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Net oil exports embodied in China's international trade: An input-output analysis

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Abstract

As the world's second largest oil importer, China has been one of the important factors which affect the global oil market. In recent years, China has attained great international trade surplus through exporting a large number of "Made in China" products even during the global economic crisis. Due to direct and indirect effects in production chain, each "*Made in China*" product contains oil directly or indirectly. China is exporting much oil through "*Made in China*" products, which is not often considered even within China. An input-output model is established to calculate oil embodied in the international trade of China. The research results suggest the following: China's net oil exports embodied in the international trade were 87.02 million tonnes in 2007; manufacture of communication equipment, computers and other electronic equipment is the largest sector to export embodied oil; United States, China Hong Kong SAR and Netherlands are the top three countries and regions which benefit most from the embodied oil in "*Made in China*" products. China's adjusted degree of dependence on foreign oil is 24.9% in 2007, and 38.4% in 2011 if net oil exports embodied in international trade are considered.

Keywords

Net oil exports; Embodied oil; Made in China; Input-Output Analysis

1 Introduction

With the growth of international trade, many researchers have studied the energy embodied in trade for a number of countries using a variety of assumptions. Embodied energy analysis is the process of determining the energy required directly and indirectly to produce a specific product or service [1]. Embodied energy mainly refers to indirect effects as pointed by Bullard and Herendeen [2]. Wyckoff and Roop [3] studied the embodied energy in imported products of the six major OECD countries including Britain, France, Germany, Japan, the United States and Canada during the time from 1984 to 1986, and the research results show that those countries imported a lot of embodied energy which accounts for a large proportion in their domestic consumption. Machado et al. [4] calculated the energy embodied in the international trade of Brazil, and the results show that the total energy embodied in the exports of non-energy goods of Brazil equals 831 PJ in 1995, while the amount embodied in the imports of non-energy goods equals 679 PJ, which accounts for 10 and 12% of the total energy use respectively. Atkinson et al. [5] examined international resource flows using an input–output framework that is akin to ‘*ecological balance of payments*’ analysis and the research results show that developed countries are reliant on developing countries for resources.

Being the largest developing country in the world, China’s international trade surplus has been growing through exporting a large number of products labelled “*Made in China*”. Exports have been the primary driver of China's economic growth over the last decade, particularly since the country's accession to the World Trade Organization in 2001. In fact, due to direct and indirect effects in production chain, each “*Made in China*” product contains energy directly or indirectly, which means China is exporting a lot of energy embodied in international trade. Ying et al. [6] pointed out that China’s net energy export embodied in trade was about 240 million tce (ton of coal equivalence) in 2002, and it was up to about 630 million tce in 2006. Hong et al. [7] evaluated the energy embodied in goods produced in China for the three sub-periods of 1992–1997, 1997–2002, and 2002–2005, and results show that China is a net exporter of energy.

Although the issue of energy embodied in international trade of China has aroused concern and some work has been done, there is still a lot of work that need to be done on this topic. For example, even though both China’s oil supply and demand situations are more severe than energy situation as a whole, researches on oil embodied in China’s trade are very insufficient. China’s peak oil production will probably come before 2017 as pointed out by Tang et al. [8], Feng et al. [9-10], Pang et al. [11]. The oil production of giant oilfields such as Daqing will continue declining proposed by Tang et al. [12] and Höök et al. [13]. China has been a net oil import country since 1993 and the degree of dependence on foreign oil increased to 56.3% in 2011. The gap between oil consumption and production in China will continue enlarging in the next thirty years, because peak oil consumption in China is 17 years later than peak oil production as pointed out by Feng et al. [14].

Some preliminary quantitative analysis on oil embodied in China’s trade

has been done by Tang et al. [15]. However, that study did not involve the efficiency difference in oil consumption between China and other countries, which is an important factor. Therefore, based on the study of both domestic and foreign literature, this paper seeks to address the gap between the imported oil and the exported oil embodied in international trade of China, and conduct in-depth study on this issue, such as the trend change of oil embodied in exports over time and as well as sector and country distributions of China's embodied oil export. The purpose of the paper is to let the world including China itself understand China's oil consumption and oil security better. Relevant suggestions on future research are also proposed in this paper.

2. Status analysis of China's foreign trade

As the metaphor goes, China's economy is growing mainly driven by "*three carriages*" which are investment, export and consumption. Although China's government strongly advocates the development of domestic demand, the economic growth still chiefly depends on investment and export, and the proportion of consumption in the national economy has dropped obviously in recent years according to National Bureau of Statistics of China [16–17]. Table 1 shows the percentage change of consumption, investment and net export in China's national economy.

