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Research on Unsustainable Embodied Oil Leakage and Its Influence Factors in China's Export Trade

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Abstract

Over the past few decades, China has "leaked out" massive oil resource through exporting different kinds of products, which intensified the county's energy dilemma and obviously is unsustainable. The aim of this paper was to calculate the total and industrial amount of oil embodied in China's export during 2002~2012 and to analyze its influence factors. An exported embodied oil model was built based on the Input Output Analysis, and the influence factors of embodied oil were decomposed into energy utilization technology, export structure and export scale on the basis of the Structure Decomposition Analysis. The results indicated that the direct and the complete oil consumption efficiency in 2012 are lower than that in 2002. The total exported embodied oil grows from 0.58×10^8 tons in 2002 to 1.11×10^4 tons in 2012, which accounts for a large percentage of the domestic oil consumption. The enlargement of export scale is the main positive promotion for embodied energy increase in exports during 2002~2007 and 2007~2012, and the energy utilization technology is the key factor for the part of negative influence in embodied energy decrease. Though the export structure factor doesn't play a key role in embodied energy change in exports, comparing with the other two factors, it has substantial potential for decreasing the exported embodied oil. Finally, policy suggestions were proposed based on the results to improve the situation.

Keywords: Embodied oil flow; Export trade; Input-output; Structure decomposition analysis; China

Introduction

After the accession to the World Trade Organization (WTO), China's integration with the global economy has contributed to sustained growth in international trade. Both its exports and imports have grown faster during the past dozen years, while China's trade surplus increased dramatically. Although this trend was affected by the global financial crisis and the international political volatility, the Chinese government has made some plans recently to promote the economic prosperity, including "Silk Road Economic Belt and the 21st-Century Maritime Silk Road" [1] and "Made in China 2025" [2], and so forth. Under these background, China's export trade will keep on developing predictably. On one hand, the huge trade surplus has brought China a great amount of foreign exchange reserve; on the other hand, it also cost China significant volumes of energy [3], because all goods and services produced in an economy are directly and/or indirectly associated with oil use [4].

The debate on the impacts of international trade on energy flow is not new. Many researchers have studied the embodied energy/carbon imports or exports for a number of countries and regions, such as Brazil [4], China [5], the United Kingdom [6], and the United States [7], and so on. These studies show that there are a lot of energy flow embodied in the international trade, which is not often considered and still not sufficiently clear. In China's energy supply system, oil highly dependent on import, and the gap between its consumption and production has been increasing quickly. At the same time, with the continued growth of international trade, China are "leaking" a large number of oil through exporting different kinds of products, which is unsustainable. It is significant and urgent to answer the questions including, but are not limited to: How many embodied oil are exported? Which export industrial sectors are most oil-consuming? What is the major driving force factors of the increase for the embodied oil export? The aims of this paper focus on calculating the amount and the pathway of oil flow embodied in China's export trade by using the Input Output Model and the Structure Decomposition Analysis. The study hopefully offers consultations for a sustainable development and management of China's international trade.

Methodology and Data

Basic input output model

The Input-Output Analysis was firstly developed by Leontief in the 1930s, which has been widely used for analyzing the economic relationship of linkages between different sectors. The basic Input-Output Model can be expressed as equation (1):

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

Where, X and Y represent exogenous and endogenous accounts respectively, I is identity matrix, and A is the technical coefficient matrix that can be expressed as equation (2):

$$A = \left[a_{ij} \right]_{n \times n} \tag{2}$$

Where $I = (1,n)$; $j= (1,n)$; n is the count of sectors in an economy system; a_{ij} is the technical coefficient, also called as direct consumption coefficient, which can be expressed as equation (3):

$$a_{ij} = \frac{x_{ij}}{x_j} \tag{3}$$

Where, x_{ij} is marked as sector j's use of products from sector i; and x_j is marked as the total output of sector j. The matrix $(I - A)^{-1}$

