as changes in the final demand. The carbon emission model is a function of the emission structure, non-construction technology and non-construction final demand. If we let $L_{nc} = (I - A_{nc})^{-1}$, the carbon emission model function is shown in equation (9).

$$CO_{nc} = f\left(Eg_{nc}, L_{nc}, f_{nc}\right) \tag{9}$$

Using equation (9), we can carry out its decomposition over time by

$$\frac{\partial CO_{nc}}{\partial t} = \frac{\partial Eg_{nc}}{\partial t} L_{nc} f_{nc} + Eg_{nc} \frac{\partial L_{nc}}{\partial t} f_{nc} + Eg_{nc} L_{nc} \frac{\partial f_{nc}}{\partial t} \tag{10}$$

This is a continuous function, since we are dealing with discrete time periods and the model is a static model, we define the discrete approximation of the continuous function as shown in equation 11:

$$\Delta CO_{nc} = \left\{E_{gnc}\left(I - A_{nc}\right)^{-1} f_{nc}\right\}_1 - \left\{E_{gnc}\left(I - A_{nc}\right)^{-1} f_{nc}\right\}_0 \tag{11}$$

The subscripts 1 and 0 denote the future year t1 and base year t0, respectively. Using the defined technology function we have:

$$\Delta CO_{nc} = E_{gnc1} L_{nc1} f^{c}_{nc1} - E_{gnc0} L_{nc0} f^{c}_{nc0} \tag{12}$$

Equation (12) can be transformed into six different types of decomposition forms. The six decomposition form are the different growth paths that lead to the reasons for carbon emission changes. Dietzenbacher and Los (1998) suggested that the average of polar decompositions be computed for cases with more than two determinants. So the average effects of the determinants are computed. The average effects of the emission structure changes of the carbon producing industries, ΔE_{gnc}, can be calculated by the formula:

$$\frac{1}{6}\left(\Delta E_{gnc} L^{1}_{nc} f^{1}_{nc} + \Delta E_{gnc} L^{0}_{nc} f^{0}_{nc} + \Delta E_{gnc} L^{1}_{nc} f^{0}_{nc} + \Delta E_{gnc} L^{0}_{nc} f^{0}_{nc} + \Delta E_{gnc} L^{0}_{nc} f^{1}_{nc} + \Delta E_{gnc} L^{1}_{nc} f^{1}_{nc}\right) \tag{13}$$

Equation 14 estimates the average effects of non-construction technological changes.

$$\frac{1}{6}(E^{0}_{gnc} L^{0}_{nc} \Delta A_{nc} L^{0}_{nc} f^{1}_{nc} + E^{1}_{gnc} L^{0}_{nc} \Delta A_{nc} L^{1}_{nc} f^{0}_{nc} + E^{0}_{gnc} L^{0}_{nc} \Delta A_{nc} L^{1}_{nc} f^{0}_{nc} + E^{1}_{gnc} L^{0}_{nc} \Delta A_{nc} L^{0}_{nc} f^{1}_{nc} + \ldots$$
$$E^{1}_{gnc} L^{0}_{nc} \Delta A_{nc} L^{1}_{nc} f^{1}_{nc} + E^{0}_{gnc} L^{0}_{nc} \Delta A_{nc} L^{1}_{nc} f^{0}_{nc}) \tag{14}$$

The average effects of non-construction final demand is given in equation 15.

$$\frac{1}{6}\left(E^{0}_{gnc} L^{0}_{nc} \Delta f_{nc} + E^{1}_{gnc} L^{1}_{nc} \Delta f_{nc} + E^{1}_{gnc} L^{1}_{nc} \Delta f_{nc} + E^{1}_{gnc} L^{0}_{nc} \Delta f_{nc} + E^{0}_{gnc} L^{1}_{nc} \Delta f_{nc} + E^{0}_{gnc} L^{1}_{nc} \Delta f_{nc}\right) \tag{15}$$

