Embodied Energy and CO_2 Emission in Sino-Japan Trade

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Abstract:

Along with the active trade in goods and services between China and Japan, energy use and environment issues also become complex. Under the support of Japan International Cooperation Agency (JICA), a multi-regional input-output table of energy use and CO_2 emission for China and Japan is established in this paper. Based on the table, this study puts emphasis on the relation between Japan and China in energy use and CO_2 emission in 2007 by employing a series of models. The paper not only evaluates the interregional impact of final demand on energy use and CO_2 emission of China and Japan, but also proposes a method to evaluate the energy and CO_2 embodied in bilateral trade using Multi-region input-output table. Besides, by supposing a non-trade scenario, the paper also estimates the effect of China-Japan trade on energy use and CO_2 emission of China and Japan. The results indicate that for the same production in 2007 in bilateral trade, China not only has consumed more energy, but also has discharged more CO_2 than Japan. In China-Japan trade of 2007, China is net importer of goods and services, but net ‘exporter’ of energy and CO_2. The results also witness that China-Japan trade is helpful to reduce energy consumption and CO_2 emission of China, while drive up that of Japan, but overall, the Sino-Japan trade is beneficial to the global environment.

Keywords: China-Japan international input-output table, Sino-Japan trade, energy consumption, CO_2 emission.

1. Introduction

Along with the rapid development of international trade, it becomes more and more common that production and consumption of the same commodity are often located in different countries. The environmental impacts of producing trade goods will finally affect the ecological system of the exporting country rather than that of the importing country. In this sense, trade can allow countries to move away from producing environmentally sensitive activities (Dietzenbacher and Mukhopadhyay, 2007). This phenomenon has enhanced the complexity to national environmental policy. A famous theory, pollution haven hypothesis, indicates that the counties with stringent environment regulationas will shift their pollution-intensive industry to countries with weaker regulations in free trade (Copeland and Rayloe, 2004). To reduce the damage to environment, Kyoto protocol, which determines emission ceilings on six specified greenhouse gases (GHG) for each ratifier country was adopted (Serrano and Dietzenbacher, 2010). However, literatures find that most of countries with emission commitments in the Kyoto Protocol are net importers of emissions and have move their emission into other countries, especially the developing countries. (Peters and Hertwich, 2008).

Under this circumstance, significant attention has been given to whether producers or consumers should take the responsbility of environment, especially the green gas emisison. The

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‘consumption-based’ emission inverntory seems more appropriate than the IPCC’s territorial or ‘production-based’ emission inventory. Then, analyzing energy consumption and CO_2 emissions embodied in international trade, and further to estimate the so-called“consumption-based” emissions has been an actively research topic in the last decade (Su and Ang, 2011).

A common conclusion in present literatures is that the major developed countries are net energy and CO_2 importers, while developing countries and a number of developed countries with rich resources are net exporters of energy and CO_2. Just as Wyckoff & Roop (1994) shows, about 13% of the total carbon emissions of six OECD countries were embodied in their manufactured imports in mid 1980s. For individual country cases, which are indicated to be significant net carbon or energy exporter including Australia (Lenzen, 1998), Norway (Peters and Hertwich, 2006), Sweden (Kander and Lindmark, 2006), Finland (Maenpaa and siikavirta, 2007), China (Pan et al, 2008) and so on, while the net importers including Japan (Kondo et al, 1998), US, Korea and all the large European country (Ahmad and Wyckoff, 2003). At multi-region level, Hayami and Nakamura (2002) indicate that Japan is net importer of pollution in Japan-Canada trade. Shui and Harriss (2006) prove China has significant CO_2 surplus in trade with the US. McGregor et al (2008) find Scotland runs an environmental trade surplus in trade with rest of UK.

Among these cases, Japan and China are regarded as two typical countries in energy and enviomental impact of trade. The former is usually net importer of energy and carbon in global or bilateral trade, while the latter is always a signicant net exporter. Ackerman et al (2007) proves that Japan is net importer in Japan-US trade. Lee and Roland-Holst (2000) found that Japan was displacing a significant amount of pollution onto other countries in a study of Japan’s trade with Asia/Pacific trading partners from 1981 to 1995. Hayami and Nakamura (2002) also show that Canada exports nearly twice as much CO_2 to Japan as that Japan exports to Canada. For China, Li and Sun (2010) prove emissions from production in China exceeded those from its consumption by 18.8% in 2000. Ahmad and Wyckoff (2003) indicate that net carbon exports form China and Russia in 1995 were roughly equal to net carbon imports of the OECD in total. Zhou and Kojima (2009) also find USA, Japan and Singapore had deficit in trade balance of embodied carbon, while developing countries especially China had great trade surplus.

The massive trade flows between these two largest national economies in Asia are of enormous global importance in both economic and environmental terms. It seems obvious that in China-Japan trade, China will be net exporters of energy and carbon, while Japan is net importer.. However, China always runs a deficit position in trade of goods and service in China-Japan trade. Data from China’s Customs shows, the total export value from China to Japan is up to 148.3 billion US$ in 2011, about 7.8% of China’s total export value, meanwhile, import value of China from Japan is about 194.6 billion US$, about 11.2% of China’s total import value. In this circumstance, it becomes interesting to determine whether one country is a net importer of carbon and energy from the other in China-Japan trade and whether China-Japan trade reduces or increases total global emissions. So the present paper will focus on these questions and explore the environmental impact of China-Japan trade in energy consumption and CO_2 emission. In this paper we focus on the energy consumption and CO_2 emission in production, excluding the energy and emssion in residential consumption.

Lots of methodologies have been developed to estimate the embodied energy or CO_2 in international trade, among which input-output model has been widely used, including Single-Region Input Output (SRIO) model and Multi-Region Input Output (MRIO) model.

Wiedmann et al. (2007) and Wiedmann (2009) provide a detailed review of literatures on embodied environment impacts of trade, or consumption-based emission by employing SRIO table and MRIO tables. Usually, the SRIO tables are applied to estimate the environmental impacts of final demand in national economy, including consumption, capital investment, exports or imports. It's assumed that imported goods and services are being produced with the same technology as the domestic production in the same sector. However, this poor assumption can be relaxed by modifying the import intensity with several multiplicative facors (Ghertner and Fripp, 2007). The related literatures include Peters et al (2007)'s research on China, Ghertner and Fripp (2007)'s research on US, Wachsmann et al (2009) on Brazil, Cruz and Barata (2008) on Portugal, Dietzenbacher and mukhopadhyay (2007) on India, Normal et al (2007) on Canada-US trade and so on.

However, the SRIO approach can not allow for a distinction between domestic and foreign production, and can not reflect the supply paths among different regions either. So it sounds more reasonable to employ MRIO table, where interdependencies between foreign sectors with different technology and pollution intensity can be quantified. More regions and sectors the table can distinguish, more specific the analysis will be. The related studies include Shimoda et al (2008) and Zhou and kojima (2009)'s research on 9 Asian-Pacific countries and US, Peters and Hertwich (2008)'s research on all countries in GTAP 6 and so on.

However, different from the SRIO model, in MRIO model, the exports include two parts, i.e. for intermediate consumptions (intermediate exports) and for final demands (final exports). It will bring multiple-counting problems if we multiply exports by Leontief Inverse matrix, just like we do in SRIO model. This makes it difficult to measure the energy and carbon content of trade. Most of the existed researches based on MRIO model ususlly estimate total embodied emissions of final demand (Peters and Hertwich, 2008), or assume a "no trade" scenario (Ackerman et al, 2007) to refelect which one has replaced its environment responsbility of consumption on another. But these methods can not provide the real energy or emissions embodied in trade. So we propose a new method to measure the energy or other factor content of trade in MRIO model in present paper. The new method also provides a way to estimate the factor content in exports of a certain sector or several certain sectors. Moreover, the application of the new idea is not limited in trade, but also applies to measure the factor content of any intermediate input.