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is often called Leontief Inverse Matrix. Another important conception in the basic Input Output Model is complete consumption coefficient, denoted by b_{ij}, which measures how much direct and indirect output from sector *i* will be used in sector *j*'s one unit worth of value of final output. It can be expressed as equation (4):

$$b_{ij} = a_{ij} + \sum_k (b_{ik} \times a_{kj}) \tag{4}$$

Where, *k* means the middle sector. If the complete consumption coefficient matrix is set as *B*, i.e. $B = \left(b_{ij}\right)_{n\times n}$, the equation (4) can be solved and transferred to equation (5):

$$B = (I - A)^{-1} - I \tag{5}$$

Exported embodied oil model

Based on the basic Input Output Model, the model for calculating oil flow embodied in international trade can be established as equation (6):

$$\begin{cases} A^m = MA \\ A^d = (I - M)A \end{cases} \tag{6}$$

Where, *EO* is the amount of embodied oil in international trade; eo_i is the amount of embodied oil in one unit worth of value of product *i*, i.e. embodied oil intensity; V_i is the total value of product *i*, in import or export trade. Before calculation the technical coefficient matrix *A* should be modified to eliminate the influence of the processing and manufacturing trade, for example, some products are made by imported semi-finished products and be exported again after assembled. Firstly, *A* can be distinguished to two parts: the imported middle products part A^m and the domestic middle products part A^d, i.e., $A = A^m + A^d$. Secondly, the import coefficient matrix *M* is set to establish equation (7):

$$\begin{cases} A^m = MA \\ A^d = (I - M)A \end{cases} \tag{7}$$

Where, *M* is a diagonal matrix that can measures the dependence of sector *i* on the imported middle products, and the element of the diagonal matrix, marked as m_{ii}, can be expressed as equation (8):

$$m_{ii} = im_i / (X_i + im_i - ex_i) \tag{8}$$

Where, X_i is the total output value of sector *i*, im_i is the total import value of sector *i* and ex_i is the total export value of sector *i*. It is assumed in this analysis that the share of imported products in every sector are same. Finally, the model of calculating exported oil flow embodied in international trade can be expressed as equation (9):

$$EO_{ex} = \sum_{i=1}^{n} eo_i \cdot (I - A^d)^{-1} \cdot ex_i \tag{9}$$

Structure decomposition analysis

Based on the exported embodied oil model, the Structure Decomposition Analysis can be continued: firstly, set $g_i = eo_i\left(I - A^d\right)^{-1}$, which is complete oil consumption of sector *i*; secondly, set $s_i = ex_i / EX$, where ex_i is the total export value of sector *i* as mentioned above, *EX* is the total export value of the country, and, so, s_i is the share of sector *i*'s export value on the total export of the country. Then, the exported embodied oil of sector *i* can be transferred to equation (10):

$$EO_{exi} = t_i \cdot s_i \cdot EX \tag{10}$$

The amount of exported embodied oil are divided by this equation into three parts: the complete oil consumption coefficient, the structure of export and the scale of export, which are called the technology effect, the structure effect and the scale effect. The change of the exported embodied oil from time *t*1 to time *t*1 can be expressed as equation (11):

$$\Delta EO_{exi} = EO_{exi}^{t2} - EO_{exi}^{t1} = t_i^{t2} \cdot s_i^{t2} \cdot EX^{t2} - t_i^{t1} \cdot s_i^{t1} \cdot EX^{t1} \tag{11}$$

Equation (11) can be solved by using the Logarithmic Mean Divisia Index (LMDI) method. The solution are shown as equation (12):

$$\begin{cases} \Delta EO_{exi} = EO_{exi}^{t2} - EO_{exi}^{t1} = t_i^{eff} + s_i^{eff} + EX^{eff} \\ t_i^{eff} = L(EO_{exi}^{t2}, EO_{exi}^{t1}) \cdot \ln(t_i^{t2} / t_i^{t1}) \\ s_i^{eff} = L(EO_{exi}^{t2}, EO_{exi}^{t1}) \cdot \ln(s_i^{t2} / s_i^{t1}) \\ EX^{eff} = L(EO_{exi}^{t2}, EO_{exi}^{t1}) \cdot \ln(EX^{t2} / EX^{t1}) \\ L(EO_{exi}^{t2}, EO_{exi}^{t1}) = (EO_{exi}^{t2} - EO_{exi}^{t1}) / \ln(EO_{exi}^{t2} / EO_{exi}^{t1}) \end{cases} \tag{12}$$

Where, t_i^{eff}, s_i^{eff} and EX^{eff} represent the influence effects of the export embodied oil changes caused by technology, the structure of export and the scale of export.