As it can be seen from Table 1, the proportion of domestic consumption in the national economy has continued declining, especially since 2002. China's foreign trade almost reached a balance in 1987, and then the proportion of net exports increases rapidly, especially after 2002. Although the proportion of net exports declined during the global economic crisis, the trend still needs further observation as it is not an active drop. This phenomenon can also be seen from the changes of China's trade balance since 1978 (Fig. 1).

Table 1. *Change of Components of GDP in China. Data sources: National Bureau of Statistics of China [16-17]*

Year	Consumption	Investment	Net export
1987	63.6%	36.3%	0.1%
1992	62.4%	36.6%	1.0%
1997	59.0%	36.7%	4.3%
2002	59.6%	37.9%	2.6%
2007	49.0%	42.2%	8.9%
2008	48.4%	43.9%	7.7%
2009	48.0%	47.7%	4.4%
2010	46.5%	48.6%	4.8%

Fig. 1 shows that the growth of China's trade surplus was not obvious before 2004. There was even trade deficit for some years. However, the trade surplus

increased dramatically at an average annual growth rate of 74.6% during the period of 2004 to 2008. The exports also increased quickly at an average annual growth rate of 24.6% during the same period. Although this trend is affected by the global economic crisis, China's trade surplus is still at a high level. The trade surplus has brought China a huge amount of foreign exchange reserve, but it also brings upon China heavy international pressure, particularly the continuous pressure of RMB appreciation. The trade surplus also costs China significant volumes of oil indirectly, which will be discussed later in this study.

3. Methodology and Data

3.1 Methodology

The input–output (IO) model which is useful for analyzing the economic relationship of linkages among sectors of an economy was developed by Leontief [18] in the 1930s. In the basic IO model, X which stands for the total output of an economy can be expressed as the sum of intermediate consumption (AX) and final consumption (Y) as follows:

$$AX + Y = X \quad (1)$$

Where, A is the technical coefficient matrix, and it can be expressed as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1j} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2j} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{i1} & a_{i2} & \dots & a_{ij} & \dots & a_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nj} & \dots & a_{nn} \end{bmatrix} \quad (2)$$

a_{ij} is the technical coefficient, which can be calculated in Eq. (3).

$$a_{ij} = \frac{x_{ij}}{X_j} \quad (3)$$

Where, x_{ij} = sector j 's purchase of the goods produced by sector i ; y_i = sales from sector i to final demand; and X_j is the total output of sector j . The solution of equation (1) can be expressed as follows:

$$X = (I - A)^{-1} Y \quad (4)$$

Where, I is identity matrix, and the matrix $(I - A)^{-1}$ is called Leontief inverse matrix (key matrix).

Beside technical coefficient a_{ij} , complete consumption coefficient b_{ij} is also widely used in IO modeling. The parameter b_{ij} measures how much direct and indirect output from sector i will be used given increase of each output in sector j . Matrix notation can be used as follows to give a reformulation of the relations:

$$B = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1j} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2j} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ b_{i1} & b_{i2} & \dots & b_{ij} & \dots & b_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ b_{n1} & b_{n2} & \dots & b_{nj} & \dots & b_{nn} \end{bmatrix} \quad (5)$$

Where, B is the complete consumption coefficient matrix. It can be calculated as follows:

$$B = (I - A)^{-1} - I \quad (6)$$

Xu Tang et al. [15] have established a model based on IO analysis to calculate the net oil exports embodied in international trade as follows:

$$E = \frac{C}{Y_i} \sum_{j=1}^n (E_j - I_j) \times b_{ij} \quad (7)$$

Where, E is the net oil exports embodied in international trade; E_j is exports in sector j ; C is China's total oil consumption; I_j is imports in sector j ; Y_i is the petroleum industry's total output; b_{ij} is the complete consumption coefficient.

Figure 1. *Changes of China's trade balance since 1978.* Data sources: National Bureau of Statistics of China [16-17]

Although China's oil consumption efficiency is lower than the average level of other countries, China still exports oil embodied in international trade even under the situation of zero surplus. Thus, the main weakness of equation (7) is that it doesn't reflect the efficiency difference in oil consumption between China and other countries. In this paper, the exports and imports of embodied oil are calculated separately, so China's oil consumption efficiency will be used in the calculation of exports of embodied oil, and other countries' oil consumption efficiency will be used in the calculation of imports of embodied oil.