The remaining sections are organized as follows. Section 2 introduces the methodology to estimate the factor content in MRIO model. Section 3 describes the input output table and environmental data the present paper employs. Section 4 provides the empirical analysis of embodied energy and CO_2 in China-Japan trade at national level, while Section 5 provides the results at sector level. Section 6 explores whether China-Japan trade is beneficial or harmful to global environment. Section 7 indicates the difference between China and Japan in energy consumption and CO_2 emission, and Section 8 further explains why the difference happens. At last, Section 9 concludes.

2. Methodology

Our research involves the extension of a two-country input output model to incorporate energy consumption and CO_2 emission for all economic sectors. The basic form of the table is as table 1 shows.

Table1 Two-country Input Output Table reflecting energy consumption and CO_2 emssion

		Intermediate Use		Final Use				Total Output/Total Import
		Country 1	Country 2	Country 1		Country 2		
				Domestic final demand	Exports to ROW	Domestic Final Demand	Exports to ROW	
Intermediate input	Country 1	$\mathbf{Z}_{11}$	$\mathbf{Z}_{12}$	$\mathbf{Y}_{11}$	$\mathbf{Y}_{13}$	$\mathbf{Y}_{12}$	$\mathbf{0}$	$\mathbf{X}_1$
	Country 2	$\mathbf{Z}_{21}$	$\mathbf{Z}_{22}$	$\mathbf{Y}_{21}$	$\mathbf{0}$	$\mathbf{Y}_{22}$	$\mathbf{Y}_{23}$	$\mathbf{X}_2$
	Imports from ROW	$\mathbf{Z}_{31}$	$\mathbf{Z}_{32}$	$\mathbf{Y}_{31}$	$\mathbf{0}$	$\mathbf{Y}_{32}$	$\mathbf{0}$	$\mathbf{X}_3$
Value-added		$V_{\mathbf{1}}$	$V_{\mathbf{2}}$					
Total input		$(\mathbf{X}_1)^{\mathbf{T}}$	$(\mathbf{X}_2)^{\mathbf{T}}$					
Energy consumption		$\mathbf{E}_1$	$\mathbf{E}_2$					
CO_2 emission		$\mathbf{C}_1$	$\mathbf{C}_2$					

Let subscripts 1, 2 and 3 stand for Country 1, country 2 and Rest of World (ROW in short) respectively. **X** denotes the output column vector, while V represents the value-added row vector. Z denotes the transaction flows. The element $z_{ST(i,j)}$ (S=1, 2 or 3, T=1, 2 or 3) gives the intermediate deliveries from industry i in country S to industry j in country T. The column $\mathbf{Y}^{11}$ gives the domestic final demand in country 1, consisting of private consumption, private investments and government expenditures, while $\mathbf{Y}^{22}$ gives the domestic final demand in Country 2. $\mathbf{Y}^{12}$ is Country 1's exports to Country 2 for domestic final demand purposes (final exports), while conversely for $\mathbf{Y}^{21}$**.** $\mathbf{Y}^{13}$ is the final exports of Country 1 to ROW and $\mathbf{Y}^{23}$ is the final exports of Country 2 to ROW. **E** is the vector of energy consumption and **C** is the vector of CO_2 emission.

The coefficients matrices are determined as follows: $\mathbf{A}_{11}=\mathbf{Z}_{11}(\widehat{\mathbf{X}}_1)^{-1}$, where a 'hat' is used to indicate a diagonal matrix. Similarly, $\mathbf{A}_{12}=\mathbf{Z}_{12}(\widehat{\mathbf{X}}_2)^{-1}$, $\mathbf{A}_{21}=\mathbf{Z}_{21}(\widehat{\mathbf{X}}_1)^{-1}$, $\mathbf{A}_{22}=\mathbf{Z}_{22}(\widehat{\mathbf{X}}_2)^{-1}$, $\mathbf{A}_{31}=\mathbf{Z}_{31}(\widehat{\mathbf{X}}_1)^{-1}$, $\mathbf{A}_{32}=\mathbf{Z}_{32}(\widehat{\mathbf{X}}_2)^{-1}$. $\mathbf{e}_1$ is the vector of energy consumption intensity in Country 1, whose element $e_{1(i)}$ are defined as $e_{1(i)}=E_{1(i)}/X_{1(i)}$, representing energy consumption per unit of total output in Country 1. $\mathbf{c}_1$ is the vector of CO_2 emission intensity in Country 1, whose element c_1^i are defined as $c_1^i=(\mathbf{C}_1)_i/(\mathbf{X}_1)_i$, representing CO_2 emission per unit of total output in Country 1. Similarly, for Country 2, $\mathbf{e}_2^i=(\mathbf{E}_2)_i/(\mathbf{X}_2)_i$ and $c_2^i=(\mathbf{C}_2)_i/(\mathbf{X}_2)_i$.

The basic equation in two-country input output table is:

$$\begin{pmatrix}\mathbf{X}_1\\ \mathbf{X}_2\end{pmatrix}=\begin{pmatrix}\mathbf{A}_{11} & \mathbf{A}_{12}\\ \mathbf{A}_{21} & \mathbf{A}_{22}\end{pmatrix}\begin{pmatrix}\mathbf{X}_1\\ \mathbf{X}_2\end{pmatrix}+\begin{pmatrix}\mathbf{F}_{11}\\ \mathbf{F}_{21}\end{pmatrix}+\begin{pmatrix}\mathbf{F}_{12}\\ \mathbf{F}_{22}\end{pmatrix}+\begin{pmatrix}\mathbf{F}_{13}\\ \mathbf{F}_{23}\end{pmatrix} \tag{1}$$

The solution is:

$$\begin{pmatrix}\mathbf{X}_1\\ \mathbf{X}_2\end{pmatrix}=\begin{pmatrix}\mathbf{B}_{11} & \mathbf{B}_{12}\\ \mathbf{B}_{21} & \mathbf{B}_{22}\end{pmatrix}\begin{pmatrix}\mathbf{F}_{11}+\mathbf{F}_{12}+\mathbf{F}_{13}\\ \mathbf{F}_{21}+\mathbf{F}_{22}+\mathbf{F}_{23}\end{pmatrix} \tag{2}$$

where $\begin{pmatrix}\mathbf{B}_{11} & \mathbf{B}_{12}\\ \mathbf{B}_{21} & \mathbf{B}_{22}\end{pmatrix}=\begin{pmatrix}\mathbf{I}-\mathbf{A}_{11} & -\mathbf{A}_{12}\\ -\mathbf{A}_{21} & \mathbf{I}-\mathbf{A}_{22}\end{pmatrix}^{-1}$ and I indicates the identity matrix.

The energy and CO_2 embodied in trade means the direct and indirect energy consumption and CO_2 emission to produce the traded products. In SRIO model, since all exports belong to final demand, the embodied energy or CO_2 are easy to be estimated: multiplying export vector by Leontief Inverse matrix and energy intensity or CO_2 emission intensity. However, in MRIO model, exports include final exports and intermediate exports. The former are still part of final demand, while the latter are part of intermediate input. By input output technique, it's easy to estimate the embodied energy and CO_2 in final exports, just like the way we do in single-country input-output model. However, this method is not suit for intermediate exports, for it’s incorrect to multipling intermediate input by Leontief Inverse Matrix. In fact, this will lead serious multi-counting problems.We will explain it by the production of Desktop Computer.

In the production chain of Desktop Computer, firstly, Country 1 exports hard disk to Country 2 as its intermediate input. And then, Country 2 produces Computer Mainframe by using the Hard Disk with other parts and then exports the Computer Mainframe to Country 1. By using the Computer Mainframe, Country 1 produces the computers and exports them to Country 2 as its final use. In this chain, exported goods of Country 1 to Country 2 include Hard Disk, which belongs to intermediate exports, and Computer, which is final export. However, the energy or other factor content embodied in exported Computer also includes the factor content embodied in exported Hard Disk. So if we use the way in SRIO to estimate the factor content embodied in exports of country 1 to country 2, the factor content in Hard Disk will be double-counted. In fact, the multiple-counting problem not only exists between final exports and intermediate exports, but also exists among different intermediate exports. We also take the Computer as an example and continue its production chain. When Country 1 exports computers to Country 2, however, Country 2 further processes them to be functional computer by adding new software and other function, rather than take them as final use. In this way, both the Hard Disk and Computer Country 1 exports to region 2 are intermediate exports. And the factor content of exported Hard Disk are already included in the factor content of exported Computer. Consequently, exports in MRIO model is multi-counting concept, we should remove the double-counting parts to figure out the real factor content in trade.