2.2 Comparative Index for Carbon Emissions

Theoretical and experimental analysis of carbon emissions from industries has been confined to the calculation of emissions but the comparison of carbon emissions between countries have not been done from the viewpoint of international trade between China and Japan using an index. This section aims to present an index that compares the carbon emissions from China and Japan. The index is inspired by the export base theory in regional economics. The export base theory basically divides industries into basic industries which export their products and industries which cater to purely local market for their products. The technique is called the Location Quotient. It compares a local economy to a reference economy in terms of employment. This analysis tool is modified for carbon emissions. The main hypothesis that is submitted here is that exports from one country to another also involves the transfer of carbon emissions. An increase in trade will generally not only increase emissions in the country itself but also to the receiving country. A carbon emission quotient (CEQ) is presented to compare the emissions of two countries, one being the analysis region and another the benchmark region. The CEQ is based on the ratio of the carbon emissions emitted by an industry in the studied region and that of some reference unit.

$$\mathrm{CEQ}_i = \left[\frac{\mathrm{CO}_{nci}}{\sum_i \mathrm{CO}_{nci}}\right] \Bigg/ \left[\frac{\mathrm{CO}^h_{nci}}{\sum_i \mathrm{CO}^h_{nci}}\right] \tag{16}$$

where:

CEQ_i= the carbon emission quotient for sector i;
CO_{nci}= carbon emission intensity of sector i for the studied region (China);
CO_{nci}^h= carbon emission intensity of sector i for the benchmark region (Japan);

Only two general outcomes are possible when calculating the carbon emission quotients. These outcomes are as follows:

If $\mathrm{CEQ}_i < 1.0$ then the carbon emission in the study region comes from the industries' country itself;
If $\mathrm{CEQ}_i > 1.0$ then some of the carbon emission in the study region is greater than expected;

The CEQ can be defined as the ratio of the share of carbon emissions from a local country's industry to the base country's share of industrial carbon emissions. The carbon emission quotient is calculated for all industries to determine whether or not the local country's industries has a greater share of emissions than expected when compared to a reference. This index measures the change in the magnitude of emissions of the countries studied. A CEQ > 1, in other words, includes carbon emissions that are not only generated from the studied region's industries. The basic assumption behind the model is that carbon emissions are generated from the local economy and when the local industries import or export the goods that they produce, carbon emissions are also transferred.

To test the robustness of the model, several properties of the CEQ are presented. The quotient satisfies the Identity Test (Diewert, 1993) wherein the CEQ is equal to one when the emissions in the two regions are the same. It can also be stated that the proposed carbon emission quotient is proportional. This means that when the ratio of the share of Chinese emissions is multiplied by a certain α, then the new quotient is equal to α times the old carbon emission quotient. The proportionality, however, is only towards each country and not towards each industry. If we interchange the roles of the benchmark and the studied region, then the new carbon emission quotient is the reciprocal of the original index. This satisfies the Symmetric Treatment of Countries Test (Diewert, 1993).

Noting that the carbon emission quotient (CEQ) satisfies several tests for an index number we can say that the index can be used to compare the emissions between two regions and it can be said that the emissions are implicitly transferred as well. The amount of emissions transferred can be determined. This formula is used only for quotients greater than 1.

$$\mathrm{ET}_i = \left[1 - \left({}^{1}\!/\!_{\mathrm{CEQ}} \right)\right] * \mathrm{CO}_{nci} = \left[\frac{\mathrm{CO}_{nci}}{\mathrm{CO}^{h}_{nci}} - \frac{\sum_i \mathrm{CO}_{nci}}{\sum_i \mathrm{CO}^{h}_{nci}} \right] * \mathrm{CO}_{nci} \tag{17}$$

where:
ET_i = emissions from exports of China to Japan;
CO_{nci}= carbon emission intensity of sector i for the studied region (China);

3. Comparison of Carbon Emissions for China and Japan

The data used for the international comparison of carbon emissions is the International Input-Output Tables for China-Japan in 1985 and 1990. The table is published by the Institute of Developing Economies (IDE) in Japan. To be able to compare the two countries for two different time periods, the data was re-coded from more than 180 sectors to 35 sectors and 1985 prices were used. The hybrid system and hierarchical decomposition method were also applied to be able to segregate the carbon producing sector, non-construction sector and the construction sector. It is also important to note that to be able to compare different currencies, the US dollar was the currency used for comparison as adopted by the IDE. Special attention was given to the imports and exports between these two countries to be able to analyze the emissions coming from trade. China was chosen as the country to be compared with Japan because it is experiencing a very rapid growth in its economy. It would be worthwhile to study the carbon emissions due to technological changes and its economic structure.

