Energy Policy 111 (2017) 394–402

Contents lists available at ScienceDirect

Energy Policy

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

Promoting green productivity growth for China's industrial exports: Evidence from a hybrid input-output model

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ARTICLE INFO

Keywords:
China's industrial export
Hybrid input-output model
MLPI

ABSTRACT

Stimulated by low labor cost and loose environmental regulations, China's industrial exports have benefited significantly since joining the World Trade Organization (WTO). However, the extensive growth model in the past several decades has led to environmental degradation. China is now shifting her development pattern to a more sustainable model. Using a hybrid input-output model, this paper found that total energy coefficients fell sharply between 1997 and 2002, and 2007 and 2012. The total energy consumption and CO2 emission embodied in China's industrial exports grew by more than 100% from 2002 to 2007, with little variation from 2007 to 2012. Subsequently, Malmquist-Luenberger productivity index (MLPI) is employed to assess the green productivity growth in the sector. The decomposition of the MLPI is further conducted. This suggests that efficiency changes from 2002 to 2007 and 2007 to 2012 are lower than 1, indicating that technical change is the main contributor to MLPI. Finally, policy implications are provided with emphasis on dissemination of new conservation technologies.

1. Introduction

1.1. Background

Stimulated by low labor cost, extensive resource inputs and loose environmental regulations, China's industrial export has benefited significantly since joining the WTO. At the same time, China is faced with environmental deterioration, natural resource scarcity, and heavy dependence on foreign energy supplies. In the coming decades, China's industrial exports are very likely to face increasing resource scarcity and tighter environmental regulation. Hence, the traditional growth pattern would be unsustainable. China is now shifting towards a more sustainable growth path. During the Paris Climate Change Conference in 2015, the Chinese government pledged to cut CO2 emission per unit of GDP by 60–65% relative to 2005 levels, and peak emissions by 2030. An important aim of China's "13th five-year plan"[1] is to promote low-carbon development for energy and resources conservation.

At the time of joining the WTO in 2001, China's industrial export was 2.2 trillion Yuan as shown in Fig. 1. By 2015, it has risen to 13.8 trillion Yuan. However, cheap labor and extensive resource inputs would not be available in the future. Therefore, the rapid growth model of the past would be transitioned to a much "greener" pattern.

In 1992, the Asian Productivity Organization (APO) first proposed the concept of green productivity, which takes both economic development and environmental protection into consideration. Thus, green productivity is a good notion for sustainable development. The main purpose of this paper is to assess the green productivity growth of China's industrial export, and provide targeted policy suggestions for a "greener" transformation. Firstly, applying life cycle analysis (LCA), a hybrid input-output model is employed to calculate total energy coefficients, from which the total energy consumption and CO2 emission embodied in China's industrial exports can be calculated. Secondly, DDF method is used to measure energy and environmental efficiency, where energy and CO2 emission are from the hybrid input-output model. Finally, MLPI is calculated to assess the GTFP of China's industrial exports.

The remaining part of Section 1 provides a brief literature review. Section 2 presents the methodology and data description. Section 3 shows the results and discussions. The last section concludes the paper and provides policy implications.

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[1] Five years of plan, with the full name of five year plan outlines for the People's Republic of China national economic and social development, is an important part of China's national economic plan.

http://dx.doi.org/10.1016/j.enpol.2017.09.033
Received 3 May 2017; Received in revised form 15 September 2017; Accepted 17 September 2017

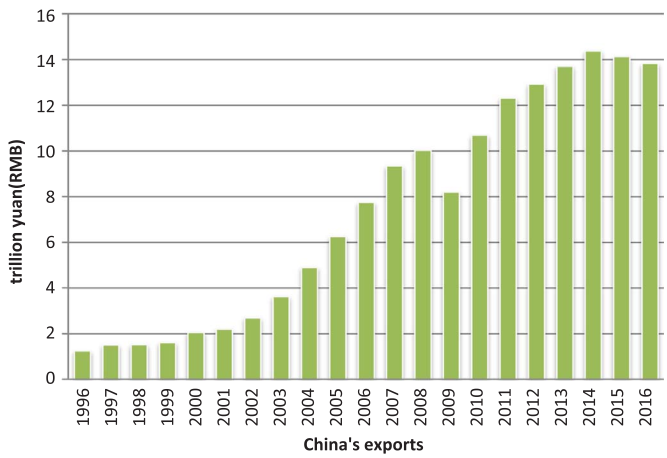

Fig. 1. China's exports growth in the past two decades.
Source: National Bureau of statistics of China

1.2. Embodied energy and emission in literature

The "flying-geese" model first promoted by Akamatsu (1935) and then expanded by Kojima (1960), Yamazawa (1990), and Ozawa (1996) revealed the transfer of primary manufacturing sectors, which are usually labor-, energy/resource- and emission-intensive, from developed to developing countries. There are lots of studies that relates to the cross-country pollution transfer (particularly in terms of the energy consumption) and carbon emissions embodied in the traded commodities. As the responsibility related to carbon emission raises controversies, the energy consumption embodied in emerging economy's exports has been a hotly discussed topic recently. Antweiler and Taylor (2001) pointed out that carbon-intensive commodities tended to be less competitive in developed economies with strict environmental regulation compared to non-carbon constrained developing economies. Weber and Matthews (2007) calculated the embodied emission in trade between the US and its commercial partners, and showed that the net emission of imports rose sharply from 1997 to 2004. Machado et al. (2001) predicted the impact of international trade on Brazil's energy consumption and carbon emissions, using a 14 sector input-output model. They revealed that carbon emissions embodied in exports was much larger than that in imports. Lenzen (1998) studied the direct and indirect energy and greenhouse gas emissions related to Australian final demand, and argued that indirect energy consumption and carbon emission cannot be neglected.