In this paper, we will propose a method to estimate the factor content of exports in MRIO table. As table 1 shows, export vector of Country 1 to Country 2 is:

$$\mathbf{EX}_{12} = \mathbf{F}_{12} + \mathbf{Z}_{12}\boldsymbol{\mu} \tag{3}$$

And export vector of Country 2 to Country 1 is:

$$\mathbf{EX}_{21} = \mathbf{F}_{21} + \mathbf{Z}_{21}\boldsymbol{\mu} \tag{4}$$

We will take the exports of Country 1 to Country 2 as an example. In equation (2), final demands are taken as exogenous variables and all the intermediate input including $\mathbf{Z}_{12}$ are taken as endogenous variables. In this form, all flows of intermediate input are induced by the final demand. By equation (2), the intermediate exports of Country 1 to Country 2 can be expressed as:

$$\mathbf{Z}_{12}\boldsymbol{\mu} = \mathbf{A}_{12}\mathbf{X}_{2} = \mathbf{A}_{12}\mathbf{B}_{21}(\mathbf{Y}_{11} + \mathbf{Y}_{12} + \mathbf{Y}_{13}) + \mathbf{A}_{12}\mathbf{B}_{22}(\mathbf{Y}_{21} + \mathbf{Y}_{22} + \mathbf{Y}_{23})\,; \tag{5}$$

Eq (5) proves that according to the different allocation, the intermediate exports of Country 1 to Country 2 can be divided into six parts, which are induced by Y_{11}, Y_{12}, Y_{1R}, Y_{21}, Y_{22} and Y_{2R}

respectively. In this way, the intermediate exports have already embodied in the total effects of final demand. The factor content of $\mathbf{Z}_{12}\boldsymbol{\mu}$ is already embodied into the factor content of final demand either. Intermediate exports induced by country 1' final exports to country 2 is $\mathbf{A}_{12}\mathbf{B}_{21}\mathbf{Y}_{12}$, Whose factor content was already embodied in the factor content of Country 1's final exports to Country 2. The other intermediate exports, which is $\mathbf{Z}_{12}\boldsymbol{\mu}-\mathbf{A}_{12}\mathbf{B}_{21}\mathbf{Y}_{12}$, also have multi-counting problems, according to the above case of Computer. In fact, we can rewrite the equation (1) as:

$$\begin{pmatrix}\mathbf{X}_1\\ \mathbf{X}_2\end{pmatrix}=\begin{pmatrix}\mathbf{Z}_{11} & \mathbf{0}\\ \mathbf{Z}_{21} & \mathbf{Z}_{22}\end{pmatrix}\boldsymbol{\mu}+\begin{pmatrix}\mathbf{Z}_{12}\boldsymbol{\mu}\\ 0\end{pmatrix}+\begin{pmatrix}\mathbf{Y}_{11}\\ \mathbf{Y}_{21}\end{pmatrix}+\begin{pmatrix}\mathbf{Y}_{12}\\ \mathbf{Y}_{22}\end{pmatrix}+\begin{pmatrix}\mathbf{Y}_{13}\\ \mathbf{Y}_{23}\end{pmatrix}; \tag{6}$$

i.e

$$\begin{pmatrix}\mathbf{X}_1\\ \mathbf{X}_2\end{pmatrix}=\begin{pmatrix}\mathbf{A}_{11} & \mathbf{0}\\ \mathbf{A}_{21} & \mathbf{A}_{22}\end{pmatrix}\begin{pmatrix}\mathbf{X}_1\\ \mathbf{X}_2\end{pmatrix}+\begin{pmatrix}\mathbf{Z}_{12}\boldsymbol{\mu}+\mathbf{Y}_{12}\\ \mathbf{0}\end{pmatrix}+\begin{pmatrix}\mathbf{Y}_{11}+\mathbf{Y}_{13}\\ \mathbf{Y}_{21}+\mathbf{Y}_{22}+\mathbf{Y}_{23}\end{pmatrix} \tag{7}$$

So we have

$$\begin{pmatrix}\mathbf{X}_1\\ \mathbf{X}_2\end{pmatrix}=\left[\mathbf{I}-\begin{pmatrix}\mathbf{A}_{11} & \mathbf{0}\\ \mathbf{A}_{21} & \mathbf{A}_{22}\end{pmatrix}\right]^{-1}\left[\begin{pmatrix}\mathbf{EX}_{12}\\ \mathbf{0}\end{pmatrix}+\begin{pmatrix}\mathbf{Y}_{11}+\mathbf{Y}_{13}\\ \mathbf{Y}_{21}+\mathbf{Y}_{22}+\mathbf{Y}_{23}\end{pmatrix}\right] \tag{8}$$

So output induced by exports of Country 1 to Country 2 is:

$$\begin{pmatrix}\mathbf{X}_1^{12}\\ \mathbf{X}_2^{12}\end{pmatrix}=\left[\mathbf{I}-\begin{pmatrix}\mathbf{A}_{11} & \mathbf{0}\\ \mathbf{A}_{21} & \mathbf{A}_{22}\end{pmatrix}\right]^{-1}\begin{pmatrix}\mathbf{EX}_{12}\\ \mathbf{0}\end{pmatrix} \tag{9}$$

Then we can further get the factor content of Country 1's exports to Country 2 by multiplying the factor coefficients. For example, the energy embodied in exports of Country 1 to Country 2 is

$$\begin{pmatrix}E_1^{12}\\ E_2^{12}\end{pmatrix}=\begin{pmatrix}\mathbf{e}_1 & 0\\ 0 & \mathbf{e}_2\end{pmatrix}\begin{pmatrix}\mathbf{X}_1^{12}\\ \mathbf{X}_2^{12}\end{pmatrix}=\begin{pmatrix}\mathbf{e}_1 & 0\\ 0 & \mathbf{e}_2\end{pmatrix}\left[\mathbf{I}-\begin{pmatrix}\mathbf{A}_{11} & \mathbf{0}\\ \mathbf{A}_{21} & \mathbf{A}_{22}\end{pmatrix}\right]^{-1}\begin{pmatrix}\mathbf{EX}_{12}\\ \mathbf{0}\end{pmatrix} \tag{10}$$

Where E_1^{12} is embodied energy located in country 1 of country 1's exports to country 2, while E_2^{12} is embodied energy located in country 2 of country 1's exports country 2.

In fact, it's not difficult to understand the form of eq. (10). Exports of country 1 to country 2, i.e. $\mathbf{EX}_{12}$, will drive output of both country 1 and country 2 by backward linkage, and then will further induce the intermediate exports of country 1 to country 2. However, as export is an multi-counting concept in MRIO, exports of Country 1 to Country 2 includes all the intermediate exports from country 1 to country 2, which means the intermediate exports induced by $\mathbf{EX}_{12}$ have already been included in $\mathbf{EX}_{12}$. So when estimate the total effect of $\mathbf{EX}_{12}$ on output, we should remove the intermediate exports, which is $\mathbf{Z}_{12}$, from the input output circle to avoid the multi-counting problems.