Figure 1 presents the carbon emissions for China and Japan for 1985 and 1990. It shows that carbon emissions in China is 600 per cent more than that of Japan in1990 while in 1985 it was just about 50 per cent more. It shows that the carbon emissions for China increased by about 70 percent from 1985 to 1990 while that of Japan decreased by 54%.

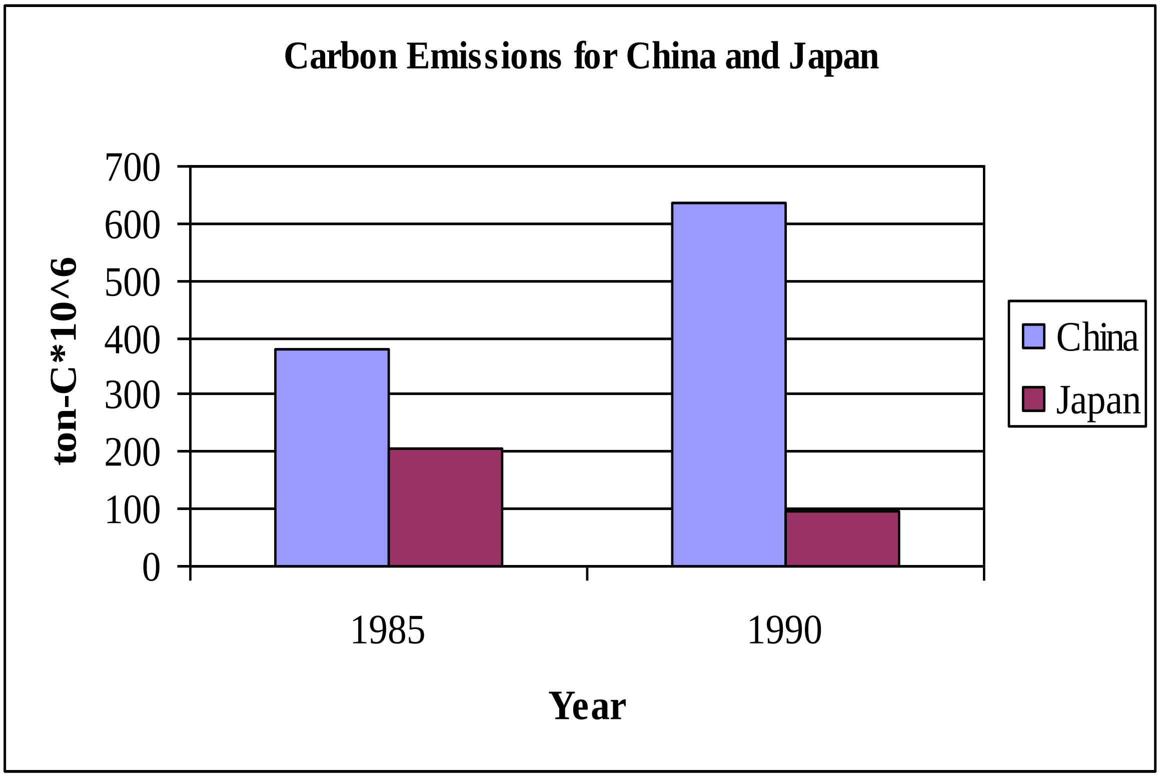

Figure 1. Carbon Emissions for China and Japan

The reasons for the changes in the carbon emissions generated in both countries can be explained using the structural decomposition analysis (SDA). The results of the SDA is shown in Figure 2. The reasons for the increase in emissions were mainly due to the emission structure and technological structure of the economy. Figure 2 shows that the increase in emission for China is due to the increase in emission structure as well as its technological structure. This means that during the 5 year period, manufacturing industries were flourishing which can be proven by the increase in the technological structure. The increase in technological structure for China means that the presence of industries in China during this period increased tremendously but technological advances did not develop much thereby an increase in the technology led to the increase in the emissions. Final demand was not the major reason for the increase in carbon emissions in China as compared to the manufacturing technology increase. The production in industries were generally made for exports and not primarily for local consumption. Japan, on the other hand, was the reverse, having a stable economy and high investment in research and technology, the carbon emission level decreased due to technological advances and cleaner emission structure. In Japan, emissions due to final demand increased which means that private and public consumption were main economic motivators.

It was shown in Figure 2 that emission structure was the main cause for the increase in emissions in China while it was also the main reason for the decease in emissions for Japan. Figure 3 shows the carbon emissions classified into the different emission categories.