Data

The oil consumption, the total output value of every industry, the technical coefficient matrix A between all industries and the import/export value of every industry are needed to calculate the embodied oil flow. All of the data above are available from China's statistical yearbooks and China's Input Output tables that both released by the National Bureau of Statistics of China [8]. Classification of industries are different between the two data sources, so it should be modified for consistency. Twenty-eight industry sectors are used in this study, as shown in Table 1. It is worth noting that production values in different

No.	Industry Sectors
S1	Agriculture, Forestry, Animal Husbandry, Fishery
S2	Mining and Washing of Coal
S3	Extraction of Petroleum and Natural Gas
S4	Mining and Processing of Metal Ores
S5	Mining and Processing of Non-Metal Ores, other Mining and Quarrying
S6	Manufacture of food, beverages and tobacco
S7	Manufacture of Textile
S8	Manufacture of Apparel, Leather, Fur, Feather and Related Products
S9	Processing of Wood and Manufacture of Furniture
S10	Manufacture of Paper, Printing, Manufacture of Articles
S11	Processing of Petroleum, Coking and Processing of Nuclear Fuel
S12	Manufacture of Raw Chemical Materials and Chemical Products
S13	Manufacture of Non-metallic Mineral Products
S14	Smelting and Pressing of Metals
S15	Manufacture of Metal Products
S16	Manufacture of General and Special Purpose Machinery
S17	Manufacture of Transport Equipments
S18	Manufacture of Electrical Machinery and Apparatus
S19	Manufacture of Computers, Communication and Other Electronic Equipment
S20	Manufacture of Measuring Instruments and Machinery
S21	Other Manufacture
S22	Production and Supply of Electric Power and Heat Power
S23	Production and Supply of Gas
S24	Production and Supply of Water
S25	Construction
S26	Transportation, Postal, Telecommunication services
S27	Wholesale, Retail Trade and Hotel ,Restaurants
S28	Others

Table 1: Modified industry sectors of China.

years are not directly comparable because of the fluctuations in prices. To solve this problem, all values in every year are converted based on 2002's industrial constant prices.

Results and Analysis

Crude oil utilization efficiency

The oil utilization efficiency, i.e. oil intensity, is indicated by two indicators in this paper: the direct oil consumption coefficient and the complete oil consumption coefficient. The results of the oil utilization efficiency in 2002, 2007 and 2012 are shown in Table 2. As for the direct coefficient, most sectors have sustained downward trend from 2002 to 2012 except a few industries, such as sector No. 11 (Processing of Petroleum, Coking and Processing of Nuclear Fuel). The direct coefficient of sector No.11 grown from 2.68×10^4 to 2.72×10^4 tons per 10^8 CNY during 2002~2007. As for the complete coefficient, the values are larger than their corresponding direct coefficients, because it calculates the total oil used in the whole industrial chain. The trends of changes are similar with the direct coefficient, but there are also a few exceptions, such as sector No. 26.

Amount of exported embodied oil

According to the model built above and annual data, the amount of oil embodied in China's export trade of all industry sectors are calculated as shown in Table 3. The total domestic oil consumption in China and the proportion of exported embodied oil on the domestic consumption are also displayed in Table 3. With the rapid development of China's export, export of "Made in China" especially, the amount of exported embodied oil is also grown. It can be seen from Table 3 that both the total domestic consumption of oil and exported embodied oil have massive growth from 2002 to 2012. The growth rate of exported embodied oil is 110%, which approximately equals that of domestic consumption (107%). In 2007, the percentage of exported embodied oil is around 34%, which means there are about 34% of China's oil consumption are contributed to other countries through international trade. But the trend has revealed a clear decline trend after 2007. The main reasons include but not limit to: implement of China's Energy Saving and Waste Reduction Plans made the energy use per unit GDP decline, the Global Economic Crisis affected China's export trade scale, and China's export structure were improved in recent years (Table 3). From the perspective of individual industry sector, the contributions of exported embodied oil vary widely, as shown in Table 4. Four sectors, No. 11 (Processing of Petroleum, Coking and Processing of Nuclear Fuel), No. 12 (Manufacture of Raw Chemical Materials and Chemical Products), No. 19 (Manufacture of Computers, Communication and Other Electronic Equipment) and No. 26 (Transportation, Postal, Telecommunication services) are the first four largest sources of exported embodied oil in 2002, 2007 and 2012, and their contributions account for 48%, 49% and 51% respectively (Table 4).

Influence factors of embodied oil

The change on the amount of embodied oil in international trade are derived from combined action of three effects (technology, structure and scale) by using the Structure Decomposition Analysis method.