We can further simplifying the equation (10). By the matrix operation:

$$\left[\mathbf{I}-\begin{pmatrix}\mathbf{A}_{11} & \mathbf{0}\\ \mathbf{A}_{21} & \mathbf{A}_{22}\end{pmatrix}\right]^{-1}=\begin{pmatrix}\mathbf{I}-\mathbf{A}_{11} & \mathbf{0}\\ -\mathbf{A}_{21} & \mathbf{I}-\mathbf{A}_{22}\end{pmatrix}^{-1}=\begin{pmatrix}\mathbf{B}'_{11} & \mathbf{0}\\ \mathbf{B}'_{22}\mathbf{A}_{21}\mathbf{B}'_{11} & \mathbf{B}'_{22}\end{pmatrix} \tag{11}$$

Where $\mathbf{B}'_{11}=(\mathbf{I}-\mathbf{A}_{11})^{-1}$ and $\mathbf{B}'_{22}=(\mathbf{I}-\mathbf{A}_{22})^{-1}$. Put eq. (11) into the eq.(10), then:

$$\begin{pmatrix}E_1^{12}\\ E_2^{12}\end{pmatrix}=\begin{pmatrix}\mathbf{e}_1 & 0\\ 0 & \mathbf{e}_2\end{pmatrix}\begin{pmatrix}\mathbf{B}'_{11} & \mathbf{0}\\ \mathbf{B}'_{22}\mathbf{A}_{21}\mathbf{B}'_{11} & \mathbf{B}'_{22}\end{pmatrix}\begin{pmatrix}\mathbf{EX}_{12}\\ \mathbf{0}\end{pmatrix}=\begin{pmatrix}\mathbf{e}_1\mathbf{B}'_{11}(\mathbf{EX}_{12})\\ \mathbf{B}'_{22}\mathbf{A}_{21}\mathbf{B}'_{11}(\mathbf{EX}_{12})\end{pmatrix} \tag{12}$$

Due to the complex consumption relationship between the products in two countries, country 1's exports will not only generate the energy consumption located in country 1, but also generate the energy consumption located in country 2. In national input output model of country 1, we know that embodied energy of country 1 in its exports to country 2 is $\mathbf{e}_1\mathbf{B}'_{11}(\mathbf{EX}_{12})$, which is exactly as same as the result in two-country input output model[2]. However, the national input output model can not provide the embodied energy located in country 2 of country 1's exports.

The method proposed in present paper not only can estimate the embodied energy in trade, but also can estimate other embodied factor of the trade, such as, value-added, employment, water and so on. Besides, the method also can be extended to n-country input output model, where n is an intenger bigger than 2. More significantly, the method provides an idea to measure the factor content of intermediate input: we just need to remove this part of intermediate input out of the circle by setting the corresponding matrix blocks to zero and take them as exogenous variables.

In fact, Deitzenbacher and Los (2011) also have proposed an idea to estimate the factor content of exports in MRIO model (DL method in short). As the export is a multi-counting concept, their idea is removing the repeating parts from the exports firstly, getting the so-called "net" exports. Then multiply the "net" export vector by the Leontief Inverse and factor intensity. We have proved that the method proposed in present paper is equivalent to the method of Deitzenbacher and Los (2011).

Moreover, besides the simpler expression and calculation, the method proposed in present paper has more advantages than DL method: it also applies to estimate the factor content in a certain sector or serval certain sectors' exports. Similar with the idea of eq.(6), eq.(7) and eq.(8), we just need to remove the intermediate exports of the certain sector (or sectors) out of the input output circle by setting the corresponding matrix blocks to zero and take them as exogenous variables. We will illustrate it by taking sector 1 as an example. To estimate the factor content in exports of sector 1 from country 1 to country 2, we rewrite the eq.(1) as:

$$\begin{pmatrix}\mathbf{X}_1\\ \mathbf{X}_2\end{pmatrix}=\begin{pmatrix}\mathbf{Z}_{11} & \overline{\mathbf{Z}}_{12}\\ \mathbf{Z}_{21} & \mathbf{Z}_{22}\end{pmatrix}\boldsymbol{\mu}+\begin{pmatrix}\mathbf{ex}_{12(1)}\\ 0\end{pmatrix}+\begin{pmatrix}\mathbf{Y}_{11}+\mathbf{Y}_{12}+\mathbf{Y}_{13}\\ \mathbf{Y}_{21}+\mathbf{Y}_{22}+\mathbf{Y}_{23}\end{pmatrix} \tag{13}$$

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[2] In fact, when we extend the method to n-country input output model, where n is bigger than 2, we find that some interesting conclusions: the country 1's factor content embodied in the exports of country 1 to country 2 by using n-country input output model is greater than that by using single input output model. Along with the increase of n, the results became bigger and bigger.

Where $\overline{\mathbf{Z}}_{\mathbf{12}} = \begin{pmatrix} 0 & 0 & \cdots & 0 \\ z_{12(2,1)} & z_{12(2,2)} & \cdots & z_{12(2,n)} \\ \vdots & \vdots & \ddots & \vdots \\ z_{12(n,1)} & z_{12(n,2)} & \cdots & z_{12(n,n)} \end{pmatrix}$, i.e: making the first row of $\mathbf{Z}_{\mathbf{12}}$ become zero.

$\overline{\mathbf{ex}}_{12(1)} = \begin{pmatrix} \sum_{j=1}^{n} z_{12(1,j)} \\ 0 \\ \vdots \\ 0 \end{pmatrix}$, whose first element is total intermediate exports of sector 1 from country 1 to country 2. Then we ignore all the final demand except final exports from sector 1 in country 1 to country 2, the embodied factor in exports of sector 1 in country 1 to country 2 can be attained.

$$\begin{pmatrix} E_1^{12(1)} \\ E_2^{12(1)} \end{pmatrix} = \begin{pmatrix} \mathbf{e_1} & 0 \\ 0 & \mathbf{e_2} \end{pmatrix} \left[\mathbf{I} - \begin{pmatrix} \mathbf{A_{11}} & \overline{\mathbf{A}}_{\mathbf{12}(1)} \\ \mathbf{A_{21}} & \mathbf{A_{22}} \end{pmatrix} \right]^{-1} \begin{pmatrix} \mathbf{EX}_{\mathbf{12}(1)} \\ \mathbf{0} \end{pmatrix} \tag{14}$$

Where $E_1^{12(1)}$ denotes embodied factor located in country 1 of sector 1's exports from country 1 to country 2, while $E_1^{12(1)}$ denotes that of country 2. $\overline{\mathbf{A}}_{\mathbf{12}(1)}$ is defined as $\overline{\mathbf{A}}_{\mathbf{12}(1)} = \overline{\mathbf{Z}}_{\mathbf{12}} / \widehat{\mathbf{X}}_{\mathbf{1}}$, while

$\mathbf{EX}_{\mathbf{12}(1)} = \begin{pmatrix} \sum_{j=1}^{n} z_{12(1,j)} + y_{12(1)} \\ 0 \\ \vdots \\ 0 \end{pmatrix}$ represents the total exports of sector 1 in country 1 to country 2.

In the similar way, we also can estimate the energy content of country 2's exports to country 1, which is:

$$\begin{pmatrix} E_1^{21} \\ E_2^{21} \end{pmatrix} = \begin{pmatrix} \mathbf{e_1} & 0 \\ 0 & \mathbf{e_2} \end{pmatrix} \left[\mathbf{I} - \begin{pmatrix} \mathbf{A_{11}} & \mathbf{A}_{12} \\ \mathbf{0} & \mathbf{A_{22}} \end{pmatrix} \right]^{-1} \begin{pmatrix} \mathbf{0} \\ \mathbf{EX_{21}} \end{pmatrix} = \begin{pmatrix} \mathbf{e_1} & 0 \\ 0 & \mathbf{e_2} \end{pmatrix} \begin{pmatrix} \mathbf{B}'_{\mathbf{11}} & \mathbf{B}'_{11}\mathbf{A}_{12}\mathbf{B}'_{22} \\ 0 & \mathbf{B}'_{\mathbf{22}} \end{pmatrix} \begin{pmatrix} \mathbf{0} \\ \mathbf{EX_{21}} \end{pmatrix}$$
$$= \begin{pmatrix} \mathbf{e_1}\mathbf{B}'_{11}\mathbf{A}_{12}\mathbf{B}'_{22}(\mathbf{EX_{21}}) \\ \mathbf{e_2}\mathbf{B}'_{22}(\mathbf{EX_{21}}) \end{pmatrix} \tag{15}$$

Where E_1^{21} is the embodied energy located in country 1 of country 2's exports to country 1. E_2^{21} is the embodied energy located in country 2 of country 2's exports to country 1. The results at sector level also can be attained in similar way.