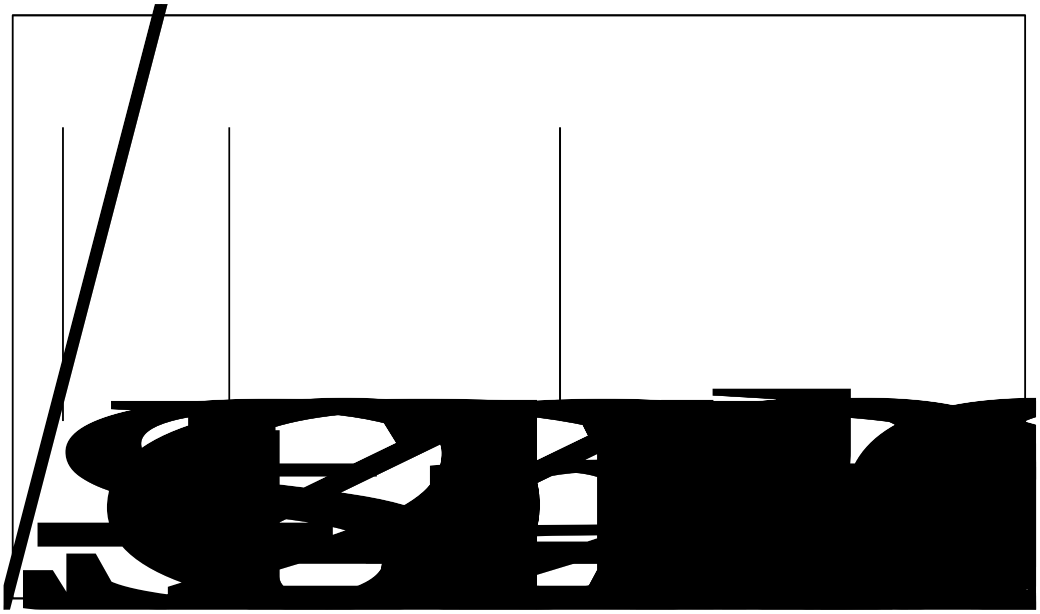

Figure 2. Reasons for the changes in emissions for China and Japan

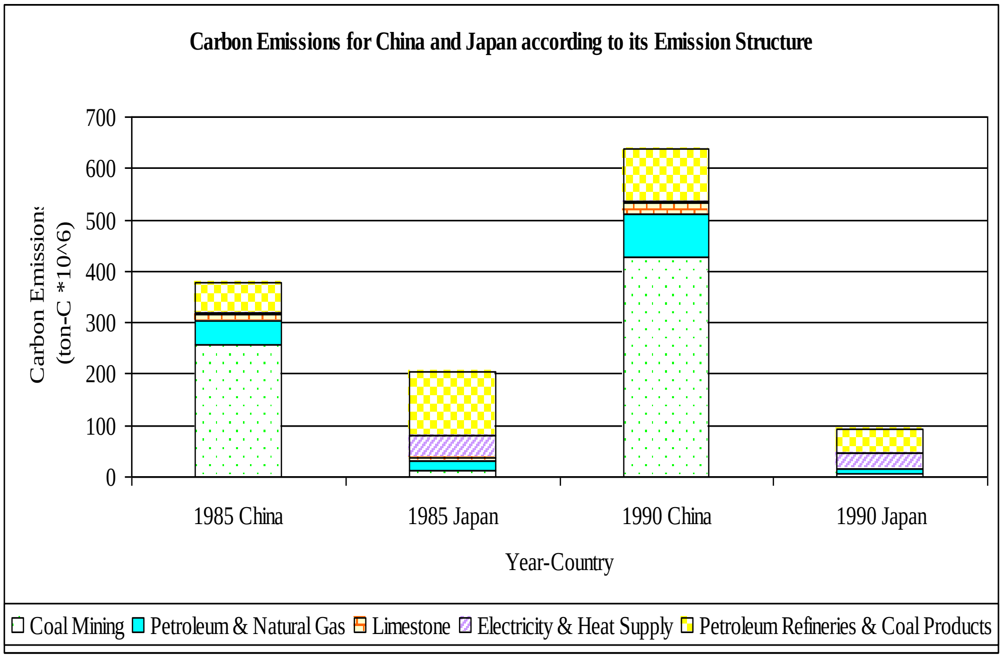

Figure 3. Carbon emissions decomposed into its emission structure for China and Japan

