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Export Carbon Emissions of China from 2002 to 2007 in an Import Energy View: An Input-Output Approach

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Abstract. After accession to the WTO in 2001, the export emissions of China grow rapidly. We introduced an energy I-O table to calculate the export emissions from import goods by using SRIO analysis and SDA method. We found that the dependency of China's export emissions kept increasing from 26% in 2002 to 45% in 2007. It mainly caused by export scale expanding, whereas the carbon intensity (reflect production structure) and technology effect improved from 2002 to 2005, but stagnated from 2005 to 2007.

Keywords: CO2 Emissions, Input-Output Analysis, Energy, SDA Method.

1. Introduction

China's economic growth keeps rapidly due to the expansion of world market after accession to the WTO in 2001. However, the expense of environment becomes an obstacle in the continuous growth of China's economy. The CO_2 emissions increased from 3440 Mt in 2002 to 6499 Mt in 2007, which has been doubled in 5 years. Agency (IEA) even estimates China's CO_2 emissions will continue to increase to 11.4 Gt in 2030 in the scenario of BAU (Business As Usual). [1]

Besides, the export emissions of China toke a large proportion in total during these years. It is computed that about 30% of the growth in emissions between 1990 and 2002 was attributable to export production in China[1], with this share in growth increasing to 50% from 2002 to 2005.[1] It is shown that China was a net exporter of at least 484.18MT carbon emissions in 2007, which accounted for 8.59% of total on a production basis. In total emissions, imported carbon accounted for 21.97% while exported carbon occupied 30.56%.[1]

The import energy only cause direct emission, while other goods and material imported in China cause indirect CO_2 emissions. Emissions not related to fossil fuel combustion only account for 3% of the total CO_2 emissions in the world, even in China the ratio is about 10%. [1] Hence, in this paper, it is necessary to describe the structure of export CO_2 emissions by counting the emissions from the total import goods.

2. Methodology

2.1. Input-Output Analysis

IO analysis was originated by Leontief (1941), and then was extended to interregional and international trade applications in early contributions by Chenery (1953), Isard (1951) and Moses (1955).[1]-[4]

Table 1: Traditional I-O Table

	Intermediate Output	Final Output	Total Output
Intermediate Input	A	Y	X
Add. Value	V		
Total Input	X		

Where the A is technical coefficients matrix, X is a vector represents the domestic production of each sector, for the element of A, that $A_{ij}=X_{ij}/X_j$. The final demand Y in the IO model compromise of household

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consumption, government consumption, investment, and net export, for V represents additional value. When considering the output, a related equation can be established as eq. (1), and solved as eq. (2):

$$X = AX + Y \tag{1}$$

$$X = (I - A)^{-1}Y \tag{2}$$

The inverse matrix of I-A is called Leontief Matrix, which as a multiplier to compute total output X from Final Output Y. When coupled with a CO_2 emissions coefficient vector, G, which represents the direct CO_2 emissions row vector, each element G_j representing the direct CO2 emissions per unit of industry j. The total amount of CO_2 emissions could be calculated as

$$R = G(I - A)^{-1}Y \tag{3}$$

This equation is the basis of environmental I-O analysis, which is introduced in Walter (1973). Additionally, the sectors of this model were further refined by Wyckoff and Roop (1994), who took into account the CO_2 emissions embodied in the export of manufacturing products.[1], [2]

2.2. Import Energy Adjustment I-O Table

As Lawrence (2006) hypothesis, 1.Within the intermediate inputs of all sectors of the national economy department, the proportion of imported inputs is the same in all sectors. 2. A product of the industry can be broken down into two parts, the intermediate products and final products, and it can be assumed that, the ratio of imports and domestic products of intermediate goods is equal to the ratio of imports and domestic production of the final product.[1]

According to the hypothesis 2, we can get the eq. (4), and by the hypothesis 1, we can conduct eq. (5):

$$\frac{C_i^M}{C_i^D} = \frac{I_i^M}{I_i^D} \tag{4}$$

$$\lambda_{ij} = \frac{I_i^M}{I_i^D + I_i^M} = \frac{I_i^M + C_i^M}{C_i^D + I_i^D + C_i^M + I_i^M} \tag{5}$$

C_i^M、C_i^D represent the quantity of imports and domestic production in the final product of the industry i, and I_i^M、I_i^D represent the quantity of imports and domestic production in the intermediate goods of industry i. Besides, λ_{ij} is the proportion of imported goods in the intermediate products of industry i.

From λ_{ij}, we can calculate the proportion of the consumption of imported intermediate goods, and then get the Import Energy Adjustment I-O Table.