3. Table and Data

The method based on MRIO model can provide more detial and accurate results, but the great drawback to this proproach is the difficulty of developing detailed data on international transactions. However, we are fortunate to be able to use the China-Japan International Input-Output (CJIO) Table developed by National Bureau of Statistics of China,and METI

(Ministry of Economy, Trade and Industry) of Japan. So far it has been compiled only for the year of 2007 at 77-sector level. However, because of the limited data resource on energy consumption and CO_2 emission, we have to combine the 77 sectors into 40 sectors.

It's very kind of API (Applied Research Institute. Inc) in Japan to provide us with the energy consumption and CO_2 emission data table of Japan, showing total energy consumption and total CO_2 emission in each sector. And For China, we compiled energy consumption and CO_2 emissions table by employing Peters (2006)'s method. But before that, energy use data for some sectors in China also need to be estimated firstly. Such as, only energy use data for the "Transport Equipment" is available in China, so we need to split it into energy use of "Motor Vehicle" (26), energy use of "Motor Vehicle Parts" (27) and energy use of "Other Transport Equipment" (28). The other sectors whose energy use data need to be further split including "Electrical Machinery and Equipment" and "Communication Equipment, Computers" and "Other Electronic Equipment"; the former was split into "Household electric and non-electric equipment" (22) and "Industrial Electric Equipment" (24), while the latter was split into "Household Electronic Equipment, Communications Equipment" (21), "Electronic Component" (23) and "Electronic Computing Equipment and Accessories" (25). For each sector, its energy consumption is resulted from its use of energy intermediate inputs. So the split process taking each sector's consumption structure in CJIO Table as a reference. Taking the spilt of "Transport Equipment" as an example, assume its final consumption to coal energy in 2007 was 3.81 million tce[3]. The use of coal energy is mainly due to its consumption to the products of "Coal Mining" (04) [4]. According to the intermediate flow in CJIO table, Products of Coal sectors consumed by "Motor Vehicle" (26), "Motor Vehicle Parts (27) and "Other Transport Equipment (28) was 108.6 million US$, 120.7 million US$ and 136.5 million US$ respectively. Then we know that, the final consumption to coal energy of "Motor Vehicle" (26) was $3.81\times108.6/(108.6+120.7+135.6)=1.13$ million tce, while that for "Motor Vehicle Parts" (27) was $120.7/(108.6+120.7+135.6)=1.26$ million tce, that for "Other Transport Equipment" (28) was $135.6/(108.6+120.7+135.6)=1.42$ million tce. According to this method, we finally get the energy final consumption vector in physical for each sector, and then the energy consumption vector will be further attained by adding energy losses of each sector to final consumption vector. By adopting Perters' (2006) method, we also have estimated CO_2 emission for each sector in China.

4. Energy and Carbon content of China-Japan trade.

Table 2 Energy and CO_2 embodied in China-Japan trade

	Exports of Janpan to China		Exports of China to Japan	
	Energy （million TCE）	CO_2 （million Tons）	Energy （million TCE）	CO_2 （million Tons）
Japan	25.87	48.94	0.90	1.57
China	2.51	6.07	77.46	178.35
Sum	28.38	55.01	78.36	179.91

By formula (12) and (13), we eventually get the energy and carbon embodied in China-Japan trade, which are shown in table 2. The results show both the energy and CO_2 embodied in China's exports to Japan is much greater than that in Japan's exports to China. For energy, the former is

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[3] Tce is a measurement of energy, which in detail is Ton of Standard Coal Equivalent.

[4] Includes both domestic coal inputs and imported coal inputs.

nearly three times as much as the latter, while for CO_2 emission, the former is more than three times as much as the latter. In China-Japan trade, China was a net importer of goods and service in 2007. According to CJIO table, Japan’s exports (including both goods and service) to China is about 139.01 billion US$, about 1.07 times of China’s exports to Japan. The environment resluts imply the production in China is much more energy intensive and carbon intensive than that in Japan.

No matter for Japan’s exports to China, or China’s exports to Japan, most of the energy and CO_2 they generate happens at home. The embodied energy in Japan’s exports to China was 2839 wtce in total in 2007, and nearly 91.11% of it was located in Japan and for CO_2 emission, this proportion was a little lower, which was 88.97%. The energy embodied in China’s exports to Japan was 78.36 million tce in total in 2007, and about 98.85% of it happened in China and for CO_2 emission, this proportion was a little higher, which was 99.13%. Comparing with Japan’s exports to China, more embodied energy and CO_2 in China’s exports to Japan happened at home. In other words, the impact of Japan’s exports on China’s energy and environment is greater than impact of China’s exports on Japan’s energy and environment.

China’s energy embodied in Japan’s exports is due to the consumption of Japan’s exports to its imports from China. So this part of energy already included in the China’s energy embodied in China’s exports to Japan. It’s similar for the CO_2 emission. Consequently, the total energy Japan exports to China were 25.87 million tce, accounting for 4.92% of Japan’s total industrial energy consumption. Meanwhile, the total energy China exports to Japan were 77.46 million tce, about 3.24% of China’s total industrial energy consumption. For CO_2 emission, the amount Japan exports to China was 48.94 million tons, about 4.33% of Japan’s total industrial CO_2 emission. At the same time, the volume of CO_2 China exports to Japan was 178.35 million tons, about 2.84% of China’s industrial CO_2 emission. In China-Japan trade, energy embodied in China’s exports was about three times as much as that in Japan’s exports, while CO_2 China exported to Japan was nearly four times as much as CO_2 Japan exported to China. The results witnessed that though China was net importer of goods and services in 2007, China was net exporter of both energy and CO_2 in Sino-Japan trade, runing about 51.58 million tce energy and 129.40 million tons CO_2 surplus respectively. In our research, the results suggest Japan has effectively displaced part of energy and environmental burden of their consumption onto China.

5. Energy and Carbon Content at Sector Level

By employing the idea of Eq. (15), the energy consumption and CO_2 emission embodied in China-Japan trade at sector level can also be obtained. We list the results in tabular form, where table 3 is for Japan’s exports to China, while table 4 is for China’s exports to Japan. Due to the limited space, the paper just listed the top 15 sectors whose exports contain the most energy and CO_2 in China-Japan trade. Due to the intermediate exports, one country’s exports not only contain energy and carbon of itself, but also that of the other country. In table 3, the figures in second column show the volume of embodied energy which is located in Japan in Japan’s exports to China, while the figures in third column means that which is located in China. The figures in fourth column show the proportion of energy which occurs at home in total embodied energy in Japan’s exports to China. It’s similar for CO_2 emission, which is listed in column five, six and seven. The eighth column provides the export proportion for each sector in Japan’s total exports to China. The figures in table 4 can be explained in a similar way.

The sectors in table 3 and table 4 all also have the largest export volumes or import volumes in China-Japan trade. By correlation test, embodied energy and CO_2 are significantly positive correlation with the exports volume. In Japan's exports to China, Chemical product (12) has the most embodied energy and third largest embodied CO_2, not only due to its high energy and CO_2 intensity, but also its high exports volume. Besides that, Steel (17) has the second largest embodied enegy and the largest embodied CO_2. As export volume of Steel (17) is not great enough, the high embodied energy and CO_2 is mainy due to its high energy and CO_2 intensity. Machinery Manufacturing (20-29), whose products have occupied the most of trade goods in China-Japan trade, also has high embodied energy and CO_2. The exports of this industry had accounted for 56.3% in Japan's total exports to China in 2007. By a simple addition, in 2007 the emodied energy in Machinery Manufacturing's exports accounts for 40.4% in sum of embodied energy of all sectors' exports[5]. And the embodied CO_2 of Machinery Manufacturing's exports accounted for 45.6% in sum of embodied CO_2 of all sectors' exports. Especially for General machinery (15), it has the third largest embodied energy and CO_2 due to its high export proportion.

