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Calculation of embodied energy in Sino-USA trade: 1997–2011

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HIGHLIGHTS

- An EIO-LCA model is established to examine China's embodied energy in Sino-USA trade.
- Embodied energy is calculated from the perspective of energy sources.
- China is found to be the net exporter of embodied energy in Sino-USA trade.
- Coal, crude oil and natural gas are the major components of China's net embodied energy exports.
- China's energy consumption has increased and America's has shifted to China in Sino-USA trade.

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ABSTRACT

In order to find efficient trade measures to reduce China's energy consumption and to provide theoretical support for the climate talks between China and America, we investigate the impact of Sino-USA trade on energy consumption from the perspective of embodied energy. An Environmental Input–Output Life Cycle Assessment (EIO-LCA) model was established to calculate the total energy consumption coefficient, the direct consumption coefficient and the complete consumption coefficient of the sectors of the national economies of China and America. After taking into consideration the data of every sector of the national economy in Sino-USA trade, energy embodied in the import and export trade between China and America was calculated to verify the real energy flows in Sino-USA trade. The research results suggest the following: China is the net exporter of embodied energy in Sino-USA trade, and coal, crude oil and natural gas are the major components. In 1997–2011, the net exports of China's embodied energy totaled 1523,082,200 t of standard coal, the amount of China's energy consumption increased by 895,527,900 t of standard coal, and America's energy consumption decreased by 11,871,200 t of standard coal as a result of Sino-USA trade. On this basis, corresponding policies and recommendations are proposed.

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1. Introduction

Since China's reform and opening up, foreign trade has been an important factor in promoting the rapid development of China's economy. Sino-USA trade has developed rapidly since China established diplomatic relations with America in 1979 and China has formed a high degree of dependence on foreign trade. Excluding the EU and other regional organizations, the goods trade data announced by the US Census Bureau in July 2013 showed that American exports to China accounted for 7% of their exports to the world. China is the third-largest export market of America, after Canada and Mexico. American imports from China accounted for 18.5% of its total imports and is now the largest source of its imports. China is the second-largest trading partner of America, after Canada. Sino-USA trade in goods accounted for 13.8% of the world total (United States Census Bureau, 2013). Data announced by China's Ministry of Commerce in April 2013 showed that Sino-USA trade accounted for 12.5% of the total foreign trade of China, with America now being China's second-largest trading partner after the EU and China's largest export market (Ministry of Commerce of China Comprehensive Department, 2013). With the huge numbers involved in Sino-USA trade, it clearly plays a vital role in those two countries and on world economic development.

The rapid development of China's foreign trade and its status as the primary processing factory of the world has resulted in China having a trade surplus with America and other developed countries, but it has also resulted in China consuming enormous energy in producing goods for export markets (Wang et al., 2013). Excessive energy consumption is a disadvantage to China's energy security and may also shift the impact of price fluctuations in international bulk energy resources onto China. It is worth noting that in 2012 China's dependence on foreign oil reached 58.7% and

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that in 2009 China became a net importer of coal for the first time (Tencent Finance, 2013; China Coal Website, 2010).

Excessive energy consumption has led to many environmental problems. At present, China is in a disadvantageous position in international climate negotiations and Western developed countries are requesting more environmental responsibility from developing countries such as China. Some countries have imposed green trade barriers on China in international trade, which not only restricts China's development and causes huge losses in foreign trade but also damages the international image of China. Meanwhile, some Western politicians are agitated about a "Chinese energy threat" that produces environmental consequences such as excessive energy consumption and environmental pollution; they maintain that these are generated because China is trying to control more oil and natural gas resources in the process of fostering its rapid economic growth. Former American President Bush asserted that one of the reasons for high oil prices is that China wants to maintain a 10% economic development rate.

A key question arising from China's massive surplus in Sino-USA trade is how much energy is consumed by China instead of America? Therefore, it is very important to carry out research on the distinction of trade interests in terms of energy consumption in Sino-USA trade from the perspective of embodied energy. Current research on Sino-USA trade has been focused on analyses of the essence of the trade frictions and imbalances, and the main reasons for these, but rarely on energy consumption. To look for efficient trade measures to reduce China's energy consumption, and to provide theoretical support for refuting unfavorable international public opinion on China's energy security and climate change policies, this study investigated the distinction of trade interests in terms of energy consumption in Sino-USA trade from the perspective of energy flows.

