Carbon Emissions Embodied in China's International Trade Based on Input-Output Method

Wang Dan
School of Economics, Huazhong University of Science and Technology, Wuhan, P.R. China, 430074
(E-mail: wd5529@126.com)

Abstract: This paper uses input-output method and the energy consumption data by sectors to estimate the effects of international trade on carbon emissions of China in 2007. It is revealed that China is a net export nation in embodied carbon. The net exports of embodied carbon account for about 26.77% of the total carbon emissions in 2007. Sectors of Electrical Machinery and Communication Electronic Equipment (182.59Mt), Chemical Industry (89.96 Mt), Smelting and Processing of Metals (86.30Mt), Textile (50.60 Mt) and General and Special Purpose Machinery (47.40 Mt) are the largest five carbon emitters in foreign trade. About 61.30% of total exported carbon emission is from above five sectors. As producers and consumers, China and other nations that import from China gain much benefit from carbon emissions. They both should be responsible for climate change.
Keywords: International trade; Carbon emissions; Input-output method; China

1 Introduction

International trade has played an important role for China's recent economic growth. From 1997 to 2010, the value of China's total imports and exports grew at an average annual rate is up to 20.49%. However, this rapid growth has brought rapid increases in energy demand and carbon emissions since1997, which curbs the sustainable development of Chinese economy. China is now the world's largest emitter of carbon dioxide.

With the growing concern about climate change and the impacts of growth in international trade, there are now an increasing number of studies on carbon embodiment in trade. It is showed that, on average, about 13% of the total carbon dioxide emissions of the six largest OECD countries were embodied in manufactured imports during 1984-1986 (Wyckoff and Roop, 1994). For Brazil, the carbon embodied in exports is higher than imports during 1970-1992, which is a net exporter of energy; meantime, there existing developed countries are shifting their carbon dioxide emissions to developing countries through outsourcing their manufacturing goods for domestic consumption (Schaeffer and de Sa, 1996; Machado *et al*., 2001). Through calculating the carbon dioxide emissions embodied in international trade of goods for 24 counties, the researcher found that the impacts of trade-driven geographical movement of industries on global emissions (Ahmad and Wyckoff, 2003). The Chinese scholar used input-output analysis estimating carbon emissions embodied in China's international trade during 1997—2006, it is showed that the share of net exported emissions on domestic emissions accounting for 12%--14%, which increased rapidly since 2002 and it is up to 29.28% in 2007(Q.Hui *et al.*, 2008). A general conclusion has been that the more open the country is, the larger the impact of foreign trade has on a country's carbon emissions.

In this paper we try to use input-output method to estimate the carbon emissions embodied in the international trade of China in 2007. Section 2 introduces the methodology and data used; section 3 proposes the results; section 4 concludes the paper with some policy implications.

2 Methodology and Data Sources

2.1 The input-output method

Input-output method was introduced by Leontief in the 1936. It is popular for analyzing carbon embodiment in goods and services underlying the changes in energy consumption.

Assuming that an economy includes n industries, the equation can be represented as:

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

It can be adjusted to $X = (I - A)^{-1}Y$ (2)

where $A = \{\frac{x_{ij}}{X_j}\}$ (i, j =1,2,….n)is the direct consumption coefficients matrix representing the amount of input from industry i required directly in order to produce one unit of output from industry j;

$(I-A)^{-1}$ is called the Leontief inverse matrix, which is also called the cumulative demand coefficients matrix.; Y is the column vector of final demand. The domestic emissions embodied in the final demand (C) is

$$C = E(I-A)^{-1}Y \tag{3}$$

Where E is a row vector representing the coefficients of direct carbon emissions per unit output by sector.

For an open economy, A includes two components A^d and A^m, which represents the intermediate use of domestic inputs and the intermediate use of imported inputs, respectively. The domestically total output of an open economy (X^d) can be represented as:

$$X^d = (I-A^d)^{-1}(Y^d + Y^z) \tag{4}$$

where Y^d represents domestic consumption; Y^z represents the exports demand, $(Y^d + Y^z)$ is the final demand of an economy.

Therefore, the total domestic emissions embodied in the final demand (C^d) which satisfies domestic use and exports demand can be expressed as:

$$C^d = E^d X = E^d (I-A^d)^{-1}(Y^d + Y^z) = R^d Y^d + R^d Y^z \tag{5}$$

where $E^d = \{\frac{F_j^d}{X_j^d}\}$ represents the direct carbon intensity in each domestic sector; F_j^d is the domestic direct carbon emissions generated by sector j; $R^d = E^d (I-A^d)^{-1}$ represents the direct and indirect emissions generated in China to obtain a unit of final demand; $R^d Y^d$ is the emissions embodied in domestic consumption (C^{dd}); $R^d Y^z$ is the domestic emissions (C^{dz}) embodied in exports.