Sector Number	Direct Coefficient			Complete Coefficient		
	2002	2007	2012	2002	2007	2012
S1	0	0	0	876.98	731.36	940.81
S2	2.94	0	0	1 018.15	1 357.45	980.19
S3	10 350.52	2 907.41	2 283.31	11 463.62	5 270.57	4 071.06
S4	0	0	0.02	2 995.97	3 429.23	2 302.63
S5	0	0	59.43	1 938.73	1 766.66	1 808.97
S6	0.91	0.17	0.01	807.29	654.99	531.07
S7	0.06	0.08	0	1 105.04	968.60	706.57
S8	0.18	0.17	0.06	975.88	852.41	584.17
S9	0	0.17	0.11	1 361.65	964.34	744.82
S10	0.84	0.41	0.05	1 177.95	964.04	733.98
S11	26 818.31	27 163.25	26 297.79	33 276.90	30 798.34	29 569.79
S12	1 169.96	474.00	357.31	4 009.03	3 315.91	2 643.19
S13	85.47	6.84	2.07	2 099.47	1 487.32	1 375.23
S14	9.42	0.11	0.04	2 491.50	2 839.04	1 908.99
S15	0.07	0	0	1 741.09	1 417.36	1 052.81
S16	0.26	0.09	0.01	1 390.96	1 110.15	754.03
S17	0.05	0.03	0.01	1 240.12	872.58	619.40
S18	0.70	0.10	0.02	1 575.27	1 309.36	941.29
S19	0	0.08	0	874.19	502.18	331.81
S20	0	0.07	0	1 136.17	691.68	471.15
S21	1.52	0	0	997.43	862.44	671.58
S22	87.55	3.02	0.63	1 981.67	1 602.80	1 164.38
S23	0	2.83	0	4 571.51	1 671.34	1 044.66
S24	0	0	0	912.96	971.64	654.66
S25	1.49	0	0	2 019.23	1 711.40	1 347.90
S26	88.44	45.22	18.62	2 415.59	3 039.84	2 149.65
S27	0.05	0	0	903.36	605.31	359.93
S28	0.26	0	0	804.36	884.12	824.91
Average	719.17	495.32	406.61	-	-	-

Note: based on 2002 price; unit is ton per 10^8 CNY.

Table 2: The direct and the complete oil utilization efficiency.

The results of the analysis on embodied oil between 2002~2007 and 2007~2012 are displayed in Table 5. It can be seen from Table 5 that China's exported embodied oil increased 6 346 × 10^4 tons from 2002 to 2007, while the increasing trend was restrained during 2007~2012 (decreased 507 × 10^4 tons). The scale effect is positive, while the technology effect and the structure effect are negative (Table 5). The industrial distributions of China's exported embodied oil during 2002~2007 and 2007~2012 are also analyzed, as shown in Figures 1 and 2 respectively. It can be seen from Figures 1 and 2 that the export scale effect is always the major part of positive promotion, while the technology effect is the major part of negative influence. The export structure has lesser impacts, comparing with the other two effects. The industry sectors of No.S1~No.S6, No.S22, and No.S23 export pretty small amount of oil embodied in international trade. The reason is all of these sectors are low energy consuming or have very small value of exports due to their own industrial characteristics. The scale effect of sector No.S12 Manufacture of Raw Chemical Materials and Chemical Products is the largest source for the increment of exported embodied oil, even its technology contributes a large negative effect.

Conclusions

The amount and the pathway of oil flow embodied in China's export trade during 2002~2012 are calculated by using the Input Output Model, the Structure Decomposition Analysis and China's public annual data. The results show that, the total exported embodied oil has grown from 0.58 × 10^8 tons in 2002 to 1.11 × 10^8 tons in 2012,

	2002	2007	2012
Embodied Oil in Export (10^4 tons)	5 289	11 635	11 129
Domestic Oil Consumption (10^4 tons)	22 541	34 032	46 679
Share	23.46%	34.19%	23.84%

Table 3: China's exported embodied oil and the share on domestic consumption.