When it comes to China's exports to Japan, the export products are focus on Textiles and wearing apparels (08), Machinery Manufacturing (20-29) and Chemical products (12), whose exports volume accounted for 17.0%, 39.3% and 7.4% respectively in China's total exports to Japan in 2007. Textiles and wearing apparels (08) had the largest embodied energy and CO_2, about 17.1% and 14.4% respectively in the sum of embodied energy or CO_2 of all sectors. The Chemical products (12) had the second largest embodied energy and CO_2, accounting for 10.9% and 10.3% in the sum of embodied energy or CO_2 of all sectors. As for Machinery Manufacturing, proportion of its embodied energy was about 28.6%, while proportion of its embodied CO_2 was about 31.1%.

In bilateral trade, one country's production of exports consumes the imports from the other country, which will lead to parts of embodied energy and CO_2 in exports locating in the other country. More imports the exports consume, more energy and CO_2 will locate in the other country. The comparison between the column 4, 7 in table 3 and that in table 4 shows that more embodied energy and CO_2 in Japan's exports were located in the other country. Especially for Household electronic equipment, communications equipment (21) and Industrial electric equipment (24), more than 20% of their embodied energy and CO_2 was located in China. This means Japan's exports to China have great infulence not only on the environment of itself, but also on that of China. It also suggests Japan's exports to China, especially the exports of Machinery Manufacturing, have really high dependence on the imports from China. In other word, lots of China's exports happened for Japan's exports. The proportion for other sectors was shown in table 3. However, in China's exports to Japan for each sector, most of the embodied energy and CO_2 occured at home, only no more than 5% was located in Japan. In this way, China's exports only have small impact on Japan's environment.

As for the trade balance in energy and CO_2, except Steel (17), Motor vehicle (26), Reuse and recycling (32) and Construction (33), for other sectors, China was always the net exporter of energy and CO_2, while Japan was net importer. There are even 12 sectors, for which China was net importer in goods while net exporter in energy and CO_2, such as Chemical products (12), Plastic and rubber products (13), General machinery (20), Electronic component (23), Motor vehicle parts

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[5] Strictly speaking, the embodied energy of Machinery Manufacturing (20-29) is smaller than the simple addition of embodied energy of the 10 sectors, because there are repetitions among different sectors. The total energy embodied in exports is also smaller than the sum of embodied energy of all sectors. But to simplify the results, we just use the proportion by simple addition.

(27) , Precision instruments (29), Wholesale and Retail Trades (37) and so on. It suggested that their energy and carbon intensities were much bigger than that in Japan.

Table 3 Energy and CO_2 embodied in Japan's exports to China by sector (Top 15).

Sector	Energy located in Japan (unit: thousand tce)	Energy located in China (unit: thousand tce)	Proportion of energy at home	CO_2 located in Japan (unit: thousand tons)	CO_2 located in China (unit: thousand tons)	Proportion of CO_2 at home	Proportion in total exports
08 Textiles and wearing apparels	311	65	0.827	520	134	0.796	0.018
12 Chemical products	7560	346	0.956	7349	758	0.906	0.136
16 Nonmetallic Mineral Products	296	13	0.958	1236	40	0.969	0.008
17 Steel	4514	199	0.958	11770	446	0.964	0.048
18 Non-steel metals	373	64	0.853	826	143	0.852	0.025
19 Metal products	318	28	0.919	751	67	0.919	0.011
20 General machinery	3396	404	0.894	7745	994	0.886	0.159
21 Household electronic equipment, Communications equipment	207	65	0.762	376	164	0.696	0.015
23 Electronic component	2551	558	0.820	5462	1426	0.793	0.178
24 Industrial electric equipment	1249	317	0.798	2483	755	0.767	0.071
26 Motor vehicle	435	63	0.873	862	152	0.850	0.022
27 Motor vehicle parts	654	81	0.890	1304	192	0.872	0.029
29 Precision instruments	984	181	0.845	2035	490	0.806	0.072
37 Wholesale and Retail Trades	648	21	0.968	1261	50	0.962	0.082
38 Transportation	1411	19	0.986	2803	45	0.984	0.048

Table 4 Energy and CO_2 embodied in China's exports to Japan by sector. (Top 15)

Sector	Energy located in China (unit: thousand tce)	Energy located in Japan (unit: thousand tce)	Proportion of energy at home	CO_2 located in China (unit:thousand tons)	CO_2 located in Japan (unit: thousand tons)	Proportion of CO_2 at home	Proportion in total exports
06 Food	2645	12	0.996	5859	19	0.997	0.049
08 Textiles and wearing apparels	13307	117	0.991	25790	167	0.994	0.170
12 Chemical products	8469	114	0.987	18401	132	0.993	0.074
14 Petroleum and coal products	6414	16	0.998	9584	26	0.997	0.030
16 Nonmetallic Mineral Products	2451	8	0.997	11192	14	0.999	0.015
17 Steel	3609	7	0.998	8951	14	0.998	0.016
18 Non-steel metals	2618	9	0.996	5606	18	0.997	0.022
19 Metal products	2814	28	0.990	7399	65	0.991	0.023
20 General machinery	4869	60	0.988	12564	130	0.990	0.053
21 Household electronic equipment, Communications equipment	1598	57	0.965	3993	111	0.973	0.047

22 Household electric and non-electric equipment	1607	28	0.983	3944	51	0.987	0.024
23 Electronic component	3203	76	0.977	8418	138	0.984	0.055
24 Industrial electric equipment	5466	73	0.987	13006	145	0.989	0.068
25 Electronic computing equipment and accessories	2346	111	0.955	6000	220	0.965	0.099
31 Articles for Culture, Education and Sports Activities	2958	61	0.980	6860	93	0.987	0.044
38 Transportation	2300	7	0.997	5179	13	0.997	0.024

6. Whether China-Japan trade benefits or damages to environment?

To judge whether the China-Japan trade is beneficial or harmful to environment of China and Japan, we will estimates the energy consumption and CO_2 emission under the ‘no Sino-Japan trade’ scenario. In this scenario, each country produces at home the goods that are imported from the other country in the reality. In other word, China do not import from or export to Japan any more, while Japan do not import from or export to China any more either. If the energy consumptions (emissions) are smaller in scenario than in the reality, then bilateral trade has increased energy consumption (emissions); conversely, bilateral trade has decreased energy consumption (emissions).

In the scenario, the estimation is a purely domestic, single-country measure: it is the domestic emissions avoided by imports in China-Japan trade, plus the domestic emissions created by exports in China-Japan trade. We suppose that Country 1 in table 1 is Japan, while Country 2 in table 1 is China without any loss in generality. Then in the scenario, for Japan, the domestic technological coefficients became $\mathbf{A}^{1S} = \mathbf{A}^{11} + \mathbf{A}^{21}$, and for China, it is $\mathbf{A}^{2S} = \mathbf{A}^{22} + \mathbf{A}^{12}$. At the same time, the final demands for Japan and China also have changed. For Japan, the final demand became $\mathbf{F}^{1S} = \mathbf{F}^{11} + \mathbf{F}^{21} + \mathbf{F}^{13}$, while for China, the final demand became $\mathbf{F}^{2S} = \mathbf{F}^{22} + \mathbf{F}^{12} + \mathbf{F}^{23}$.So in the scenario, total energy consumption of production in Japan is

$$E^{1S} = \mathbf{e}^{1}\left(\mathbf{I} - \mathbf{A}^{1S}\right)^{-1}\mathbf{F}^{1S}; \tag{16}$$

While total energy consumption of production in China is

$$E^{2S} = \mathbf{e}^{2}\left(\mathbf{I} - \mathbf{A}^{2S}\right)^{-1}\mathbf{F}^{2S}. \tag{17}$$

So if $E^{1S} > E^{1}$, it means China-Japan trade has decreased the energy cosumption of Japan, conversely, if $E^{1S} < E^{1}$, it means China-Japan trade has increased the energy cosumption of Japan. We can get the similar expaination for China. If $E^{1S} + E^{2S} > E^{1} + E^{1}$, it means China-Japan trade has decreased the total energy consumption and can bring benefits to the whole environment.