Five primary energy sectors basically constitute the emission structure in this comparison. The 5 primary energy sectors are coal mining, petroleum & natural gas, limestone, electricity & heat supply and petroleum refineries & coal products. It shows that coal mining and petroleum refineries & coal products contributed to the increase in carbon emissions in China. It can also be seen that coal mining have an almost 65% increase from 1985 to 1990. Petroleum & natural gas also increased by as much as 78%. Other categories also experienced an increase but is negligible compared to the increase in coal mining and petroleum & natural gas. While for the Japanese case, petroleum refineries & coal products and electricity & heat supply were the contributors to its emission structure. Moreover, carbon emissions from limestone decreased by as much as 75%.

3.1 Carbon Emission from Trade

The carbon emissions from trade between China and Japan are presented in this section. The empirical results of the carbon emission index for 1990 and 1985 and the emissions transferred as a result of the exports from China to Japan are also included.

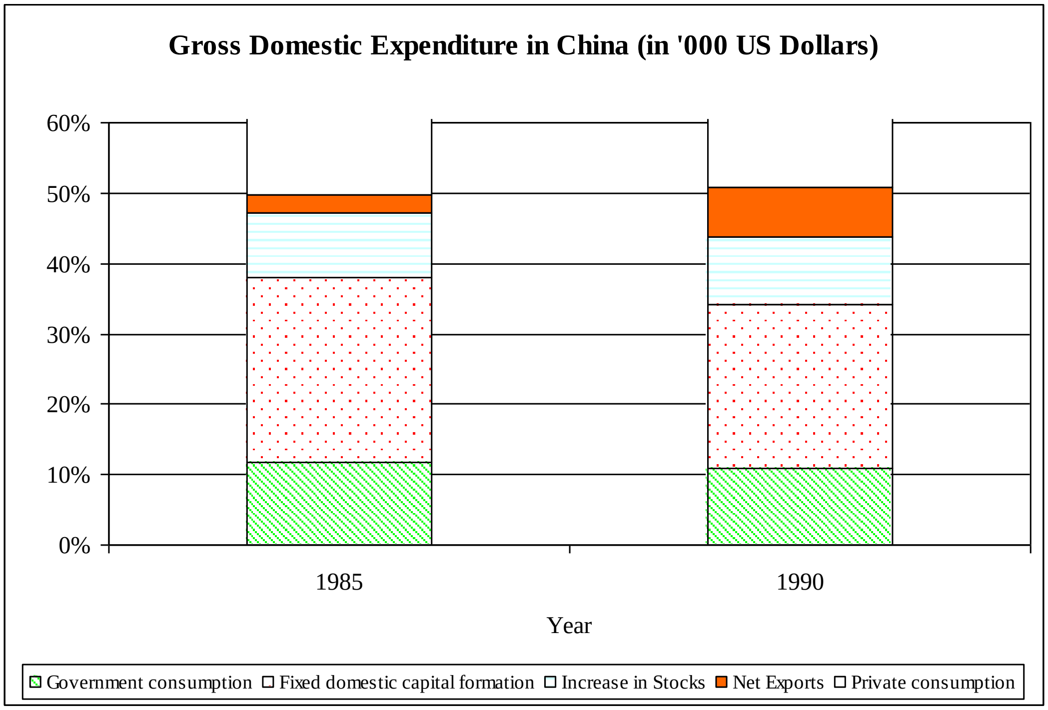

Figure 4. Gross domestic production for China

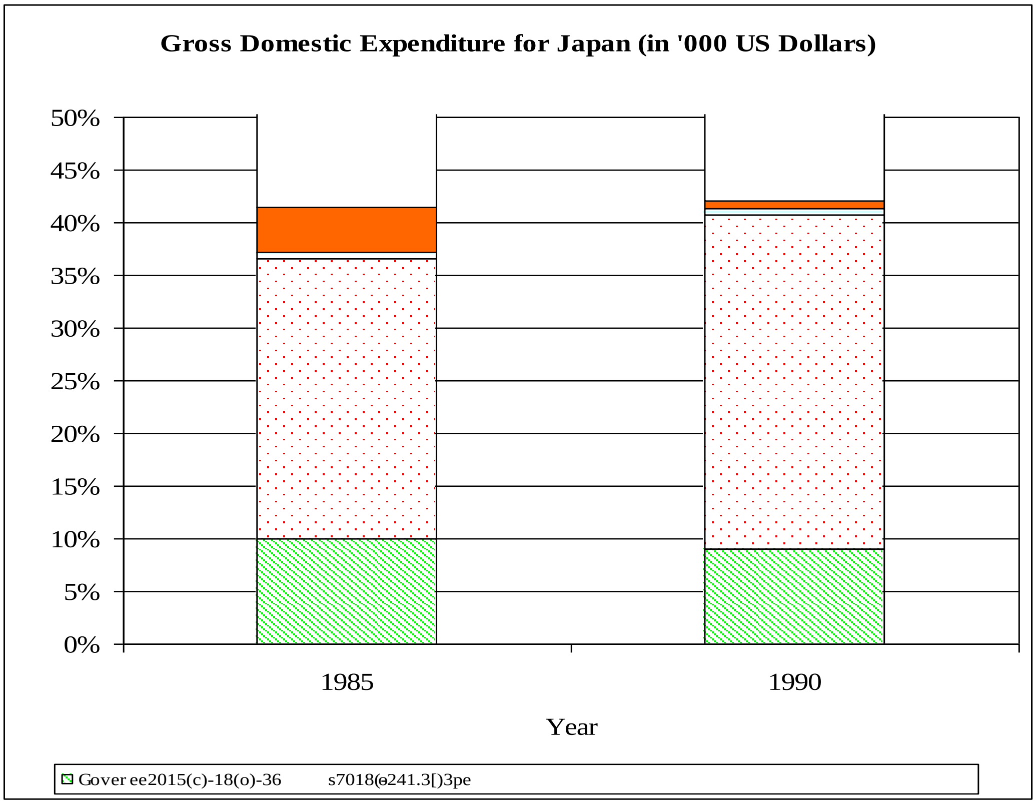

Figure 5. Gross domestic expenditure for Japan

The gross domestic production for China and Japan for 1985 and 1990 are presented in Figures 1 and 2. What is interesting in the gross domestic expenditure in China is the increase in exports from 1985 to 1990. The increase in exports during the period was about 116%, while all other factors almost had a minimal increase or decreased. Government consumption and private consumption almost remained the same while capital formation decreased by 29% from 1985 using 1985 prices.

The gross domestic expenditure for Japan showed an increase in capital formation and a decrease in exports from 1985 to 1990, the decrease in exports was as much as 92%. All other factors increased by as much as 300% for capital formation and 200% for private consumption.

