Applied Energy 150 (2015) 296–307

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Assessing the impact of foreign content in China's exports on the carbon outsourcing hypothesis

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HIGHLIGHTS

- New assumptions of estimating emission intensity for three parts are proposed.
- More detailed disaggregation of primary and secondary energy sector is proposed.
- Multiplicative structural decomposition analysis method is proposed.
- Emissions are related with value added, but its induced by trade are different.
- Export structure was deteriorating emission intensity from 2002 to 2007.

ARTICLE INFO

Article history:
Received 25 November 2014
Received in revised form 29 March 2015
Accepted 8 April 2015
Available online 29 April 2015

Keywords:
Virtual carbon
Processing exports
DPN hybrid input–output model
Structural decomposition analysis

ABSTRACT

Much academic attention has been given to the so-called carbon outsourcing hypothesis: the idea that increased outputs and exports of energy intensive goods from developed countries, especially China, has allowed more developed countries to grow, while reducing their carbon emissions. However, most studies on the issue overlook the complexities of increasingly globalized input markets, where exports themselves are made up of inputs assembled from around other countries around the world. This study estimates such effects on China's net carbon dioxide emissions by accounting for the energy and carbon embodied in its processing and non-processing exports sectors. China's policies of carbon dioxide emission intensity aimed at reducing its carbon dioxide emission intensity are then re-evaluated. To do this we use an extended input–output framework with new assumptions for estimating energy and carbon intensities. This includes a detailed energy disaggregation for domestic use of energy, processing exports and non-processing exports. In across 32 industries, after which a multiplicative structural decomposition analysis is applied. Our findings confirm that industrial emission intensity and final demands were driving factors behind the significant downward shift in national emission intensity from 2002 to 2007. However, by considering the embodied emissions effects of imported inputs into Chinese exports, we found that the energy and resource intensive industries accounted for a smaller proportion of exports than typically understood. However, we also found that within the industry sector changes in structure contributed to an increase in energy intensity.

1. Introduction

Already the world's first largest exporter and second largest economy, much of China's population remains poor and it still sees itself as a developing country. Furthermore, Domestic energy consumption is primarily coal, and this contributes to China being the world's largest emitter of greenhouse gases, responsible for 24% of global CO_2 emissions. While the expansion of China's foreign trade has been successful at promoting economic growth and employment, it has also given rise to various pressures around trade and the environment. Among these, how to account for embodied carbon emissions in Chinese trade has become a key issue in assessing the carbon outsourcing hypothesis and equity issues relating to global climate governance In addition, If a country has become efficient as a result of exporting (or importing) energy intensive goods to (or from) other countries, then there is an argument that some or all of the energy associated with that country's imports should be attributed to the consuming country, not the one where

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http://dx.doi.org/10.1016/j.apenergy.2015.04.028
0306-2619/

those energy intensive goods are produced, as air quality deteriorates and health concerns magnify, China is increasingly seeking to control pollution.

In recent years, China's policymakers have committed to a carbon dioxide (CO_2) emission reduction target in order to reduce carbon intensity by 40–45% by 2020 based on 2005 levels from Chinese government declaration in 2009. Carbon intensity refers to the amount of CO_2 emitted per unit of Gross Domestic Production, (GDP). From 1950 to 2007, international trade increased from 5.5% to 21% of worldwide GDP [1,2]. Around 26% of CO_2 emissions has be linked to production for international trade [3]. It seems clear from this situation that policies aiming to achieve long-term sustainable development must address the environmental effects of production and consumption. However, when considering the production activities of a country or region, it must not be forgotten that these activities are connected with international trade demands. Complicating this picture further, roughly two-thirds of world trade is trade in intermediate inputs. Correctly accounting for domestic content in trade is essential in understanding world trade, global imbalances and the distribution of gains across nations [4].

Different production patterns, trade modes, energy mixes, consumer behaviors and levels of technical efficiency and economic growth affect a country's carbon emissions. All the while, energy is an essential input for growth and development in most modern economies. Carbon emissions from trade can be measured using different accounting standards and can lead to very different conclusions on virtual carbon emissions. Such distinctions extend beyond academic curiosity and have gone to the heart of questions regarding the responsibility for emissions. Meanwhile, various approaches have been discussed for sharing responsibility between producers and consumers across countries [5–10]. If nations that import more embodied emissions than they export were to become partially responsible for emissions that occur elsewhere, exporting nations might be more willing to play an active role in post-Kyoto climate commitments [11,12].