However, industries also require imported inputs to produce goods and services for the final demand, which is $A^m X^d$. And the final consumers may also need imports (Y^m) from the rest of the world. If R^m represents the average direct and indirect carbon emissions generated abroad to obtain a unit of final demand, the emissions embodied in Chinese total imports can be obtained using the following expression:

$$C^m = R^m X^m = R^m A^m (I-A^d)^{-1}(Y^d + Y^z) + R^m Y^m = R^m A^m (I-A^d)^{-1} Y^d + R^m A^m (I-A^d)^{-1} Y^z + R^m Y^m \tag{6}$$

where $R^m A^m (I-A^d)^{-1} Y^d$ is the emissions embodiment in the imported inputs to obtain China's domestic consumption; $R^m A^m (I-A^d)^{-1} Y^z$ is the emissions imported and later exported (C^{mz}); $R^m Y^m$ is the emissions in imported consumption..

According to (6), we can obtain the actual imported carbon emissions to satisfy the requirements of China's domestic consumption:

$$C^{md} = R^m A^m (I-A^d)^{-1} Y^d + R^m Y^m \tag{7}$$

However, the total exported emissions can be expressed as:

$$C^z = C^{dz} + C^{mz} = R^d Y^z + R^m A^m (I-A^d)^{-1} Y^z \tag{8}$$

According to (6) and (8), the net balance of carbon emissions embodied in Chinese international trade (C^b) can be represented as:

$$C^b = C^z - C^m = C^{dz} - C^{md} = R^d Y^z - R^m A^m (I-A^d)^{-1} Y^d - R^m Y^m \tag{9}$$

If the value of balance is positive, China is net exported emissions; on the contrary, if the value is negative, China is net imported emissions; and if the value is zero, it will be net balance.

However, because of China has too many trading partners, it is difficult to evaluate the R^m of every country. Therefore, in this paper we assume that $R^m = R^d$.

2.2 Data sources

Chinese input-output tables are estimated only every 5 years, we choose the latest Input–Output Tables of China in 2007 (National Accounts Division, National Bureau of Statistics of China, 2009) to estimate the effects of Chinese international trade in carbon emissions. The energy consumption of 2007 is from China Statistical Yearbook 2008 (NBS, 2008). Chinese export/import data (including goods and services) is obtained from the input-output table of 2007.

In China Statistical Yearbook 2008 of energy consumption, the entire economy is categorized into 44 sectors. However, in Input–Output Tables of China 2007, there are 42 sectors and 135 sectors. Therefore, neither of them is not the same. So we make a match between the 42-sector of input-output table and the 44-sector of energy consumption, and re-categorize the entire economy into 27sectors. In this paper, the average coefficient of carbon emissions of solid, liquid and gas fuels are 25.54kg/GJ, 19.90kg/GJ and 15.15kg/GJ, respectively.

3 Results

The net carbon emissions embodied in China's foreign trade in 2007 by sector are listed in Table 1 and Table2.

In 2007 the carbon emissions embodied in exports are 745.28 billion tons, accounting for 33.60% of the total emissions of output. By taking the $R^m = R^d$ assumption, the emissions avoided by imported are 151.53 million tons (Mt), accounting for 6.83% of the total emissions. China is a net exporter, exporting carbon emission is about 593.75Mt, accounting for 26.77% of the total emissions of output. Furthermore, about 86.29% of the total imported emissions were generated to obtain the imported inputs; the other parts, about 13.71% of the total imported emissions were embodied in consumption goods and services. We can also find that about 31.63% of the total imported emissions were imported and later exported emissions in 2007.

Table 2 shows the embodiment emission by sector in 2007. It could be found that sector Electrical Machinery and Communication Electronic Equipment (182.59Mt), Chemical Industry (89.96 Mt), Smelting and Processing of Metals (86.30Mt), Textile (50.60 Mt)and General and Special Purpose Machinery (47.40 Mt) are the largest five carbon emitters in foreign trade, accounting for 24.50%, 12.07%, 11.58%, 6.79% and 6.36%, respectively. The top five sectors emit 61.30% and the top ten sectors emit 81.30% of the total exported emissions. As for the carbon emissions embodied in imports, sectors Electrical Machinery and Communication Electronic Equipment (30.81 Mt), Chemical Industry (26.09 Mt), Smelting and Processing of Metals (17.30 Mt), General and Special Purpose Machinery (14.11 Mt), Extraction of Petroleum and Natural Gas (11.74 Mt) are the five largest emitter, accounting for 20.33%, 17.22%, 11.42%, 9.31% and 7.75% of the total imported emissions. The top ten sectors emit 88.36% of the total imported emissions. Moreover, there are 23 net exporter sectors, 2 net import sectors, and 2 sectors not involved in international trade.

