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Exploring the prospects of cooperation in the manufacturing industries between India and China: A perspective of embodied energy in India-China trade

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ABSTRACT

Manufacturing reforms are facing energy constraint in both India and China. In this paper, an international input-output analysis (IOA) was applied and several expanding-descriptive indicators were chosen to measure the energy transformation embodied in India-China manufacturing trade from 1996 to 2011. Furthermore, the main driving factors of the change in embodied energy were examined by structural decomposition analysis (SDA). The results showed that the total energy use in bilateral trade and net embodied energy imports in India's manufacturing increased by about 11 times and 40 times, respectively. Energy terms of trade in India's manufacturing appeared in an "M" shape with a deteriorating tendency, which indicated that India's manufacturing gradually lost its advantage of energy conservation exchanged by trade deficit. The major manufactures, which had lower trade profits and larger energy demands, were of light industries in India but were of heavy industries in China. Scale effect was the strongest driving factor for the increase of the embodied energy. Technique effect had the greatest negative effect and could offset the increase in embodied energy by about 13.18–54.49%. According to our research, it could be concluded that energy cooperation is necessary and has a wide prospect for India and China.

1. Introduction

After years of strong performance, emerging economies are experiencing a slowdown. A new round of reforms will be necessary if growth is to be sustained in the face of a more challenging external environment (IMF, 2013). As the most dynamic countries with great potentials, India and China have manufacturing outputs accounted for 15% and 32% of their GDPs, respectively (Crabtree, 2014). Based on India's demographic dividend, prime minister Narendra Modi is reinvigorating his flagship 'Made in India' to develop a Chinese-style global manufacturing and export powerhouse (Keohane and Crabtree, 2016). Meanwhile, China's leaders are trying to move manufacturing up along the global value chain with the 'Made in China 2025' plan in the face of the coming 'Lewis turning point' between 2020 and 2025 (China Daily, 2015). However, the common severe problem that India and China are facing is energy constraint in manufacturing reforms. In spite of their efforts on saving energy, such as India's 'UDAY' and China's 'Made in China 2025-energy equipment implementation plan' (Sohu, 2016; NEA, 2016), the energy imports of the two countries have been increasing rapidly. As China has become India's most important trading partner, the number one export destination and the fourth largest source of imports (MOFCOM, 2015), India-China manufacturing trade involves more and more embodied energy — the total energy consumption of a product in its life-cycle. Also, with the growing of India-China manufacturing trade, both India and China want to step up cooperation and develop together. Hence, carefully considering the transformation of embodied energy in India-China manufacturing trade would give us a fair and win-win picture for pursing energy and industrial cooperation between the two countries.

Recent studies have focused on the issue of transformation of energy or carbon in different international trades. The most commonly used methodology in these literatures is IO model, which can be further divided into single-region IO (SRIO) model, interregional IO (IRIO) model and multiregional IO (MRIO) model according to different research scopes. SRIO model has the advantages of simple calculation and timely data updating. It assumes that domestic and foreign technical factors are the same (also called 'emissions avoided by imported', EAI). The paper of Lin and Sun (2010) adopted SRIO model and EAI assumption to measure CO_2 embodied in China's foreign trade. Yan and Yang (2010) calculated the CO_2 emissions in China's foreign trade during

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Table 1
Basic framework of an India-China IO model.

		Intermediate demand		Final demand			Total output
		India	China	India	China	Exports to other countries	
Domestic intermediate input	India	x_{ij}^{II}	x_{ij}^{IC}	y_i^{II}	y_i^{IC}	E_i^C	X_i^I
	China	x_{ij}^{CI}	x_{ij}^{CC}	y_i^{CI}	y_i^{CC}	E_i^I	X_i^C
Imports from other countries		M_j^C	M_j^I				
Additional value		V_j^C	V_j^I				
Total input		X_j^C	X_j^I				
Energy consumption		EN_j^C	EN_j^I				

Note: For easy of reference, energy consumption is added in the last row of the table.

1997–2007 by the same way. Atkinson et al. (2010) compared embodied carbons in the net exports of all major developing countries. The application of SRIO in these papers shows that SRIO model can easily calculate the total embodied energy or carbon in a single region and is suitable to make a multiregional comparison due to its easy operating. IRIO model provides researchers a framework to study interregional transformation of embodied energy or carbon. For example, Yin et al. (2015) used IRIO model to analyze the pollution transformation among China's industries. Chen et al. (2017) established an interprovincial IO model based on IRIO model to study the transformation of embodied energy between Beijing-Tianjin-Hebei Region and other regions in China. In addition, some studies are based on MRIO model, such as the work about Austria's consumption-based CO_2 emissions done by Munoz and Steininger (2010), the work about embodied carbon of 48 sectors of 53 countries done by Wiebe et al. (2012) and the work about embodied energy of net export of the UK done by Tang et al. (2013). Fully considering all of the trading partners, MRIO model can produce more accurate results, while it has difficulties in calculating and updating data.