No.	2002	2007	2012	No.	2002	2007	2012
S1	41.59	35.14	37.10	S15	185.57	433.95	359.89
S2	16.05	19.48	3.70	S16	181.84	600.02	709.36
S3	138.70	39.73	28.61	S17	81.04	302.42	368.51
S4	5.60	13.87	6.03	S18	320.23	766.22	850.63
S5	29.30	21.68	14.56	S19	434.27	1343.05	1315.95
S6	72.13	112.22	114.15	S20	168.55	241.26	88.60
S7	300.56	724.61	291.83	S21	42.57	86.60	26.42
S8	270.83	463.34	547.32	S22	10.16	9.23	7.22
S9	90.74	217.15	225.47	S23	0	0	0
S10	116.27	214.11	371.49	S24	0	0	0
S11	875.19	1252.08	1399.78	S25	21.12	56.63	64.74
S12	872.52	1901.23	1849.49	S26	381.97	1160.33	1059.75
S13	87.70	207.30	296.25	S27	260.88	259.33	299.14
S14	114.91	873.14	528.00	S28	168.83	281.28	264.72

Table 4: China's industrial exported embodied oil in 2002, 2007 and 2012.

Unit: 10^4 tons	2002~2007	2007~2012	2002~2012
Changes of Embodied Oil	6346	-507	5840
Technology Effect	-917	-3024	-2893
Structure Effect	-948	-757	-1484
Scale Effect	8211	3274	10216

Table 5: Influence factors of embodied oil in China's export during 2002~2007, 2007~2012 and 2002~2012.

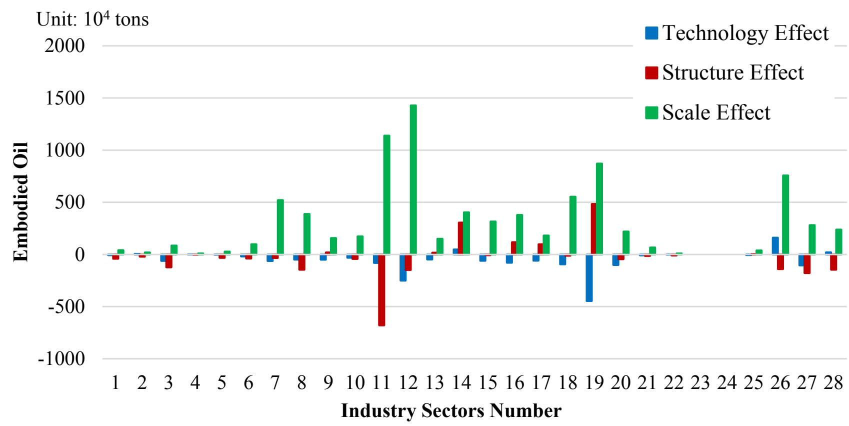

Figure 1: Influence factors of the change on exported embodied oil during 2002~2007.

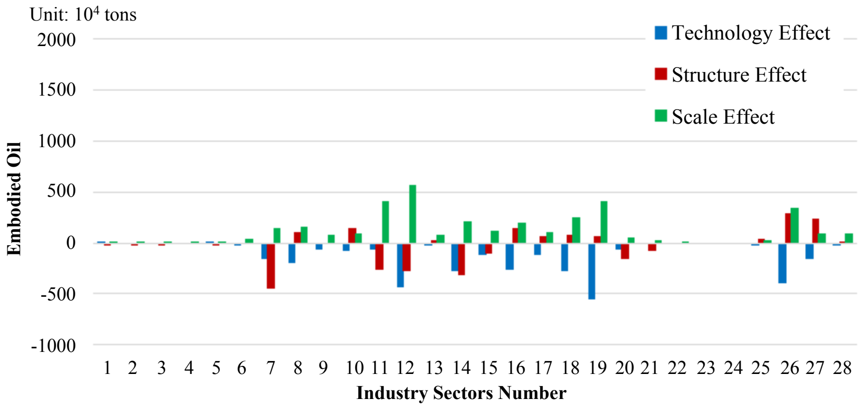

Figure 2: Influence factors of the change on exported embodied oil during 2007~2012.

which account for a large percent of China's domestic oil consumption. Four sectors (Processing of Petroleum, Coking and Processing of Nuclear Fuel; Manufacture of Raw Chemical Materials and Chemical Products; Manufacture of Computers, Communication and Other Electronic Equipment; Transportation, Postal, Telecommunication services) are the top largest sources of exported embodied oil in 2002, 2007 and 2012, and their total contributions account for 48%, 49% and 51% respectively. The export scale effect is always the major part of positive promotion, while the technology effect is the major part of negative influence. The export structure has lesser impacts, comparing with the other two effects. The oil flow embodied in international trade and its influence factors should be considered during the development and management in the future.

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