3.1.1 Calculation of oil embodied in China's exports

Suppose China exports a total of n kinds of commodities and has k export trading partners. E which is oil embodied in China's exports can be theoretically expressed as follows:

$$E = \sum_{i=1}^k \sum_{j=1}^n M_{ij} \times \gamma_j \quad (8)$$

Where, M_{ij} , the data from customs statistics, is the value of commodity j exported by China to country i ; and γ_j is the embodied oil contained in unit value of commodity j .

Thus, the calculation of oil embodied in China's exports lies in the embodied oil

contained in unit value of exported commodities. The full life-cycle approach is usually used to calculate it and oil consumption in every aspect of the whole production chain needs to be traced, so this method costs too much work and also has more subjectivity. Therefore, the input-output method is an important and operable choice to study the topic. The model to calculate E which is oil exports embodied in international trade is established as follows:

$$E = \frac{C}{Y_i + Y_i^I - Y_i^E} \sum_{j=1}^n M_j \times b_{ij} \quad (9)$$

Where, C is China's total oil consumption; Y_i is the petroleum industry's total output; Y_i^I is the petroleum industry's imports from other countries; Y_i^E is the petroleum industry's exports to other countries. The unit of Y is Chinese Yuan, and it is a monetary unit. $\frac{C}{Y_i + Y_i^I - Y_i^E}$ measures the oil content of oil industry's each output for domestic use. Because the unit in IO table is also monetary, it can be transferred into material connection via $\frac{C}{Y_i + Y_i^I - Y_i^E}$ ratio. M_j is exports in sector j , and b_{ij} is sector j 's complete consumption coefficient on oil industry (sector i).

3.1.2 Calculation of oil embodied in imports

The calculation of oil embodied in imports is complicated. In theory, oil consumption coefficients of imported commodities from different countries should be calculated based on each country's input-output table respectively. However, China has more than one hundred trade countries, and so it is very difficult to calculate oil consumption coefficients of each commodity according to different countries' input-output tables one by one.

For the sake of simplification, this paper adopts the method of “*substitution effect*” and improves the method. The method of “*substitution effect*” refers to calculating oil embodied in China's imports based on complete oil consumption coefficients of China's industrial sectors. The reason is that imported commodities in a way avoid the domestic consumption of oil in production process, and “*substitution effect*” makes some sense.

However, the implied basic assumption of “*substitution effect*” method is that the technical level of processing commodities in exporting countries is the same with the importing country. It certainly does not meet the actual situation from the point of view of oil consumption. Usually there is a great difference in oil consumption efficiency among countries at different developing level. The exports of developed countries are relatively high value-added, while the exports of developing countries

are relatively low value-added. For commodities of equal value, oil consumption in developing countries is much higher than it in developed countries. However, it is very difficult to obtain the oil consumption efficiency differences of each commodity among China and its all importing trade partners. Limited to the available data, the differences of embodied oil in unit of China's imported and exported commodities are measured according to the ratio of the world average oil consumption intensity to China's oil consumption intensity in this paper. China is excluded when calculating the world average oil consumption intensity. The model to calculate I which is China's oil imports embodied in international trade is established as follows:

$$I = \frac{C}{Y_i + Y_i^I - Y_i^E} \sum_{j=1}^n I_j \times b_{ij} \times \frac{Q_w}{Q_c} \quad (10)$$

Where, $\frac{C}{Y_i + Y_i^I - Y_i^E}$ measures the oil content of oil industry's each output for China's domestic use; I_j is China's imports in sector j ; Q_w is the average oil consumption intensity in the world except China; Q_c is China's oil consumption intensity.

3.1.3 Calculation of net oil exports embodied in international trade

Based on Eq. (9) and (10), E_{net} which is China's net oil exports embodied in international trade can be calculated as follows:

$$E_{net} = \frac{C}{Y_i + Y_i^I - Y_i^E} \sum_{j=1}^n (E_j \times b_{ij} - I_j \times b_{ij} \times \frac{Q_w}{Q_c}) \quad (11)$$

Eq. (11) can be further revised to calculate the net oil exports embodied in international trade from China to country A as follows:

$$E_A = \frac{C}{Y_i + Y_i^I - Y_i^E} \left\{ \sum_{j=1}^n (b_{ij} \times w_j) \times (E_A - I_A \times \frac{Q_A}{Q_c}) \right\} \quad (12)$$

Where, E_A is the net oil export embodied in international trade from China to country A ; w_j is the proportion of sector j 's output in the national output; E_A is China's exports to country A ; I_A is China's imports from country A .