Our aggregate results are shown in table 3. In global level, China-Japan trade has brought benefits for the energy and environment. There is a net global energy consumption reduction of 7.19 million tce attributable to China-Japan trade. Meanwhile, the China-Japan trade has reduced 36.58 million tons CO_2 emission. However, the bilateral trade has different effects on Japan and China. It has increased Japan’s energy consumption by 4.57 million tce, or 0.87% of Japan’s energy consumption in reality. The bilateral trade also has increased Japan’s CO_2 emission by 2.89 million tons, or 0.26% of Japan’s CO_2 emission in reality. At the same time, the bilateral trade has reduced China’s energy consumption and CO_2 emission with a decrement of 11.76 million tce and

39.44 million tons respectively. However, in total output of Japan and China, the volume of China-Japan trade only accounts for a small proportion, which was about 1.4% in 2007. So the bilateral trade had very limited impact on the total energy consumption and CO_2 emission of Japan and China.

Table 3 Total Industrial emissions: reality and scenario

	Japan		China		Japan and China
	Reality	Change of scenario from reality	Reality	Change of scenario from reality	Change of scenario from Reality
Energy (Million tce)	525.63	0.87%	2387.69	-0.49%	-0.25%
CO2 (Million tons)	1129.14	0.26%	6281.70	-0.63%	-0.49%

It seems like there is a contradiction between the results in this section and results in section 4. In section 4, China was net exporter of energy and CO_2 in China-Japan trade, so if there are no Sino-Japan trade, China's energy consumption and CO_2 emission should decrease. However, the results in this section indicated, in "no Sino-Japan trade" scenario, China will consume more energy and emit more CO_2. This phenomenon is due to the much higher energy intensity and carbon intensity of China's production.

The estimates in the scenario witnessed that both under China's technology and under Japan's technology, Japan's exports to China contain more energy and CO_2 emission than China's exports to Japan, so China-Japan trade can decrease energy consumption and CO_2 emission China's,of China and increase that of Japan. However, in the reality, the energy use and CO_2 emission of China's exports to Japan is under China's technology, while that of Japan's exports to China is under Japan's technology. The results also suggest that not the export structure, but China's much higher energy intensity and carbon intensity is the main reason for China's exports contain much more energy and CO_2 than Japan's exports.

However, these results can not deny the fact that Japan has displaced part of the energy and environmental burden of their consumption onto China. In the scenario, we assumed that the energy intensity and carbon intensity of China and Japan remain unchanged. But the fact is China-Japan trade is also one of contributors for China's high energy and carbon intensity. When the China-Japan trade disappears, the energy intensity and carbon intensity will also change. In each sector, it includes thousands of products, and for each product, it also includes many different production processes. The China-Japan trade has important impact on China and Japan's products structure or production process structure in each sector. Generally, the energy intensive processes are usually located in developing countries, whose semi-products are exported to developed countries to be further processed. So when the China-Japan trade disappears, the product (includes semi-products) structure in each sector has also changed, which eventually change the energy intensity and carbon intensity in sector level. In general, China's energy intensity and carbon intensity for most sectors will decrease, due to the reducing of energy intensive processes. Instead, Japan's energy intensity and carbon intensity will increase in some extent, because the energy intensity production process will be re-located in home. So the results in the scenario are closely related with the sector classification. More disaggregate the sectors are, more accurate the results are.

7. National difference in energy consumption and CO_2 emission

One important reason for China exports much more energy and CO_2 to Japan is China has a much more energy-intensive and carbon-intensive economy than Japan. According to our estimation, China averages 0.22 tce energy consumption and 579.02 kg CO_2 emission for per 1000 US$ of output, while the corresponding average in Japan was 0.06 tce and 137.87 kg respectively. In this way, in 2007, China's energy intensity was about 3.43 times of Japan's energy intensity, while China's carbon intensity is about 4.75 times of Japan's carbon intensity.

At sector level, Japan and China's energy consumption intensities by sector are strongly positively correlated and either for carbon intensities. For the 39 sectors[6] with energy and carbon intensities, simple regressions are as followings: (the figures in parentheses below coefficients are t statistics and p value respectively):

$$\ln(e_i^J) = -1.19 + 0.91\ln(e_i^C)$$

(-5.12) (9.88) ; Prob(F-statistic)=0.000; adjusted R^2=0.72. (18)

(0.00) (0.00)

$$\ln(c_i^J) = -1.02 + 0.80\ln(c_i^C)$$; Prob(F-statistic)=0.000; adjusted R^2=0.70. (19)

(-3.95) (9.38)

(0.00) (0.00)

Logarithms are used to reduce the influence of outliers; both in energy intensity and carbon intensity equations, the regression coefficients is significantly less than 1, implying that both the variance of induced emissions intensity and the variance of induced energy intensity by sector is larger in China than in Japan. The positive coefficients also witness that the sectors which own high energy consumption (or CO_2 emission) intensities in China always also own high energy consumption (or CO_2 emission) intensities in Japan. It means the pattern of energy consumption (CO_2 emission) intensities among sectors in Japan was similar with that in China.

Rewrite the eq.(18) and eq.(19) by applying exponential functions, we know that:

$$e_i^J = 0.37e_i^C \tag{20}$$

$$c_i^J = 0.80c_i^C \tag{21}$$

Both in eq.(20) and in eq.(21), coefficients are less than 1, implying energy intensities and CO_2 intensities of most sectors in Japan was less than that in China. In fact, most of the CO_2 emission derived from the combustion of fossil fuels to generate energy, so the lower energy intensity in Japan implies its lower CO_2 intensity to some extent. Except for "Paper, Printing, Reproduction of Recording Media" (11) and "Electricity" (34), the energy intensity of other sectors in Japan were smaller that in China. While for the CO_2 intensity, except for "Non-metal ores" (03), "Paper, Printing, Reproduction of Recording Media" (11) and "Petroleum and coal products" (14), the CO_2 intensity for other sectors in Japan were smaller than that in China. However, coefficient in CO_2 emission equation is much bigger, which suggests CO_2 intensity between Japan and China is much closer, comparing with the energy intensity.

Specifically, both in China and Japan, "Paper, Printing, Reproduction of Recording Media" (11), "Petroleum and coal products" (14) and "Electricity" (34) had the higher energy intensities

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[6] As the energy consumption intensity for the 40th sector "Unclassified" in China is zero, its logarithm cannot be used. We delete this sample in regression.

and CO_2 intensities. Besides, for China, “Coal mining” (04) and “Nonmetallic Mineral Products” (16) also had high energy intensities and CO_2 intensities. The machinery manufactures (including 20-29) and Service sectors except for transportation (38) had relatively low energy and CO_2 intensities both in Japan and China.

8. Reason for the national difference

There are several reasons why China is more energy-intensive and carbon-intensive. Firstly, Japan has a really long history of scarce resources and high energy price. Almost all the raw coal and crude oil Japan consumed is imported[7]. Ackerman et al (2007) finds that Gasoline prices are frequently twice as high in Japan as in the US, due in part to the higher tax on gasoline in Japan. Electricity costs are even more than three times as much per kilowatt hour in Japan as in the US for industrial users. Hang and Tu (2007)’s research shows, higher prices of energy can lead to the decrease in aggregate energy intensities and raising energy prices can boost efficiency of energy use. The scarce energy resource and high energy price led to the development of energy-saving industries and technology in Japan. However, it’s very different for China, who is rich in resources such as coal, oil, gas and so on. The abundant energy resources result to the development of energy-intensive industries and technology in China. Besides, the energy industry, especially for the coal industry in China develops in a typical extensive production mode. In this way, the energy utilizing efficiency in China is relatively low. China’s much higher energy intensity further lead to its higher CO_2 intensity.

Industrial structure is another important reason why Japan is less energy-intensive and carbon-intensive. In Japan’s total output, the proportion of service excluding transportation was about 50.09% in 2007, while that in China was only 19.28%. Service excluding transportation in average have both low energy intensity and CO_2 intensity, in Japan per unit output of which consumes only 0.026 tce energy and emits 79.9 kg CO_2, far less than the average level of Japan. Besides, Machinery manufacture, which has low energy and carbon intensity, also occupies high proportion in Japan, which was 15.26% in 2007. Meantime, energy-intensive sectors always occupied less proportion in Japan than that in China, such as “Chemical products” (12), “Petroleum and coal products” (14), “Nonmetallic Mineral Products”(16), “Steel”(17), “Electricity”(34) and so on. The low proportion of energy-intensive production and the higher proportion of energy-saving production results to Japan’s less energy-intensive and CO_2 emission-intensive economy.