First, we look at the trading scenario of China for 1985 and 1990. Tables 1 and 2 show the trade pattern of China. Its imports and exports to Japan and the rest of the world in 1985 and 1990.

Table 1 shows the trade transactions for 1985, 17% of China's exports went to Japan while the remaining are to different parts of the world, while its imports from Japan constituted 25% of its total imports. China's total exports in 1985 was 24% higher than its imports. Japan, on the other hand, has about 34% higher exports than its imports. Japan's exports to China is about 10% higher compared to China's exports to Japan. The exports of Japan to China constituted about 3% of its total exports while the 96% went to the rest of the world.

Table 1. The Export –Import Transactions for China and Japan in 1985 ('000 US$)

1985	**China**	**Japan**	**Rest of the World**	**Total**
China		5335244	25683783	31019027
Japan	5929847		187205778	193135625
Rest of the World	17718480	123058023		
Total	23648327	128393267		

For 1990, Japan's exports to China went down to 1%. its exports are 38% higher than it imports, an increase of 4 per cent from 1985. China's exports to Japan, on the other hand, was about 11% of its total exports, while its imports decreased to 12% compared to 1985. The amount of exports for China increased to 41% compared to its imports in 1990. China's exports to Japan was 61% higher than Japan's exports to China in this period.

Table 2. The Export-Import Transactions for China and Japan in 1990 ('000 US$)

1990	**China**	**Japan**	**Rest of the World**	**Total**
China		7363287	55438162	62801449
Japan	4563690		324596938	329160628
Rest of the World	32259409	198123145		
Total	36823099	205486432		

Now, we look at the carbon emissions generated from exports to Japan. Figure 6 shows the carbon emissions in China produced from the exports to Japan for 1985 and 1990. The figure was generated from the carbon emission model in equation 8, the final demand was decomposed into several categories and one is the exports of China to Japan.