When China's input-output tables are available (for example, year 1997, 2002 and 2007), the imports, exports and net exports of China's embodied oil can be calculated in accordance with the above method. If there is no IO table, taking year 2008 as an example, E^{2008} which is oil embodied in exports, and I^{2008} which is oil embodied in imports, can be calculated through the following methods.

$$E^{2008} = E^{2007} \times c \times d \quad (13)$$

$$I^{2008} = I^{2007} \times e \times f \quad (14)$$

Where, c is the adjustment factor of oil consumption in unit of China's exports, and $c = \frac{Q_c^{2008}}{Q_c^{2007}}$, in which Q_c is China's oil consumption intensity; d is the adjustment factor of China's exports, and $d = \frac{EX^{2008}}{EX^{2007}}$, in which EX means China's exports; e is the adjustment factor of oil consumption in unit of China's imports, and $e = \frac{Q_w^{2008}}{Q_c^{2008}} \div \frac{Q_w^{2007}}{Q_c^{2007}}$, in which Q_w is the average oil consumption intensity in the world except China; f is the adjustment factor of China's imports, and $f = \frac{IM^{2008}}{IM^{2007}}$, in which IX means China's imports.

3.2 Data

The Input-Output data are from Input-Output table of China [19] directly which is released by National Bureau of Statistics of China. Sectors' oil consumption data are from China Energy Statistical yearbook [20], and China's exports and imports data are from China statistical yearbooks 2011. Both China Energy Statistical yearbook and China statistical yearbooks are released by National Bureau of Statistics of China. Although there are 42 sectors in China's IO tables (Table 2), there are 50 sectors in China statistical yearbooks. Some similar sectors in China statistical yearbooks are combined in order to keep the same statistical caliber with IO table. The oil complete consumption coefficients of 42 sectors in China's Input-Output table in 2007 are also shown in Table 2.

Oil consumption intensity is the oil consumption per GDP. Oil consumption data of different countries are from BP Statistical Review of World Energy [21], and GDP data are from World Bank [22] directly.

Table 2. 42 sectors in China's Input-Output table (Brief Version) and each sector's oil complete consumption coefficient in 2007. Data sources: National Bureau of Statistics of China [19]

Number	Sector	Complete oil consumption coefficient
1	Agriculture	0.0739
2	Mining and Washing of Coal	0.1242
3	Extraction of Petroleum	0.1529
4	Mining and Processing of Metal Ores	0.2498
5	Mining and Processing of Nonmetal Ores	0.2135
6	Manufacture of Foods, Beverages and Tobacco	0.0882

7	Manufacture of Textile	0.1324
8	Manufacture of Textile Wearing Apparel, Footware, Caps, Leather, Fur, Feather and Related Products and Social Organization	0.1228
9	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, Straw Products and Furniture	0.1325
10	Manufacture of Paper , Paper Products, Printing, Reproduction of Recording Media, Articles For Culture, Education and Sport Activities	0.1388
11	Processing of Petroleum	0.7920
12	Chemical industry	0.3252
13	Manufacture of Non-metallic Mineral Products, Smelting and Pressing of Metals	0.2007
14	Smelting and Pressing of Ferrous Metals	0.2500
15	Manufacture of Metal Products	0.1887
16	Manufacture of General and Special Purpose Machinery	0.1695
17	Manufacture of Transport Equipment	0.1559
18	Manufacture of Electrical Machinery and Equipment	0.1837
19	Manufacture of Communication Equipment, Computers and Other Electronic Equipment	0.1383
20	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work	0.1479
21	Other Manufacturing	0.1458
22	Recycling and Disposal of Waste	0.0220
23	Production and Supply of Electric Power and Heat Power	0.2024
24	Production and Supply of Gas	0.6830
25	Production and Supply of Water	0.1112
26	Construction	0.1999
27	Transportation	0.4009
28	Postal	0.1505
29	Telecommunication Services	0.0601
30	Wholesale and Retail Trades	0.0814
31	Hotels and Catering Services	0.0798
32	Banking and Insurance	0.0471
33	Real Estate	0.0388
34	Leasing and Business Services	0.1544
35	Tourism	0.1152
36	Scientific Research	0.1054
37	General Technical Services	0.1261
38	Other Social Services	0.1238
39	Education	0.0870
40	Health, Social Security and Social Welfare	0.1670
41	Culture, Sports and Entertainment	0.0959
42	Public Management and Social Organization	0.1020

4. Calculation of net oil exports embodied in China's international trade

4.1 National Difference of oil consumption intensity

Oil consumption intensity can be calculated as oil consumption per GDP. It is a widely used indicator to measure the efficiency of oil use. Fig. 2 shows the changes of oil consumption intensity in China since 1978.