Table 1 Emissions Embodied in International Trade in 2007

Item	Computing Formula	Value/Mt
Emissions in Imported Inputs	$R^m A^m (I - A^d)^{-1}(Y^d + Y^z)$	130.75
Emissions in Imported Consumption	$R^m Y^m$	20.78
Total Imported Emissions	$R^m A^m (I - A^d)^{-1}(Y^d + Y^z) + R^m Y^m$	151.53
Actual Imported Emissions	$R^m A^m (I - A^d)^{-1} Y^d + R^m Y^m$	103.60
Domestic Exported Emissions	$R^d Y^z$	697.35
Imported and Later Exported Emissions	$R^m A^m (I - A^d)^{-1} Y^z$	47.93
Total Exported Emissions	$R^d Y^z + R^m A^m (I - A^d)^{-1} Y^z$	745.28
Net Exported Emissions	$R^d Y^z - R^m A^m (I - A^d)^{-1} Y^d - R^m Y^m$	593.75

Table 2 Net Exported Emissions Embodied in International Trade by sector (Unit/Mt)

Sector	Total Exported Emission	Total Imported Emission	Net Exported Emission	Sector	Total Exported Emission	Total Imported Emission	Net Exported Emission
Agriculture	2.46	1.89	0.57	Metal Products	37.11	1.55	35.56
Mining and Washing of Coal	4.02	0.80	3.22	Transport Equipment	21.91	4.99	16.92
Extraction of Petroleum and Natural Gas	5.44	11.74	-6.30	General and Special Purpose Machinery	47.40	14.11	33.29
Measuring Instruments and Machinery for Cultural Activity and Office Work	17.44	5.04	12.40	Electrical Machinery and Communicatio n Electronic Equipment	182.59	30.81	151.78
Mining and Processing of Non-metal Ores	1.42	0.65	0.77	Mining and Processing of Metal Ores	5.29	10.96	-5.67
Foods, Beverages, Tobacco	7.75	1.61	6.14	Other Manufacturing	6.48	1.85	4.63
Paper, Printing and Articles for Culture, Education	16.92	1.55	15.37	Production and Distribution of Electric Power and Heat Power	2.68	0.18	2.50
Textile Wearing Apparel, Leather, Feather and Related Products	26.90	0.74	26.16	Production and Distribution of Gas	0.00	0.00	0.00
Processing of Timber and Furniture	14.23	0.41	13.82	Production and Distribution of Water	0.00	0.00	0.00
Textile	50.60	1.27	49.33	Construction	3.58	0.50	3.08
Processing of Petroleum, coking and Nuclear Fuel	22.06	9.30	12.76	Smelting and Processing of Metals	86.30	17.30	69.00
Chemical Industry	89.96	26.09	63.87	Retail and Restaurant	16.02	0.45	15.57
Non-metallic Mineral Products	20.57	1.33	19.24	Other Services	15.13	3.55	11.58
Transport	41.06	2.85	38.21	Total	745.28	151.53	593.75

4 Conclusions

Through the above analysis, it is shown that carbon emissions embodied in exports are greater than those embodied in imports, China is a net export nation in embodied carbon. The average share of net export on domestic emissions is up to 26.77%. Any policies which can increase domestic products exports directly may lead to the domestic carbon emissions significantly. From the perspective of global environment, because of China's energy intensity is higher than the world average, China imports from

abroad is equivalent to reduce global carbon pollution indirectly.

About 81.30% of exported carbon emissions is mainly from 10 sectors, more than 50% of imported carbon emissions is primarily from 5 sectors in China. In the view of the net balance of exports and imports, Electrical Machinery and Communication Electronic Equipment, Chemical Industry, Smelting and Processing of Metals and General and Special Purpose Machinery are sectors affected significantly by the production technology, technology progress is to reduce carbon pollution of these above sectors effectively.

Due to the changes of the international trade's carbon emissions, not only influenced by the size and the structure of the exports and imports, but also affected by the production technology of energy usage structure and energy intensity. Taking into account the current stage of economic development and the characteristics of energy structure, on one hand, China need to control the size of the exports and imports properly; on the other hand, China introduce advanced production technology actively, reduce energy intensity, especially for the sectors of high energy consumption and high carbon emissions. Meantime, given the environmental sacrifices made by China's foreign trade for the world, especially for the developed countries, importers should take more responsibilities for carbon emissions embodied in trade, and exporters should take a certain responsibility for unreasonable energy dissipations too.

References

[1] Yan F., Yang L. China's Foreign Trade and Climate Change: A Case Study of CO2 Emissions[J]. Energy Policy, 2010,38(1): 350-356(In Chinese)

[2] Machado G., Schaeffer R., Worrel E. Energy and Carbon Embodied in the International Trade of Brazil: An Input–output Approach[J]. Ecological Economics, 2001(39): 409–424

[3] Peters Hertwich. Pollution Embodied in Trade: The Norwegian Case[J]. Global Environmental Change. 2006(16): 379–387

[4] Hui Q. et al. Accounting Embodied Carbon in Import and Export in China[J]. China Population, Resources and Environment. 2008,18(3):8–13(In Chinese)

[5] Schaeffer R, de Sá A. L. The Embodiment of Carbon Associated with Brazilian Imports and Exports[J]. Energy Conversion and Management, 1996,37(8): 955–960

[6] Weber C. L., Peters G. P. The Contribution of Chinese Exports to Climate Change[J]. Energy Policy, 2008(36): 3572–3577

[7] Wyckoff A. W., Roop J. M. The Embodiment of Carbon in Imports of Manufactured Products[J]. Energy Policy, 1994, 22(3): 187–194