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China's foreign trade and climate change: A case study of CO_2 emissions

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ABSTRACT

The globalization of trade has numerous environmental implications. Trade creates a mechanism for consumers to shift environmental pollution associated with their consumption to other countries. Carbon leakage exerts great influences on international trade and economy. Applying an input–output approach, the paper estimates the amount of carbon dioxide (CO_2) embodied in China's foreign trade during 1997–2007. It is found that 10.03–26.54% of China's annual CO_2 emissions are produced during the manufacture of export goods destined for foreign consumers, while the CO_2 emissions embodied in China's imports accounted for only 4.40% (1997) and 9.05% (2007) of that. We also estimate that the rest of world avoided emitting 150.18 Mt CO_2 in 1997, increasing to 593 Mt in 2007, as a result of importing goods from China, rather than manufacturing the same type and quantity of goods domestically. During 1997–2007, the net "additional" global CO_2 emissions resulting from China's exports were 4894 Mt. Then, the paper divides the trade-embodied emissions into scale, composition and technical effect. It was found that scale and composition effect increased the CO_2 emissions embodied in trade while the technical effect offset a small part of them. Finally, its mechanism and policy implications are presented.

1. Introduction

China's economic growth has been described as an economic miracle. However, the rapid economic growth has come at the expense of the environment. China's CO_2 emissions increased from 1460 million tonnes (Mt) in 1980 to 6499 Mt in 2007.Within a very short period of time, from 2002 to 2007, China's CO_2 emissions doubled and it is now believed that China is the world's biggest emitter of CO_2. The International Energy Agency (IEA) estimates China's CO_2 emissions will continue to increase to 11.4 Gt in 2030 in the scenario of BAU (Business As Usual). China faces increasing international pressure to curb its CO_2 emissions. Ma Kai, minister of the National Development and Reform Commission (NDRC), argues with the following points: first, China has low per-capita emissions; second, China contributes a small amount to cumulative emissions; third, limits on China's CO_2 emissions would hamper economic development; and finally, the production of exports should be responsible for China's CO_2 emissions, because increase in pollution in China is partly a result of the shift of manufacturing. Considering labor costs, marketing, environmental regulation and other factors, a number of firms in developed countries transferred their pollution-intensive industry to China. In 2008, China's foreign trade amounted to 2561.63 billion US dollars, surpassing Germany to become the world's second-largest trading nation, and it is likely to exceed the United States in 2010, becoming the world's largest trading nation. China has gained many benefits from its enormous trade surplus, but it is at the expense of the environment. We focus our study on CO_2 emissions embodied in international trade, since CO_2 is the main Green House Gas (GHG), accounting for about 72% of the global warming effects.

Several previous studies have established theoretical models to analyze the environmental effects of trade. Copeland and Taylor (1994, 1995) developed the North–South trade model to examine linkages between pollution and international trade. They show that free trade improves the developed countries' environment while the developing countries' environment exacerbated. In general, world trade has a negative impact on the environment. Chichilnisky (1994) believes that difference in property right creates a motive for trade. Compared to the North, the South has ill-defined property right on environmental resource, which will result in over-exploitation of resources. This leads to environmental deterioration. However, they are only theoretical analysis model and the reliability of their conclusions needs empirical test.

The first empirical work in this area was conducted by Grossman and Krueger who divided the environmental outcome of NAFTA into three effects, namely the scale effect, the composition effect and the technique effect, and such a division has been widely used in empirical studies on the trade–environment nexus. Antweiler et al. (2001) investigated how

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openness to international goods markets affects SO_2 concentrations. Combining the estimates of scale, composition and technique effect, they yield a surprising conclusion: freer trade appears to be good for the environment. Frankel and Rose (2002) use exogenous determinants of trade as instruments to isolate the effect of openness. Their results generally support the environmental Kuznets curve, which states that growth harms the environment at low levels of income and helps at high levels.

There is also an increase in number of studies regarding the role that trade plays in global CO_2 emissions. For example, Wyckoff and Roop (1994) found that, on average, about 13% of the totalCO_2 emissions of the six largest OECD countries were embodied in manufactured imports during 1984–1986. Ahmad and Wyckoff (2003) calculated the CO_2 emissions embodied in international trade of goods for 24 counties, and explored the impacts of trade-driven geographical movement of industries on global emissions. Peters and Hertwich (2008) determined the CO_2 emissions embodied in international trade among 87 countries for the year 2001. They found that globally there are over 5.3 Gt of CO_2 embodied in trade and that Annex B countries are net importers of CO_2 emissions. Nakano et al (2009) studied the issue using internationally comparable OECD data sources for 41 countries/regions by 17 industries. Their results suggest that "trade deficits" of CO_2 emissions are observed in 21 OECD countries in the early 2000s, and that for 16 countries, the magnitude of the trade deficit increased in the late 1990s. Moreover, many studies have applied input–output analysis to measure the emissions embodied in international trade, employing a single-country framework, such as Machado et al. (2001) for Brazil, Mongelli et al. (2006) for Italy, Peters & Hertwich (2006) for Norwegian, Kander and Lindmark (2006) for Sweden, Weber & Matthews (2007) for the US.