2. Literature review

The concept of "embodied energy" was defined in a working group meeting of energy analysis by the International Federation of Institutes for Advanced Study. Embodied energy was defined as the total energy consumption, both direct and indirect, in the life cycle of a product or service (Chen, 2009). Energy embodied in international trade, covering both embodied energy exports and imports, can be applied to measure the impact of trade products and services on the energy consumption of trade countries. Energy embodied in exports is the energy transferred from the import country to the export country to meet the consumption requirements of the import country and the energy consumed directly or indirectly in the process of manufacturing the exported products in the production country (export country). The concept of energy embodied in imports is the converse of the energy embodied in exports. A situation of net exports of embodied energy arises when the amount of energy embodied in exports is greater than the amount of energy embodied in imports.

At present, two research methods are widely used to calculate embodied energy in international trade. The first is the bottom-up Life Cycle Assessment (LCA), which is employed to calculate both direct and indirect energy consumption during the whole production process of products or services. Gavrilova et al. (2010) and Ghertner and Fripp (2007) analyzed the carbon embodied in international trade using LCA. Weber and Matthews (2008) quantified the carbon embodied environmental emissions in American international trade and revealed that carbon emissions equivalent to 30% of America's household energy consumption had been diverted to America's trading partners in 2004. Lindner et al. (2013) study, a bottom-up model was used to calculate direct CO_2 emissions embodied in electricity exports and imports between Chinese provinces. Their results demonstrated that CO_2 emissions from the electricity sectors in some provinces of China were higher than the total CO_2 emissions from the electricity sectors in some countries. Liu et al. (2008) analyzed energy embodied in China's export trade of 2005 and found that the energy embodied in 46 exported products accounted for 13.4% of China's primary energy consumption. Additionally, some research results demonstrated that the carbon emissions of the developed countries were decreased and the environmental pollution of China was increased in China's foreign trade (Li et al., 2009; Yan and Yang, 2010; You and Hewitt, 2008). Yu et al. (2014) assessed the effect of carbon emissions and calculated the coefficient of carbon emissions in coal-to-energy chains by life-cycle assessment, and their results showed that the carbon emissions coefficient of the coal-energy chain in China was at a relatively low level compared with other countries.

The second research method is the bottom-up input–output analysis, which is based on an input–output table that is employed to calculate the energy consumption of a final product that contains total intermediate inputs (Daly, 1968; Leontief, 1970). Three models have been developed to calculate the energy and carbon embodied in international trade with the input–output method: the single-region input–output model, the bilateral-region input–output model and the multi-region input–output model. The single-region input–output model is used to calculate the energy or carbon embodied in a single country or region with the input–output table of this country or region being based on the hypothesis of homogeneous technology, import substitution and major trading partners. Mongelli and Tassielli (2006) quantified the carbon embodied in the imports of Italy in 2000 and the results showed that the carbon embodied in imported goods represented almost 18% of the total GHG emissions emitted in the same year. The results of Machado et al. (2001), Su et al. (2013), Tang et al. (2013), and Xu and Dong (2012) demonstrated that England, Brazil and China were net exporters of embodied energy in their international trade. Additionally, research has been conducted to investigate the energy and carbon embodied in the international trade of countries, such as Austria (Muñoz and Steininger, 2010), Spain (Cansino et al., 2012), Korea (Chung et al., 2011), Turkey (İpek Tunç et al., 2007) and Vietnam (Thi Anh Tuyet and Ishihara, 2006).

The bilateral-region input–output model and multi-region input–output model are also used to calculate the energy or carbon embodied in bilateral or multipartite trade countries or regions using the input–output tables of these countries or regions. Using a bilateral-region input–output model, Ackerman et al. (2007) analyzed carbon emissions in the USA–Japan trade of 1995 and found that America shifted part of its carbon emissions to Japan, but global carbon emissions were decreased because of USA–Japan trade. In respect of China's bilateral trade, carbon embodied in Sino-USA trade has been a hot topic for researchers (Du et al., 2011; Gao and Liu, 2012; Guo et al., 2010; Wu and Yao, 2012). The results of this research showed that America ran its largest economic trade surplus with China and suggested the existence of a CO_2 trade surplus between America and China. Using a multi-region input–output model, McGregor et al. (2008) found that Scotland ran an economic trade deficit and embodied carbon surplus with the rest of the UK; this research highlighted pollution spillover and carbon balance problems between Scotland and the rest of the UK. A multi-region input–output model including 59 industrial sectors for all EU countries and 17 more aggregated industries for other regions of the world was developed to examine the role and consequence of embodied energy in European industries (Bordigoni et al., 2012).

Chen et al. (2004) constructed a global embodied CO_2 intensity database associated with 112 regions and 57 sectors, and using a

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