Just as Ackerman et al (2007)’s opinion, geography and climate also impact the energy consumption and CO_2 emission. The wide stretch of land and extremes of weather in China lead to higher energy requirements for heating and cooling. In contrast, the moderate climate and high-density settlement in Japan has led to low space heating and cooling requirements.

Except the technology, there is another reason leading to China’s high energy intensive and carbon intensive level of each sector, which is due to the sector classification. In present research, the input output table includes 40 sectors. However, for each sector, it still includes thousands of products and production processes. For differnent processes in the same sector, the energy intensities and carbon intensities are also significantly different. For the same sector, the products structure between Japan and China varies greatly, which also contributes to the different energy

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[7] According to the energy data of Japan in 2007, all the raw coal Japan consumed is imported, while 96% of the crude oil Japan consumed is imported.

intensity and carbon intensity between China and Japan. In this way, more disaggregate sector classification the input output table has, more accurate relation in energy and CO_2 between Japan and China it can reflect.

9. Conclusion

The papar aimed to estimate the energy and CO_2 embodied in China-Japan trade, and figure out whether the China-Japan trade increases or decreases the global energy consumption and CO_2 emission, whether one country displaces part of its emissions onto another. The model our study emoloyed is MRIO model, based on China-Japan international input output table of 2007. Since not all the exports in MRIO table are final demands, the tranditional method to estimate the factor conten in exports will bring serious multi-counting problems. The paper has proposed a new method to estimate the factor conten of trade in MRIO models, by employing which, embodied factor in trade can be clearly captured both at national level and at sector level.

The empirical results show that China was net exporter for both energy and CO_2 in China-Japan trade in 2007, though China was net importer of goods and service in the bilateral trade. This impies that Japan has replaced part of its energy use and CO_2 emission burden onto China.

By comparing a hypothetical scenario assuming “no China-Japan trade” with the actual case, the results show that China-Japan trade has decreased China’s energy consumption and CO_2 emission, at the same time has increased Japan’s energy consumption and CO_2 emission. As a whole, the bilateral trade was beneficial for the decrease of global energy consumption and CO_2 emission. The resluts also suggest that export structure is not the reason for China exported much more energy and CO_2 in the bilateral trade. Conversely, China’s much higher energy intensity and carbon intensity should be blamed.

Reference:

Copeland B R and Taylor M S, 2004. Trade growth and the environment. Journal of Economic Literature 85, 716-737.

Deitzenbacher, E. and Los, B., 2011. A correct method to determine the factor content of trade. The 19th international input output conference.. Alexandria Virginia.

Dietzenbacher, E., Mukhopadhyay, K., 2007. An empirical examination of the pollution haven hypothesis for India: towards a green Leontief paradox? Environmental and Resource Economics 36 (4), 427-449.

Ghertner, D.A., Fripp, M., 2007. Trading away damage: quantifying environmental leakage through consumption-based, life-cycle analysis. Ecological Economics 63, 563-577..

Hayami, H. and Nakamura, M.,2002. CO_2 emission of an alternative technology and bilateral trade between Japan and Canada: relocating production and an implication for joint implementation. Discussion paper 75, Keio Economic Observatory. Tokyo, Keio University.

Huang, L. and Tu, M., 2007. The impacts of energy prices on energy intensity: evidence from China. Energy Policy, 35(5), 2978-2988.

Kondo, Y., Moriguchi, Y., Shimizu, H., 1998. CO_2 emission in Japan: influence of imports and exports. Applied Energy 59, 163-174.

Lenzen, M., 1998. Primary energy and greenhouse gases embodied in Australian final consumption: an input–output analysis. Energy Policy 26 (6), 495-506.

Li, B. and Sun, C., 2010. Evaluating carbon dioxide emissions in international trade of China, Energy Policy, 38, 613-621.

Maenpaa, I. and Siikavirta, H., 2007. Greenhouse gases embodied in the international trade and final consumption of Finland: An input-output analysis. Energy Policy, 35, 128-143.

Norman, J., Charpentier, A.D., MacLean, H.L., 2007. Economic input-output life-cycle assessment of trade between Canada and the United States. Environmental Science & Technology 41(5), 1523-1532.

Pan, J., Phillips, J., Chen, Y., 2008. China's balance of emissions embodied in trade: approaches to measurement and allocating international responsibility. Oxford Reviewof Economic Policy 24 (2), 354 – 376.

Peters, G.P., Weber, C.L., Guan, D., Hubacek, K., 2007. Chinas growing CO2 emissions-a race between increasing consumption and efficiency gains. Environmental Science & Technology 41 (7), 5939-5944.

Peters, G., Weber, C., Liu, J., 2006. Construction of Chinese energy and estimations inventory. Working paper. (www.indecol.ntnu.no)

Peters, G. P., Hertwich, E.G., 2008. CO_2 embodied in international trade with implications for global climate policy. Environmental Science & Technology 42 (5), 1401-1407.

Serrano, M and Dietzenbacher, E., 2010. Responsibility and trade emission balances: an evaluation of approaches. Ecological Economics, 11(69): 2224-2232.

Su, B. and Ang, B.W., 2011. Multi-region input-output analysis of CO_2 emissions embodied in trade: The feedback effects. Ecological Economics 71:42-53.

Wachsmann, U., Wood, R., Lenzen, M., Schaeffer, R., 2009. Structural decomposition of energy use in Brazil from 1970 to 1996. Applied Energy 86 (4):578-587.

Wiedmann, T., 2009. A review of recent multi-region input-output models used for consumption-based emission and resource accounting. Ecological Economics 69(2), 211-222.

Wiedmann T., Lenzen M., Turner K., Barrett J., 2007. Examining the global environmental impact of regional consumption activities- Part 2: Review of Input-output models for the assessment of environmental impacts embodied in trade. Ecological Economics, 61:15-26.

Wood, R., 2008. Spatial structural path analysis-analysing the greenhouse impacts of trade substitution. International Input-Output Meeting on Managing the Environment, 9-11 July, Seville, Spain. http://www.upo.es/econ/IIOMME08/index.php.

Wood, R., Lenzen, M., 2009. Structural path decomposition. Energy Economics 31 (3), 335-341.

Yi, I., Itsubo, N., Inaba, A., Matsumoto, K., 2007. Development of the interregional I/O based LCA method considering region-specifics of indirect effects in regional evaluation. International Journal of Life Cycle Assessment 12 (6), 353-364. http://dx.doi.org/10.1065/lca2007.06.339.

Zhou, X., Kojima, S., 2009. How does trade adjustment influence national emissions inventory of open economies? Accounting embodied carbon based on multi-region input-output model. 17th International Input Output Conference of the International Input-Output Association (IIOA), July São Paulo, Brazil.

Appendix 1 Sector Classification

Code	Sector	Code	Sector
01	Agriculture	21	Household electronic equipment, Communications equipment
02	Metal ores	22	Household electric and non-electric equipment
03	Non-metal ores	23	Electronic component
04	Coal mining	24	Industrial electric equipment
05	Crude petroleum	25	Electronic computing equipment and

			accessories
06	Food	26	Motor vehicle
07	Tobacco	27	Motor vehicle parts
08	Textiles and wearing apparels	28	Other transportation equipment
09	Lumber and wooden products	29	Precision instruments
10	Furniture and accessories	30	Articles for Culture, Education and Sports Activities
11	Paper, Printing, Reproduction of Recording Media	31	Artwork and Other miscellaneous manufacturing
12	Chemical products	32	Reuse and recycling
13	Plastic and rubber products	33	Construction
14	Petroleum and coal products	34	Electricity
15	Fur and leather products	35	Gas
16	Nonmetallic Mineral Products	36	Water
17	Steel	37	Wholesale and Retail Trades
18	Non-steel metals	38	Transportation
19	Metal products	39	Other Services
20	General machinery	40	Unclassified