With an 8% national increase, China's CO_2 emissions accounted for two-thirds of the global CO_2 increase of 3.1% in 2007. With this, China tops the list of CO_2-emitting countries (MNP 2008). However, quantitative evaluation of the environmental repercussions of China's international trading activities has only recently begun. Hayami and Kiji (1997) studied China's energy usage and air pollutant emissions. Feenstra et al. (1998) evaluated the size of the US–China trade balance, from which economic benefits and environmental costs might be estimated. Shui and Harriss (2006) estimated that between 7% and 14% of China's current CO_2 emissions are the results of producing goods for export to the USA. Using Chinese economic input–output data and structural decomposition analysis, Peters et al. (2007) analyzed how changes in China's technology, economic structure, urbanization and lifestyles affect CO_2 emissions. They find that net trade had a small effect on total emissions due to equal, but significant, growth in emissions from the production of exports and emissions avoided by imports. You Li and Hewitt (2008) found that through trade with China, the UK reduced its CO_2 emissions by approximately 11% in 2004, whereas China–UK trade resulted in an additional 117 Mt of CO_2 to global CO_2 emissions in the same one-year period. Wang and Watson (2007) concluded that in 2004 net exports from China accounted for 23% of its total CO_2 emissions. This is due to China's trade surplus and the relatively high level of carbon intensity within the Chinese economy. Weber et al. (2008) found that in 2005, around one-third of Chinese emissions were due to the production of exports, and this proportion increased from 12% in 1987 to 21% as recently as in 2002.

However, most of the studies focused on emissions embodied in China's exports, while only a few discussed import. Some studies were concerned with China's exports and imports, but they only focused on China's one trade partner, such as the US or the UK. Furthermore, they did not identity the drivers through which foreign trade affects China's emissions. Combing the Economic Input–Output-Life Cycle Assessment (EIO-LCA) and Structural Decomposition Analysis (SDA), this paper not only estimates the change of China's CO_2 embodied in exports and imports but also identifies which factor drives the change. This paper is arranged as follows: first, we apply the EIO-LCA to estimate the CO_2 emissions embodied in China's foreign trade and divide the emissions into scale, composition and technical effect. Then, we shed light on the reasons for China's CO_2 emissions' imbalance. Finally, some conclusions are drawn and policy suggestions are made based on the analysis.

2. Methodology, procedures and data

2.1. The economic input–output-life cycle assessment (EIO-LCA)

The fundamental methodological principle to assess the carbon embodied in international trade is to multiply the CO_2 emissions factor by foreign trade figures (export and import vectors). However, the flow of CO_2 emissions from each individual category of goods cannot generally be directly observed, since the CO_2 is emitted not only from the final manufacturing process of the exported commodities but also from all processes associated with making and delivering the inputs of those commodities. A strategy for tracing the total CO_2 emissions attributed to the production of each commodity category is to employ an input–output (I–O) methodology, which can be used to map the CO_2 emissions onto final demand commodity sectors.

The input–output analysis was introduced by Leontief in the 1930s and has been applied to describe and analyze economic–environmental relationships since the 1960s.This strategy allows the environmental impact (in this case CO_2 emissions), both direct and indirect, to be explicitly determined through the matrices that express the environmental impact generated per unit of product output, valued in money, and the volume of goods produced and traded. This method has been applied to estimate the embodied energy, CO_2 emissions, pollutants and land appropriation associated with products sold in national or international markets.

The calculations are based on Economic Input–Output-Life Cycle Assessment (EIO-LCA). Life cycle assessment involves the evaluation of the relevant environmental, economic and technological implications of an object or process throughout its lifetime from creation to waste. A full life cycle assessment involves identification of environmental impacts, assessment of any hazards and improvement.

As originally formalized by Leontief in his groundbreaking work, the total output of an economy x can be expressed as the sum of intermediate consumption Ax and final consumption y

$$x = Ax + y \tag{1}$$

where A is the economy's direct requirements matrix and y is the demand for which the supply-chain output x is to be derived. The matrix A describes the relationship between all sectors of the economy. When solved for total output, this equation yields

$$x = (I - A)^{-1} y \tag{2}$$

where I is the identity matrix, in which all the coefficients are zero except those included in its main diagonal. An environmental extension of the basic input–output model can be obtained by introducing a further matrix E, which includes, for each sector, direct resources use and pollutants emission for one unit of their monetary output (Miller and Blair, 1985). The multiplication of the environmental matrix E and the well-known Leontief inverse $(I-A)^{-1}$ gives the multiplier matrix F, which shows the total (direct plus indirect) resources and pollutants intensity of each sector

$$F = E(I - A)^{-1} \tag{3}$$