Figure 2. Changes of oil consumption intensity in China since 1978. Data sources: National Bureau of Statistics of China [16–17]

China's oil consumption intensity has decreased significantly since 1978, from 0.49 tonnes per 10000 CNY (2009 prices) in 1978 to 0.12 in 2010. The average annual decrease rate is 4.5%. Table 3 shows the difference in oil consumption intensity among sectors in China. Although China's oil consumption intensity has already dropped significantly, there is still an obvious gap between China and developed countries and even the world average level as shown in Table 4.

It can be seen from Table 4 that there is still space for China's oil consumption intensity to decrease. China's oil consumption intensity is 3, 2.8, 2.7, 1.9 and 1.4 times of it in United Kingdom, France, Germany, Japan and United States respectively, and moreover, it is about 30% higher than the world average level in 2008. China has taken continuous measures to promote improvements, but it needs time to receive effect and significantly reduce China's oil consumption intensity. Generally, oil consumption intensity is influenced by the country's technology and as well as its economic structure.

Table 3. *Oil consumption intensity of various sectors in China. Data sources: China Energy Statistical yearbook 2011[20]*

Sector	2006	2010
Agriculture, Forestry, Animal Husbandry and Fishery	0.0639	0.0370
Mining	0.1391	0.1006
Manufacturing	0.0798	0.0573
Production and Supply of Electricity, Gas and Water	0.1713	0.0608
Construction	0.0504	0.0310
Transport, Storage and Post	0.9681	0.8066
Wholesale ,Retail Trades, Hotels and Catering Services	0.0131	0.0102

Table 4. *Comparison of oil consumption intensity in different countries (unit: Tonne/10⁴ US\$). Data sources: BP Statistical Review of World Energy [21], World Bank [22]*

Country	1990	2000	2005	2008
China	3.16	1.87	1.47	0.88
India	1.83	2.31	1.48	1.24
Russian Federation	4.83	4.76	1.59	0.78
Brazil	1.39	1.42	1.01	0.67
United States	1.36	0.92	0.77	0.63
Japan	0.82	0.55	0.54	0.45
United Kingdom	0.82	0.53	0.36	0.29
France	0.72	0.71	0.43	0.32
Germany	0.74	0.68	0.44	0.33
World (Average)	1.46	1.13	0.87	0.67

4.2 Net oil exports embodied in China's international trade

National Bureau of Statistics of China has already published five input-output tables in 1987, 1992, 1997, 2002 and 2007 respectively. Input-output tables in 1987 and 1992 just have the data of net exports, and the imports and exports aren't separated in that two IO tables. Consequently, only 1997, 2002 and 2007 input-output tables are used in this study. Table 5 shows the basic structure of China's IO table. There are 42 sectors in China's IO table (Brief Version), and there are two petroleum sectors among the 42 sectors, which are extraction of petroleum and processing of petroleum respectively. In the model applied to this study, extraction of petroleum and processing of petroleum are combined into one sector. China's net oil exports embodied in international trade can be calculated (Table 6) according to Eq. (11).

In 2007, China's net oil exports embodied in international trade was 87 million tonnes per year or about 1.7 million barrels per day. China's oil consumption

increased rapidly at the average annual growth rate of 6.4% from 1997 to 2007. However, China's net oil exports embodied in international trade increased much faster at the average annual growth rate of 13.4% during the same period.

The oil embodied in trade in a particular year without IO table is also calculated according to Eq. (13) and (14). Table 6 also shows the oil embodied in trade for the latest years since 2008. China's net oil exports embodied in international trade dropped a lot during global economic crisis, but they are still at a high level and keep an increasing trend again.

Table 5. *Basic structure of China's Input-Output Table.*

Input \ Output	Intermediate Use				Final Use						E x p o r t s	I m p o r t s	O t h e r s	T o t a l O u t p u t
					Final Consumption Expenditure			Gross Capital Formation						
					Household Consumption Expenditure		Government Consumption Expenditure	Gross Fixed Capital Formation	Changes in Inventories					
					Rural Household	Urban Household								
		Sect or 1	...	Secto r N										
Intermediate Inputs	Sector 1													
	...													
	Sector N													
Total Value-added	Compensation of Employees													
	Net Taxes on Production													
	Depreciation of Fixed Assets													
	Operating Surplus													
Total Inputs														