The figure show

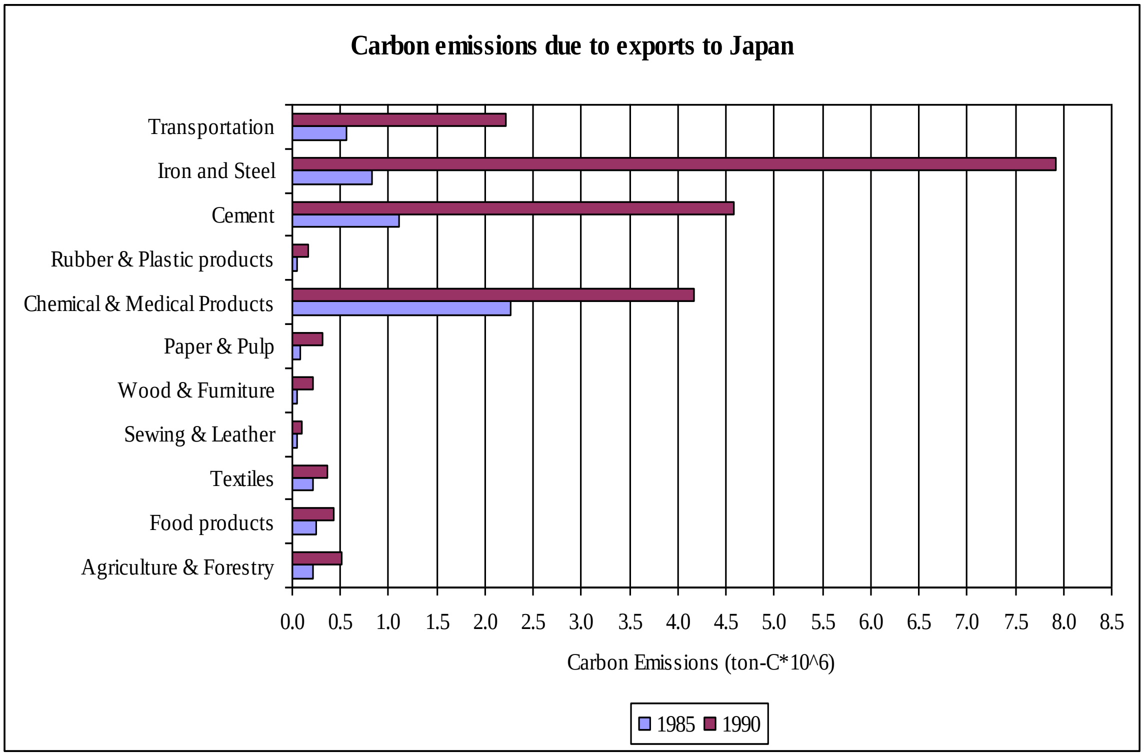

Figure 6. Chinese carbon emissions due to exports to Japan

Due to the large exports of China to Japan especially in 1990, the emissions coming from China's exports are compared to Japan's emissions. The emissions from China and Japan are compared by the use of the carbon emission quotient. Tables 3 and 4 show the calculated indices and the amount of emissions transferred. The table has 3 columns, the column on the left are the sectors while the middle column contains the calculated carbon emission quotient and the third column shows the calculated emissions transferred.

Among the 35 sectors, in 1985, there are 18 sectors which have quotients greater than 1 which means that the ratio of these industries' share of the Chinese emissions is larger than the industries' share of Japanese emissions. This suggests that the Chinese emissions generated from these industries are tremendous and that there is a possibility of an export/transfer of emissions to Japan. As shown in Table 3, the food products and agriculture gave the highest CEQ, which means the emissions from these products in China are greater than that of Japan. The accompanying emissions most likely transferred to Japan after the export of these products are shown. Even though food products and agriculture garnered the top two CEQ, the emissions transferred are less, in 1985 the highest emissions transferred to Japan are from the chemical and medical products as well as from cement products.