Table 2: Import Energy Adjusted I-O Table

			Intermediate Output		Final Output				Total Output
			Non-energy Ins.	Energy Ins.	C	I	E	F	
			1……k	k+1… n					
Intermediate Input	National Non-energy Ins.	1……k	X_{11}^D	X_{12}^D	C_{DN}	I_{DN}	E_{DN}	F_{DN}	X_1^D
	National Energy Ins.	k+1……n	X_{21}^D	X_{22}^D	C_{DE}	I_{DE}	E_{DE}	F_{DE}	X_2^D
	Import Non-energy Ins.	1……k	X_{11}^M	X_{12}^M	C_{MN}	I_{MN}	$\vec{0}$	F_{MN}	X_1^M
	Import Energy Ins.	k+1……n	X_{21}^M	X_{22}^M	C_{ME}	I_{ME}	$\vec{0}$	F_{ME}	X_2^M
Add. Value			V_1	V_2					
Total Input			$X_1^D + X_1^M$	$X_2^D + X_2^M$					

In this IO table, the energy industries are treated as the industries from k+1 to n, other industries are from 1 to k otherwise. Additionally, the final output is decomposed as consumption, which is represented as the vector C; Investment, the vector I; export, the vector E and foreign import, the vector F. Simultaneously, the intermediate use is decomposed as the national non-energy industries, national energy industries, foreign non-energy industries and foreign energy industries. The total output of each industry areX_1^D, X_2^D, X_1^M and X_2^M.

3. Model & Data

3.1. Export emissions from aboard energy

Considering in this I-O Table, we can introduce the direct consumption coefficient matrix, as block matrix, it can be defined as D11 to D22 which represents the National consumption coefficient matrixes and M11 to M22 as import consumption coefficient matrixes.

$$D_{11} = [X^D_{11}/X^D_1],\ D_{12} = [X^D_{12}/X^D_1],\ D_{21} = [X^D_{21}/X^D_2],\ D_{22} = [X^D_{22}/X^D_2]$$
$$M_{11} = [X^M_{11}/X^M_1],\ M_{12} = [X^M_{12}/X^M_1],\ M_{21} = [X^M_{21}/X^M_2],\ M_{22} = [X^M_{22}/X^M_2]$$

Introduce the CO_2 emission array G^*, which is counted in IPCC (2007)[1], the technical coefficients matrix A of the 4 categories, A^D_1, A^D_2, A^M_1 and A^M_2 can be conducted as:

$$\begin{cases} A^D_1 = G^* D_{21} \\ A^D_2 = G^* D_{22} \end{cases} \tag{6}$$

$$\begin{cases} A^M_1 = G^* M_{21} \\ A^M_2 = G^* M_{22} \end{cases} \tag{7}$$

The fully comprehensive energy consumption emissions index B_{ij} is equal to the summation of direct energy consumption emissions and the various indirect consumption emissions, which contents non-energy products emissions and energy products emissions indirectly, use Leontief Matrix in eq. (2), we can get:

$$B = \begin{pmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{pmatrix} = \begin{pmatrix} I - A_{11} & -A_{12} \\ -A_{21} & I - A_{22} \end{pmatrix}^{-1} - I \tag{8}$$

B represents the overall export emissions from the export. When producing energy resources, the industries themselves do not use their own production, that make A_{22}=0， we can conduct that:

$$B = \begin{pmatrix} (I - A_{11} - A_{12}A_{12})^{-1} - I & (I - A_{11})^{-1}A_{12}[I - A_{21}(I - A_{11})^{-1}A_{12}]^{-1} \\ A_{21}(I - A_{11} - A_{12}A_{21})^{-1} & [I - A_{21}(I - A_{11})^{-1}A_{12}]^{-1} - I \end{pmatrix} \tag{9}$$

So the overall emissions from export **R** and the export emissions that from local area R^N equals:

$$R = G^{*T}(B_{21} \quad B_{22})E \tag{10}$$

$$R^N = G^*(B^D_{21} \quad B^D_{22}) \begin{pmatrix} E_{DN} \\ E_{DE} \end{pmatrix} \tag{11}$$

Which B^D_{21} and B^D_{22} is in eq. (9) that:

$$B^D_{21} = D_{21}(I - D_{11} - D_{12}D_{21})^{-1} \tag{12}$$

$$B^D_{22} = [I - D_{21}(I - D_{11})^{-1}D_{12}]^{-1} - I \tag{13}$$

Thus, the export emissions from import energy equals export overall emissions minus export emissions from domestic, and the proportion of the import energy emissions of export δ can be conducted as eq. (15).

$$R^M = R - R^N \tag{14}$$

$$\delta = R^M / R \tag{15}$$

3.2. SDA model

Grossman and Krueger (1991) studied the impact of the international trade pattern on the environment, taking into consideration the scale, technology and the trade composition effect as the three main factors of international trade affecting the environment, composition effect having the greatest importance. [1]In this paper, we introduce the scale effect as export growing, the composition effect as carbon intensity change, and the technological improvement as technology effect.