The prevailing research methods on energy consumption in relation to world trade can be generally divided into three categories. To examine the embodied energy and carbon transferred by trade, the multiregional input-output table is often employed and there are quite a few studies that use input-output analysis (IOA). The second approach is to implement the structural decomposition analysis (SDA) to identify the various driving forces of the changes in embodied emission, such as Mi et al. (2017b). The third is via statistical regression model. The main research objective can generally be energy consumption and emission relative to either total multilateral trade volume of a country or bilateral trade between two countries. The main research methods on embodied energy generally cover process analysis, input-output analysis, process-based hybrid analysis and input-output hybrid analysis etc. Chastas et al. (2017) provided a summary, and the related limitations and benefits of each method.

China is a large trading nation with total imports and exports accounting for about one-third of its GDP. International trade has played a crucial role in the boom of China's economy, and there have been lots of research in this field. Du et al. (2011) employed the input-output analysis and structural decomposition method to examine the embodied emission between China and US trade. They found that from 2002 to 2005, which is right after China joined the WTO, net emission from export increased sharply. They also showed that there was a fall in emission during the period 2005–2007, which was mainly due to a reduction in energy and emission intensity. The main driving forces of emission from exports between the two countries were total export volume. Liu et al. (2010a) pointed out that the embodied energy outflow of China's exports would impair the rational exploitation of energy and other natural resources. Their research also investigated the embodied energy in exports from 1992 to 2005 and the underlying main driving forces. Total export volume seemed to increase during the whole study periods and the rising share of energy-intensive commodity exports also contributed significantly. Lin and Sun (2010) showed that production-based emissions exceeded consumption-based emissions and create a carbon leakage in China's international trade. Electricity generation and cement production were found to be the two largest contributors to the embodied emission factor. Other studies conducted with regards to China's foreign trade include Liu et al. (2010b), Li and Hewitt (2008), and Guo et al. (2010). Previous studies related to China's exports mainly focused on the volume of embodied energy and carbon leakage, as well as the main driving forces. However, few researches covered the green productivity growth based on LCA. This paper attempts to bridge the gap and provide useful policy alternatives.

1.3. Measuring green productivity growth in the literature

The rapid growth of the world's population and economic development has led to increasingly serious environmental deterioration and the increasing shortage of natural resources. Countries around the world are shifting to a low carbon, green, and environmentally friendly development model. According to the new classical theories, the sustainability of an economy is assessed by calculating the degree of contribution made by technology advancement (measured by total factor productivity). In Solow (1956) growth model, TFP can be calculated through the regression analysis of production functions. With respect to environmental economic studies, new methods should be implemented because the traditional measure of TFP does not consider environmental side-effects. To deal with this problem, researchers have promoted several approaches. One of them is the directional distance function (DDF), which is a measurement of efficiency, and originates from the work of Farrell (1957) and Charnes et al. (1978). The DDF takes into consideration the input factors (capital, labor, energy) as well as economic output, carbon emissions, and pollutants (e.g. waste water, NOx, SO2 etc.). Thus, it can be a good efficiency measure and can further be developed to calculate the MLPI. The MLPI can be used as a good measure of green total factor productivity (GTFP) (Chen and Golley, 2014; Li and Lin, 2015, 2016 etc.). From the micro firm-level analysis to cross-country level assessment, a lot of studies have been conducted using this method (e.g. Shestalova, 2003; Timmer and Los, 2005; Zhang et al., 2011 etc.). For the research span, both multiregional panel data and cross-industry panel data have been employed to study energy and environmental performance.

2. Methodology and data

2.1. Methodology

2.1.1. Hybrid input-output model

Since Leontief (1941) developed the input-output analysis (IOA), the method has been widely used by economists. For energy and environmental studies, Bullard and Herendeen (1975) developed a hybrid approach, which has been generally employed by many researches to deal with the embodied energy and emission in international trade (e.g. Su and Ang, 2015; Shan et al., 2016, Dixit, 2017 etc.). In Miller and Blair (2009) further provided a literature review for the method.[2] Here, we provide a brief introduction and begin with a classic input-output identity $Zi + f = x$, which can also be expressed as $Ax + f = x$, where Z

[2] Details of the method presented below can be seen in Chapter 9 (energy input-output analysis) of "Input-output analysis, foundations and extensions" written by Miller and Blair.