Table 6. *Net oil exports embodied in China's international trade.*

Year	Net oil imports [Mt]	Oil exports embodied in international trade [Mt]	Oil imports embodied in international trade [Mt]	Net oil exports embodied in international trade [Mt]
1997	35.92	45.91	21.08	24.83
2002	80.54	68.57	39.58	28.99
2007	177.71	171.77	84.75	87.02
2008	185.59	160.62	74.11	86.51
2009	198.69	120.73	60.03	60.70
2010	225.57	148.61	77.62	70.99
2011	253.26	169.24	90.55	78.69

5. Additional analysis of net oil exports embodied in China's international trade

5.1 Distribution of net oil exports embodied in China's international trade

The calculation results in Table 6 are the total net oil exports embodied in China's international trade. They are the sum of all sectors' net oil exports embodied in international trade. Sector distribution of net oil exports embodied in China's international trade is shown in Table 7.

Table 7. *Distribution of net oil exports embodied in international trade in different sectors in China.*

Rank in 2007	Sector	Net oil exports embodied in international trade [Mt]		
		2007	2002	1997
1	Manufacture of Communication Equipment, Computers and Other Electronic Equipment	15.51	2.59	0.09
2	Transportation	13.81	7.86	0.93
3	Manufacture of Textile	10.65	3.29	0.73
4	Manufacture of Electrical Machinery and Equipment	8.81	2.44	0.09
5	Manufacture of Textile Wearing Apparel, Footwear, Caps, Leather, Fur, Feather and Related Products	6.79	3.87	0.29
6	Manufacture of Metal Products	6.28	2.05	3.02
7	Metal Smelting and Rolling Processing	6.09	2.45	2.06
8	Chemical industry	4.34	0.44	0.51
9	Wholesale and Retail Trades	3.42	2.60	0.17
10	Timber Processing, Manufacture of Wood, Bamboo, Rattan, Palm, Straw Products and Furniture	3.12	1.13	-1.53

Table 7 shows net oil exports embodied in international trade for China's top 10 sectors. Manufacture of communication equipment, computers and other electronic equipment, Transportation, Manufacture of Textile are the three largest sectors, yielding 45.9% of the total net oil exports by "Made in China" products in 2007.

In China's IO table, the business of transportation sector includes both domestic and abroad transportation parts. Thus, the net oil exports embodied in

transportation sector in Table 7 also include both domestic and abroad transportation parts. In order to analyze this issue further, structure of freight traffic in China is reflected in Table 8. Considering the distance of each kind of freight traffic, Table 9 shows the structure of freight ton-kilometers in China. The data in Table 8 and Table 9 are from statistical yearbooks released by National Bureau of Statistics of China.

Table 8. *Structure of Freight Traffic in China.*

Year	Railways	Highways	Waterways	Civil Aviation	Pipelines
2005	14.5%	72.1%	11.8%	0.0%	1.7%
2006	14.2%	72.0%	12.2%	0.0%	1.6%
2007	13.8%	72.0%	12.4%	0.0%	1.8%
2008	12.8%	74.1%	11.4%	0.0%	1.7%
2009	11.8%	75.3%	11.3%	0.0%	1.6%
2010	11.2%	75.5%	11.7%	0.0%	1.5%

Table 9. *Structure of Freight Ton-Kilometers in China.*

Year	Railways	Highways	Waterways	Civil Aviation	Pipelines
2005	25.82%	10.83%	61.89%	0.10%	1.36%
2006	24.71%	10.98%	62.46%	0.11%	1.75%
2007	23.46%	11.20%	63.39%	0.11%	1.84%
2008	22.76%	29.80%	45.57%	0.11%	1.76%
2009	20.67%	30.45%	47.13%	0.10%	1.66%
2010	19.49%	30.59%	48.24%	0.13%	1.55%

It can be found from Table 8 and 9 that highways are the main transport way for China's freight traffic. However, waterways play the most important role in China's transport from the perspective of freight ton-kilometers.

Ocean transportation dominates China's waterways transportation. Fig.3 shows proportion of ocean waterway freight ton-kilometers in the total transportation in China since 2000. Ocean waterway transportation accounted for nearly half of the total freight ton-kilometers in China during the period of 2004 to 2007. Because China's foreign trade decreased during global economic crisis, the proportion dropped a lot in 2008. However, it is still at a high level and keeps increasing now.