Take these factors into account, the export emissions can be decomposed as:

$$R^N = EM = \varepsilon * [(I - M)^{-1} - I] * E \tag{16}$$

In this equation, carbon intensity ε;， technological structure $L = [(I - M)^{-1} - I]$, and export scale E are 3 factors that be taken effect, which can be decomposed by using the arithmetic mean in SDA analysis:

$$\Delta EM = \frac{1}{2}[(\Delta\varepsilon)L(0)E(0) + (\Delta\varepsilon)L(1)E(1)] + \frac{1}{2}[\varepsilon(1)(\Delta L)E(0) + \varepsilon(0)(\Delta L)E(1)] + \frac{1}{2}[\varepsilon(1)L(1)(\Delta E) + \varepsilon(0)L(0)(\Delta E)] \tag{17}$$

3.3. Data Ye Rbook 2008 Edited by National Bureau of Statistics of China, Covering 42 Industries In Total.

For The Requirement Of Research, We Merge Some Industries. This paper takes 19 industries as non-energy industries and 5 energy industries for analysis.

The CO_2 emission factor of each type of energy is used to calculate the CO_2 emissions comes from the IPCC Guidelines for National Green house Gas Inventories.[15]

4. Results

4.1. Export Emissions of Import energy

The CO_2 emissions embodied in export from import energy are calculated by using the model in Equation (14) and (15), The export emissions from import energy are shown in Fig. 1, with the total export emissions and the key proportion: emissions dependency.

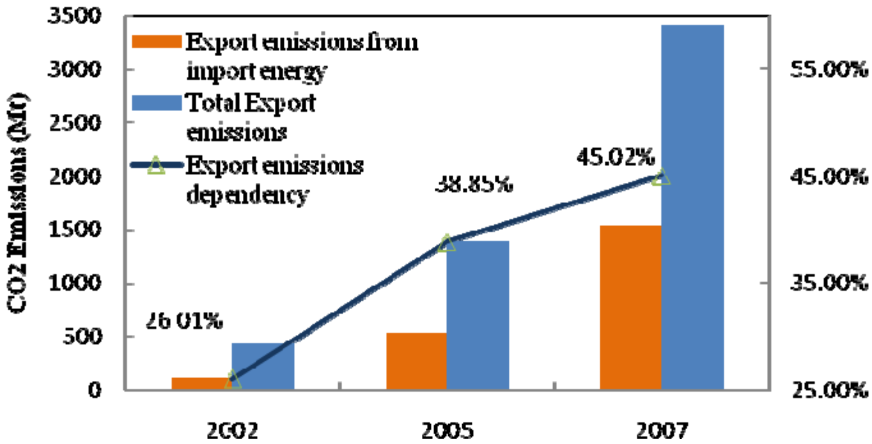

Fig. 1: Export Emissions from import energy

The export CO_2 emissions from import energy grow from 110.65Mt in 2002 to 538.67 Mt in 2005 and tremendously to 1533.24 Mt in 2007. The dependency of China's export emissions increased sharply during the year 2000 to 2005, from 26.01% in 2002 to 38.85% in 2005, and increased to about 45% in 2007, which means in 2007 about 1/2 of the emissions are from import energy (direct and indirect). The high dependency of import energy from export for one thing indicated that China's export face restrict constrain of import energy and other resources. For another, the trend of increasing dependency slows down from 2002 to 2007.

4.2. Effects in Export Emissions

Using eq. (17) in measuring 3 effects in China's export CO_2 emissions from import energy in 2002-2005 and 2005-2007, we get the information in Table 3.

Table 3: Decomposition of China's trade-embodied CO_2 emissions from import energy (Mt).

	2002-2005	2005-2007	2002-2005(%)	2005-2007(%)
Total Change	428.03	994.57	386.82%	190.43%
Composition Effect	-258.04	224.69	-233.20%	43.02%
Technical Effect	-317.87	122.82	-287.27%	23.52%
Scale Effect	1003.93	647.06	907.29%	123.89%

It is obviously shown that from 2002-2005, China's export reflects an intensive growth procedure, The Scale Effect grew significantly while Composition Effect and Technical Effect even decreased in this period. Export emissions Scale achieved 907.29% growth, at the same period, the Composition Effect and Technical Effect, which means the improvement in carbon intensity and technology structure, helped China avoid 233.2% and 287.27% of the emissions in using energy abroad.

However, from 2005-2007, China's export emissions were in an extensive growth procedure. The Composition Effect Technical Effect and Scale Effect grew 43.02%, 23.52% and 123.89% in this period, which means, the technology improvement and structure optimization were stagnant.

5. Conclusion

In this paper, we mainly discussed the export emissions from the import energy, and the factors affecting the emissions. We found that China's export faced restrict constrain of import energy and other goods, about 26% export emissions are from import energy in 2002, 38% in 2005 and 45% in 2007, the growing dependency implies that if China wants to slow down its CO_2 emissions, the external factors must be considered.

When take the affecting factors into account, the scale effect grew significantly from 2002 to 2007, it means the continuous and rapid grow of export in China is the main reason to explain the CO_2 emissions growth, and more energy and materials import from other countries. On the contrary, Composition Effect and Technical Effect were shown that they first improved from 2002 to 2005 and then stagnate from 2005 to 2007. The clean technology import seemed to a bottleneck after 5 years since China's accession in WTO.

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