The exploration of what contributions several effects make to the change in embodied energy or carbon in international trade is another important part. The main methods of studies are IDA and SDA. The latter strongly depends on IO model. Dong et al. (2010) used IDA to analyze the driving factors of increasing embodied energy in China-Japan trade. Gingrich et al. (2011) studied the influencing factors of the change of CO_2 emissions in Austria and Czechoslovakia by the same way. Ren et al. (2014) studied the influencing factors of increasing embodied emissions in China's industries. IDA directly reflects contributions of various factors, but it can only measure direct effect rather than indirect effect, which can only be calculated by SDA (Hoekstra and van den Bergh, 2003). Yan and yang (2010), Xu et al. (2010) separately adopted SDA to analyze the influencing factors of changing embodied carbon in China's foreign trade during 1997–2007 and 2002–2008. SDA was also used by Jeong and Kim (2013) to study the influencing factors of changing CO_2 emissions in South Korea's industries.

Those studies are instructive in establishing different IO models to analyze the transformation of trading embodied energy or carbon and using IDA or SDA to analyze the driving factors of them. This paper is designed to analyze the transformation of embodied energy in India-China manufacturing trade and examine its influencing effects. Since the research scope is India-China trade, an India-China IO model based on IRIO model is established to measure embodied energy from overall and sectoral aspects in India-China manufacturing trade. And we further used SDA to study the main driving factors bringing the change in embodied energy. The contributions and novelties of this paper are as follows. First, our study has taken into account the background of energy restriction in India's and China's manufacturing reforms, and the necessity of energy cooperation in the manufacturing industries between the two countries has also been analyzed, which was not fully focused in those previous literatures. Second, one distinguishable contribution is that we have introduced some expanding-descriptive indicators, such as energy total use (ETU), energy terms of trade (ETT) and etc. to analyze manufacturing relative position and features of the two countries in trade, by which way, the conclusions would be more in-depth and more comprehensive than those drawn by simple comparison. Third, we have evaluated and decomposed not only the embodied energy in total trade, but also that in 14 manufacturing sectors of the both countries, which could help us have an overall grasp of the embodied energy condition in manufacturing while capturing the differences and correlations of embodied energy of various sectors. Forth, the results might have implications for the later development of India and China and be constructive in other countries with similar issues. In Section 2, the methodology and data were presented. Section 3 discussed the results. And the conclusions and recommendations were provided in Section 4.

2. Methodology and data

2.1. Input-output analysis

We established an India-China IO model based on IRIO model which fully considered the imperfect substitutability of consumption between domestic and foreign goods to measure the transformation of embodied energy in India-China manufacturing trade. The basic framework of the model was presented in Table 1.

Assuming that an economy includes two countries and each has n sectors. Defining $A \equiv [a_{ij}] = [x_{ij}/X_j]$ as the direct consumption matrix of goods, where a_{ij} is the amount of output from sector i directly assigned to sector j for producing per unit output. According to Table 1, the model can be represented as

$$\begin{bmatrix} X^I \\ X^C \end{bmatrix} = \begin{bmatrix} A^{II} & A^{IC} \\ A^{CC} & A^{CI} \end{bmatrix} \begin{bmatrix} X^I \\ X^C \end{bmatrix} + \begin{bmatrix} Y^{II} + Y^{IC} + E^C \\ Y^{CI} + Y^{CC} + E^I \end{bmatrix} \tag{1}$$

Where superscripts I and C represent India and China, respectively. The products flow between the two countries can be described by various combination of I and C. For example, II represents the domestic consumption of goods, and CI represents China's exports to India. In Eq. (1), the left side is the total output vector ($2n \times 1$) of all sectors in the two countries. On the right side, the first part is the intermediate demand vector ($2n \times n$) in the two countries, and the second part is the final demand vector ($2n \times 1$) in India, China and other countries of the world. Rearranging Eq. (1), we get the fundamental IO identity as

$$\begin{cases} X^I = (I - A^{II})^{-1}(A^{IC}X^C + Y^{IC} + Y^{II} + E^C) \\ X^C = (I - A^{CC})^{-1}(A^{CI}X^I + Y^{CI} + Y^{CC} + E^I) \end{cases} \tag{2}$$

Where I is an identity matrix ($n \times n$). $L^{II} = (I - A^{II})^{-1}$ and $L^{CC} = (I - A^{CC})^{-1}$ are Leontief inverse matrix ($n \times n$) of domestic consumption in the two countries, respectively. $(A^{IC}X^C + Y^{IC} + Y^{II} + E^C)$ and $(A^{CI}X^I + Y^{CI} + Y^{CC} + E^I)$ are the final demand for India's and China's goods, respectively. $(A^{IC}X^C + Y^{IC})$ and $(A^{CI}X^I + Y^{CI})$ represent