Figure 3. *Proportion of ocean waterway freight ton-kilometers in the total transportation in China since 2000.*

Different kind of transportation certainly has different level of oil consumption. Jiancui [23] compared the oil consumption difference in every freight ton-kilometer transported by railways, highways, civil aviation, waterways and pipelines in China. If the oil consumption of every freight ton-kilometer transported by waterways is one unit, it will be 0.1052, 0.9881, 5.8787, and 0.0897 by railways, highways, civil aviation and pipelines respectively. So, the proportion of oil consumption for each kind of transportation in China can be calculated. For the sake of simplification, China's net oil exports embodied in transportation sector can be divided into domestic and abroad transportation parts according to those proportions (Table 10).

According to Eq. (12), China's net oil exports embodied in international trade to main countries are calculated, and the top 10 countries are shown in Table 11. United States, China Hong Kong SAR and Netherlands are the top three countries and regions which benefit most from the embodied oil in "*Made in China*" products in 2007. They account for two thirds of the total net oil exports.

China's net oil imports embodied in trade from other countries and regions can also be calculated by the same way. China benefits most from Taiwan, South Korea and Singapore, and the net oil imports from them are 16.04, 10.88, 4.06 Mt respectively in 2007.

Overall, China is at disadvantage status for oil embodied in foreign trade. One of the main reasons is that as a "*world factory*", China's foreign trade has already had the character of "*comparative advantages traps*". This means that if a country, especially a developing one, produces and exports primary and labour-

intensive products completely according to comparative advantage theory, it's always at disadvantage status when it trades with developed countries even if it can obtain the trade surplus as pointed by Hong [24] and Wang [25].

Table 10. *Distribution of China's net oil exports embodied in transportation sector.*

Year	Domestic transportation	Abroad transportation
2000	46.0%	54.0%
2001	38.8%	61.2%
2002	40.0%	60.0%
2003	41.2%	58.8%
2004	37.6%	62.4%
2005	36.8%	63.2%
2006	37.5%	62.5%
2007	38.3%	61.7%
2008	61.9%	38.1%
2009	59.6%	40.4%
2010	60.2%	39.8%

Table 11. *Distribution of net oil exports embodied in international trade from China to different countries and regions in the world.*

Rank in 2007	Countries and Regions	Net oil exports embodied in international trade [Mt]		
		2007	2002	1997
1	United States	27.19	19.61	7.03
2	China Hong Kong SAR	25.93	19.46	12.83
3	Netherlands	5.67	3.51	1.23
4	Japan	4.98	6.18	5.68
5	Germany	4.71	2.39	1.39
6	United Kingdom	4.32	2.77	1.06
7	Italy	2.54	1.33	0.42
8	France	2.30	1.46	0.38
9	Spain	2.09	0.90	0.31
10	United Arab Emirates	1.71	1.04	0.38

“Made in China” products have obvious comparative advantage in low-technology products, but its comparative advantage in high-technology products is relatively weak as pointed by Hao Wei [26]. Therefore, China's trade surplus is at the

cost of becoming "world factory" to export low-technology and low value-added products. At the same time, China also exports a lot of embodied resources, including oil products, to reduce the economic development cost of other countries.

5.2 China's adjusted degree of dependence on foreign oil

If net oil exports embodied in international trade are considered, China's degree of dependence on foreign oil can be re-calculated in Table 12.

Table 12. *China's adjusted degree of dependence on foreign oil.*

Year	Proportion of net oil exports embodied in international trade to total oil consumption in China	China's degree of dependence on foreign oil	China's adjusted degree of dependence on foreign oil
1997	12.7%	18.3%	5.7%
2002	11.7%	32.6%	20.8%
2007	23.9%	48.8%	24.9%
2008	23.0%	49.4%	26.4%
2009	15.6%	51.2%	35.6%
2010	16.6%	52.6%	36.1%
2011	17.3%	55.7%	38.4%

As it can be seen from Table 12, the proportion of net oil exports embodied in international trade in the total oil consumption increased from 12.7% in 1997 to 23.9% in 2007. China's degree of dependence on foreign oil was 48.8% in 2007, thus about half of China's oil imports from overseas are exported to other countries through "Made in China" products. If net oil exports embodied in international trade are considered, China's degree of dependence on foreign oil can be reduced obviously. China's adjusted degree of dependence on foreign oil was 24.9% in 2007, and 38.4% in 2011.

If oil price increases quickly, it will have negative impact on China's national economy. To mitigate it, China's government generally offers subsidies to oil refinery by billions of Chinese Yuan every year. By this way, oil products in China can be kept relatively cheap. From a wider perspective, these subsidies are also used to subsidize countries that import "Made in China" products. Sadly, this is seldom recognized internationally as China is always under political pressure because of its large trade surplus gained from "Made in China" products.

