Energy use by Chinese economy: A systems cross-scale input-output analysis

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ABSTRACT

An overview for energy use in Chinese economy is presented in this study by means of a systems cross-scale input-output analysis. To concretely reflect the cross-scale effect between China and the rest of the world, embodied energy intensity of foreign imports is provided on the basis of our recent work on the world economy, in contrast to the conventional assumption of the same intensity for both the foreign and domestic trade. In 2012, the energy embodied in gross fixed capital formation is found to constitute nearly half of the total energy use in China, three-quarters larger than the total household consumption. Approximately 40% of energy resources embodied in final use turn out to be imported from foreign regions, twice the share of the direct energy imports in total energy consumption recorded by traditional direct accounting. The trade imbalance in energy use is illustrated with the support of the law of comparative advantage. In addition to economic benefits, hidden social impacts, including indirect external dependence and health costs associated with non-energy trade, should also be considered by the government in industrial structure adjustment. The present embodiment study is expected to be remarkably supportive for sustainable energy policy making in China.

1. Introduction

China has achieved impressive economic growth over the past three decades of reform and opening-up. According to World Bank statistics, China's GDP (Gross domestic product) has risen from a mere 6% of the United States levels in 1978 to over 60% in 2015, and its per capita income has increased by 40 times during that period (WB, 2016). However, such rapid development is associated with a high cost of natural resources and the environment (Chen, 2016). In 2015, China's primary energy consumption ascended to 3 billion tons oil equivalent, accounting for 23% of the global total (BP, 2016). The proved reserves of fossil fuels in China at the end of 2015 are supposed to be merely able to sustain local production for 31 years (BP, 2016). As China keeps up its fast pace of industrialization, the growing demand for the limited energy resources is becoming a major challenge. Meanwhile, energy use is the largest source of anthropogenic emissions of carbon dioxide, which, along with other greenhouse gases, is believed to be the major cause of global climate change (Quadrelli and Peterson, 2007). As the world's largest emitter of carbon dioxide, China is under enormous pressure in international climate change negotiations. On November 4, 2016, the world's first comprehensive climate agreement of the Paris Agreement entered into force (UN, 2016). In order to achieve the long-term temperature goal set out in Paris, it is urgent for China, as a leading player among the contracting parties, to explore sustainable development patterns of low energy consumption and low carbon emission.

Extensive policies for sustainable energy use have been formulated in China, such as the Medium and Long-term Development Plan for Renewable Energy, the Energy Development Strategy Action Plan (2014–2020), the Thirteenth Five-year Plan for Electric Power Development and so on (Liu et al., 2013). However, these efforts only focused on the direct and on-site energy use; little attention has been paid to the indirect and off-site energy use related to trade (Li et al., 2017). For the increasingly globalized economy, various researches have pointed out that not only goods and services, but also energy use and pollution emissions can be transferred along the supply chains in inter-regional trade (Davis and Caldeira, 2010; Wiedmann et al., 2013). With the assistance of trade activities, a region or an industry sector could import energy-intensive commodities from other regions or sectors, to avoid its direct energy use. In a previous study on the energy consumption of economic sectors in China, the total amount of indirect energy consumption hidden in the domestic trade was reported in magnitude up to four times of that of direct energy consumption (Liu et al., 2012). Ignorance of the indirect energy use can therefore undermine the efforts for energy conservation and emission reduction.

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In this context, embodied energy as a combination of direct and indirect energy (Costanza, 1980), has aroused numerous attention in the academic field towards energy assessment for China (Chen and Chen, 2010; Chen et al., 2010; Zhang et al., 2013; Zhou, 2008). Tang et al. (2016) carried out an evaluation of energy embodied in China’s external trade, and found that the embodied energy exports of China approximately tripled between 2002 and 2007. Zhang et al. (2016) turned their attention to China’s domestic trade, and provided detailed analyses on regional embodied energy transfers induced by different final demand categories. Moreover, at the regional level, Zhang et al. (2015) investigated the embodied energy flows among China’s 30 provinces, and identified Zhejiang and Henan provinces as the largest embodied energy importer and exporter, respectively. Sun et al. (2017) pointed out that half of inter-regional trade of embodied energy in China was induced by the final demand in Yangtze-River-Delta, Pearl-River-Delta and Jing-Jin-Ji. At the sectoral level, Hong et al. (2016) estimated the embodied energy use of the construction industry in China, and demonstrated that this sector contributed 29.6% to total national energy consumption. A similar ratio of 33.3% was reported in a recent study (Zhang et al., 2017). Those embodiment studies have greatly deepened people’s understanding of the overall energy performance of China.

However, to properly address the energy problems in China, the literature list of embodied energy analysis for Chinese economy is still very short. Particularly, the investigation with the most recent statistics is in great need, in view of the new challenges met by China in current world. The input-output analysis (IOA) offers an efficient way to track the complex relationship between sectors and regions, and is therefore regarded as the major method for embodied energy calculation. The economic input-output table is the essential data in this method. In December 2015, the input-output table of Chinese economy 2012 is released as the sixth national basic table, which is the most recent available data (NBS, 2015). Compared with previous tables, the newest table records many changes in China during the period of rapid economic development. For example, a structural change in the economy is witnessed with an increased share of the tertiary industry in GDP, from 38.7% in 2007 to 44.8% in 2012, which is viewed as a main source of change in energy use (Rose and Chen, 1991). Hence, the target of the present work is to present a detailed energy inventory for Chinese economy with the latest data, and to systematically reveal the energy use embodied in production, consumption and trade.

Different from previous researches adopting the equal intensity assumption of imports, this paper concretely accounts for the differences of the production technology between domestic and foreign sectors (Chen et al., 2013). Limited by available data, the existing studies have generally assumed that imported products have the same embodied intensities as the domestic ones (Lindner and Guan, 2014). However, there is a large gap between China and foreign countries in economic structure and production technologies, which are the major determinants of embodied intensity. For example, as revealed by our recent study on global energy use, the embodied energy intensity of the machinery industry in China is shown to be twice that of the world average level (Chen and Wu, 2017). Therefore, it is necessary to differentiate the embodied energy flows from different economies at different scales. Next, energy resources are essentially natural resources, and cannot be simply taken as economic commodities. Most embodiment studies focus on the technical consumption of these commodities. There are many different ways of technical consumption of primary and secondary energies, such as the combustion of coal to provide heat, the conversion of wind kinetic energy to provide power, and the utilization of electricity. However, energy resources belong to the environmental system, which provides the economic system with natural resources as exogenous and external support for economic development (Odum, 1996). These resources’ initial use by the economic system occurs when they are exploited from the earth, because that is when the resources are removed from the environ-
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