Table 3. The Carbon emission quotient and emissions transferred from China in 1985

1985	CEQ	Emissions Transferred (10^6 ton-C)
Agriculture & Forestry	18.67604	0.203488
Fishery	2.999138	0.010665
Food products	31.78948	0.233419
Textiles	1.572507	0.079732
Sewing & Leather	37.39551	0.040877
Wood & Furniture	5.045425	0.040892
Printing & Education goods	1.271956	0.002138
Chemical & Medical Products	2.928727	1.493602
Rubber & Plastic products	1.667074	0.017606
Cement	3.705273	0.808967
Metal products	1.080915	0.005839
Other manufacturing	1.826398	0.009049
Transportation	2.947791	0.371349
Communication	1.683607	0.010557
Commerce	1.907934	0.03569
Restaurants / Eating	3.331704	0.020296
Public & Private service	3.805413	0.057503
Administrative organ	4.352916	0.008473
Others	0	-
Metal ore mining	0.030544	-
Paper & Pulp	0.411312	-
Iron and Steel	0.226551	-
Non-ferrous metal	0.659013	-
Machinery	0.3274	-
Transport machinery & repair	0.29679	-
Electrical Machinery	0.17444	-
Testing machines & Measuring Devices	0.142459	-
Education, Health & Research	0.712295	-
Finance & Insurance	0.593579	-

Table 4 shows the carbon emission quotient and calculated emissions transferred in 1990. In 1990, the CEQ > 1 has been reduced to 14 sectors only, however, it is noted that iron & steel, non-ferrous metals were included in the group, while the chemical & medical products sector had a CEQ less than 1. Similar to 1985, the CEQ for agriculture was the highest but the emissions transferred which came from cement products and iron & steel products were the highest. Unlike, 1985, the Chinese emissions from industries like leather, rubber and sewing industries were reduced compared to that of Japan thereby giving a CEQ value of less than 1.

Table 4 The carbon emission quotient and emissions transferred from China in 1990

1990	CEQ	Emissions Transferred (10^6 ton-C)
Agriculture & Forestry	11.9795	0.466511
Food products	3.271557	0.304119
Sewing & Leather	2.711684	0.063123
Wood & Furniture	7.74106	0.183743
Cement	6.865814	3.907801
Iron and Steel	2.108037	4.166103
Non-ferrous metal	1.604795	0.252124
Other manufacturing	3.528757	0.154072
Transportation	2.332003	1.2686
Communication	2.736177	0.043148
Commerce	1.289516	0.034351
Restaurants / Eating	4.412355	0.183287

[redacted]

Rubber & Plastic products	0.828216	-
Metal products	0.511793	-
Machinery	0.482093	

The knowledge of the carbon emission quotient can help determine which industries are major carbon emission generators as compared to a benchmark country, it can also identify the exports which create tremendous emissions and has the possibility of a transfer to the benchmark country.

4. Conclusions

The carbon emission model developed in this paper incorporated the linkages between the carbon-producing industries, non-construction and construction industries through the use of the hierarchical decomposition analysis. It shows that the carbon emission industry inputs to the non-construction sector are very important for the construction industry. Carbon emissions for China increased by about 70 percent from 1985 to 1990 while that of Japan decreased by 54%.

The reasons for the fluctuation was modeled using the structural decomposition analysis (SDA). The important sources of change in carbon emissions are the changes in emission structure, changes in non-construction technology and changes in non-construction final demand. The increase in emission for China is due to the increase in emission structure as well as its technological structure while final demand did not contribute much to the increase in emissions. This means that during the 5 year period, manufacturing industries were flourishing which can be proven by the increase in the technological structure. The increase in technological structure for China means that the presence of industries in China during this period increased tremendously but technological advances did not develop much thereby an increase in the technology led to the increase in the emissions. The decrease in emissions in Japan during the 5 year period was due to technological advances and cleaner emission structure.

The share of industrial carbon emissions from China as compared to the share of industrial carbon emissions in Japan was modeled through the carbon emission quotient. The technology transfer is defined here as the trade between China and Japan. China mainly exported agricultural products and low technology manufacturing products as seen in the CEQ index which are greater than 1. The emissions transferred from these exports were also calculated and it shows that emissions from iron & steel, cement, chemical products and rubber products were the highest though their quotients were not the largest. It can be inferred that technologies for these industries in China are much lower in quality than that for Japan and that iron& steel, cement and chemical products are much more carbon intensive. The knowledge of the carbon emission quotient can help determine which industries are major carbon emission generators as compared to a benchmark country, it can also identify the exports which create tremendous emissions and has the possibility of transfer to the benchmark country.

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