6 Conclusions and suggestions

6.1 Conclusions

Warr and Ayres [27] and Brown et al [28] showed that economic growth is linked to quantity and quality of energy consumption. Consequently, China's economy cannot continue growing smoothly without the support of required energy inputs, including oil products. Recently, China has become the second largest oil consumer in the world and needs to import more than half of its oil. When China consumes oil for its economic development, some of the oil will be embodied in the products and services labeled "*Made in China*." Thus, China's oil demand growth is not only caused by strong domestic demand and consumption, but also caused by the rapid growth of export due to the role as "*world factory*". The model established in this article aims to analyze this interdependence. The basic conclusions obtained from the analysis are as follows:

China's net oil exports embodied in international trade were estimated to be 87.02 Mt in 2007, while they were only 24.83 Mt in 1997 and 28.99 Mt in 2002. China's oil consumption increased rapidly at the average annual growth rate of 6.4% from 1997 to 2007. However, China's net oil exports embodied in international trade increased much faster at the average annual growth rate of 13.4% during the same period. China's net oil exports embodied in international trade dropped a lot during global economic crisis, but they are still at a high level and keep a trend of increasing again. China's net oil exports embodied in international trade are estimated to 78.69 Mt in 2011, close to the highest level in 2007.

Manufacture of communication equipment, computers and other electronic equipment is the largest sector to export net oil through "*Made in China*" products, and it exported 15.51 Mt in 2007. Transportation, Manufacture of Textile rank second and third, and they exported 13.81 Mt and 10.65 Mt respectively in 2007. The top three sectors account for 45.9% of the total net oil exports embodied in international trade. United States, China Hong Kong SAR and Netherlands are the top three countries and regions which benefit most from the embodied oil, and the net oil exports to them embodied in trade were 27.19 Mt, 25.93 Mt and 5.67 Mt respectively in 2007. China's foreign trade has already had the character of "*comparative advantages traps*" as a "*world factory*", which is the main reason for China's disadvantage status as for oil embodied in foreign trade. If net oil exports embodied in international trade are considered, China's adjusted degree of dependence on foreign oil is 24.9% in 2007, and 38.4% in 2011.

6.2 Discussions

Currently, energy security has become a major focus in the world economy and international political relations. Domestic oil production in China has already entered the plateau stage, while oil demand is still growing rapidly. China will undoubtedly continue importing significant amounts of oil from the international market every

year. However, China will likely face more and more international critique as a competitor for the available import volumes. Fantazzini et al. [29] showed that the oil supply is basically fixed in the short and medium term. Consequently, rising China's oil consumption will effectively mean that other countries must reduce their use of oil. Political tensions, possibly leading to decisions that alter economic conditions or relations, can also emerge from this situation and hurt China's and/or the world economy.

Meanwhile, the cost for China to obtain oil from international markets or through international cooperation will likely become higher and higher because of the decrease of petroleum availability in the future. Fantazzini et al [29] also found that economic recessions are often looming when energy takes a disproportionate amount in the total consumer expenditures. Consequently, China's economy will probably face challenges originating from oil depletion and dynamics of oil markets.

At the same time, China also exports a lot of oil embodied in international trade to reduce other countries' economic development cost, but it is not always acknowledged by analysts. Some even perceive China as an energy threat by pointing out that rising China's oil imports is the main reason for high oil prices. Such viewpoints are inconsistent, as they ignore the exports of embodied oil through "*Made in China*" products. It will be beneficial for China to promote better understanding of this issue that China exports a large quantity of embodied oil to the world. Proper understanding of oil supply mechanism, including its direct and indirect parts, may be a useful tool for avoiding such conundra as exemplified above.

The embodied oil in exported goods also brings about another problem which is that China is exporting significant volumes of embodied oil and potentially undercut domestic manufacturing in other countries. To solve this problem, China should impose strict restrictions on exporting high-energy-consuming products. It is time for China to sacrifice the interest of trade surplus to promote the sustainable development of its economy and a more balanced situation of the world trade, which also will benefit the recovery of the global economy.

Although oil embodied in "*Made in China*" products affect China's oil consumption and oil security, actually it makes tremendous contributions to China's economic growth and employment stability, and also makes a lot of contribution to the world economy and benefits other countries' consumers. If "*Made in China*" products at low prices are reduced in large scale, it will bring a lot of problems to the world including China's economic development probably. I plan to use multi-objective programming to systematically evaluate China's transition cost of decreasing the exported embodied oil, and determine the quantity that can be reduced at an affordable price for both China and the world.

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