Leontief's [13] IO analysis framework can be used for estimating the energy consumption embodied in international trade. In the literature, most studies on the relationship between trade and energy can be classified into two groups: (1) The impact of international trade on energy consumption and the environment and (2) the investigation of energy consumption and the environment using the IO model (see Miller and Blair [14]; Gay and Proops [15]; Forssell [16,17]; Gallego and Lenzen [18]; Lenzen et al. [19]; Rodrigues et al. [20]; Suh and Kagawa [21]; Turner et al. [22]; Tian et al. [23]). Previous work in the first group has focused on analyzing and predicting the impact of trade on energy consumption and emissions, primarily concluding that trade structures and production technology efficiency were the most important determinants for energy consumption and trade emissions (see Battjes et al. [24]; Machado et al. [25]; Rhee and Chung [26]).

With growing concerns about different data requirements and underlying assumptions about trade-related problems, many studies use a single region or multi-region IO model to analyze trade-related emission problems [27–38]. Davis and Caldeira [39] estimated that nearly a quarter of all carbon (from fossil fuel burning) is emitted during the course of producing goods that will ultimately be consumed elsewhere. In fact, 37% of global emissions from fossil fuels are embodied in international trade, but this only explains a portion of the increase in input trade. Andrew et al. [40] calculated that approximately 40% of each region's carbon footprint was attributable, in due course, to imports. Wyckoff and Roop [41] studied the embodied CO_2 emissions of six major Organization for Economic Cooperation and Development (OECD) countries in terms of their manufactured imports. Their result of embodied carbon emissions in manufactured imports is about 13% of the total carbon emissions of these countries.

From 2010 to 2012, China's primary energy consumption increased from 3.25 to 3.62 billion ton coal equivalents (tce), while energy imports reached 0.62 billion tce in 2011, making the nation one of the world's largest energy importers. From 2000 to 2012, the import of crude oil increased from 70.27 to 220.67 million tons. Due to the rapid development of China's economy, the nation directly imports a great deal of energy while also indirectly exporting and importing a substantial amount of energy through the trade of other products, particularly high energy-consuming products (see Fig. 1). China exports a number of high energy-consuming products, which are considered indirect energy exports. In 2012, China exported 55.73 million tons of steel products, 8.51 million tons of plastics and 323.97 billion diodes and semiconductors.

The biggest advantage of IO model is its ability to estimate both the direct and indirect effects of final demands by accounting for the inter-industry flow of the production process, and inputs include both primary and intermediate inputs. However, China's exports are quite different from that of outputs used domestically due to processing exports use much more imported input than non-processing exports [42]. Despite the many efforts to use the IO model in studying energy and emissions embodied in trade, the different trade modes and their specific impact on trade-related energy consumption has tended to vary significantly in the literature. In China, the processing trade is the most common trade mode, which changes the total value of exports, where processing trade were always accounting for more than 50% of the gross exports (see Fig. 2).

Processing exports refer to that component of exports which uses imported inputs for end products which will be eventually sold overseas; non-processing exports are ordinary exports where inputs are sourced domestically. V (Chen et al. [42]; see Fig. 3). Processing exports are also important as they not only as they reduce the amount of energy and carbon emissions required to produce a good domestically, they also reduce the share of value added generated from domestic producers in a nation's exports. These effects are thus likely to have a significant impact on China's energy and carbon intensity.

From 2007 to 2012, the total value of China's exports increased sharply from 1218.02 to 2210.02 billion dollars (an average annual rate of increase of 6.6%). Processing exports increased from 617.66 to 860.82 billion dollars, accounting for more than 40% of total exports. The total value of exports increased from 50% to 57% for processing exports between 1996 and 2007 with peak values in 1998 and 1999. The production for processing exports used imported intermediates more intensively than the production for normal exports or for domestic use. As this data shows, ignoring production technology differences may bias estimates of the share of domestic content in gross exports, and this bias may be especially large for firms that use more imported inputs [4]. Therefore, the analysis of the impact of processing and non-processing exports on virtual carbon becomes the key to policy design in pursuit of sustainable development.

The term 'virtual carbon' has roots in the term 'virtual water'. Coined by Allan in the 1990s [43–45], virtual water refers to the water used to produce agricultural products that are internationally traded. Virtual carbon is also a kind of concept carbon used to examine the extent to which carbon is embodied in the international trade of goods and services [46,47]. However, these studies made no attempt to separate trade modes, until Lau et al. [48] developed a pioneering input-holding-output model that explicitly distinguished between processing exports and normal exports (hereafter referred to as non-processing exports), and then some application to further investigation based on their model [49–52].