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China's carbon emissions embodied in (normal and processing) exports and their driving forces, 2006–2012

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ABSTRACT

This paper constructed a time-series extended input–output dataset (2006–2012) to analyze China's carbon emissions embodied in both normal and processing exports at a detailed 135-sector level. The structural decomposition analysis (SDA) was further applied to shed light on the driving forces behind the changes in their embodied emissions over the entire time period. This empirical study confirms the importance of using the extended model for analyzing the trade-related embodiment, especially for processing exports. The embodied emissions in both normal and processing exports first increased from 2006 to 2008, then dropped during the global financial crisis (2008–2009), and then rose again after 2009. The embodied emissions as a percentage of total CO_2 emissions were quite stable before and after the global financial crisis, at around 24% over the 2006–2008 period, and 18% over the 2010–2012 period. From 2006 to 2012, emission intensity played the key role in reducing the embodied emissions (around 595 Mt CO_2), while the total export effect contributed the most to the increase in embodied emissions (around 552 Mt CO_2). Similar analysis can be applied to other indicators, such as energy, water, GHG emissions, pollutants and materials.

1. Introduction

In November 2014, the General Office of the State Council (GOSC, 2014) announced "China's Energy Development Strategy Action Plan (2014–2020)", which provided the guidelines for China's energy developments during the 12th (2011–2015) and 13th (2016–2020) Five Year Plans. As the world's largest energy consumer and CO_2 emitter, China is doing all it can to conserve energy and reduce its CO_2 emissions. At the COP21 conference recently held in Paris (30 Nov–11 Dec 2015), the countries of the world agreed to limit the temperature increase below 2 °C. However, based on the national climate actions plans (intended nationally determined contributions — INDCs) submitted by the governments before COP21, these actions will not be sufficient to achieve this target.

Over the last decade, hundreds of studies have been carried out examining how international trade affects countries' domestic emissions, or "emissions embodied in trade" and result in "carbon leakage" between developed and developing countries through trade. Since 1990, due to globalization, merchandise trade value (exports plus imports) increased from USD 7090 billion in 1990 to USD 32,732 billion in 2008 (WTO, 2015), while embodied emissions increased from 4.3 Gt CO_2 to 7.8 Gt CO_2 over the same period (Peters et al., 2011). China exported more than 20% of its total CO_2 emissions after year 2000 (Su and Ang, 2013; Sato, 2014). China's energy efficiency improvements, especially those carried out in the 11th Five Year Plan (2006–2010) period greatly helped reduce the embodied emissions in China's exports. However, the demand for China's products continues to increase. Thus it is important for China to monitor this demand and understand how it affects China's energy use and resulting CO_2 emissions.

To date there have been many studies on China's embodied emissions at the national level, such as Weber et al. (2008), Su et al. (2010), Lin and Sun (2010), Chen and Chen (2010, 2011), Yan and Yang (2010), Xu et al. (2011) and Ren et al. (2014). Most of these were based on the environmental input–output (I-O) framework (Leontief, 1970; Miller and Blair, 2009). A review of them and their estimates for China can be found in Su and Ang (2013), Sato (2014) and Hawkins et al. (2015). Some recent studies look into China's embodied emissions in both interregional and international trade, such as Su and Ang (2010, 2011), Feng et al. (2012), Guo et al. (2012), Meng et al. (2013), Chen et al. (2013), Su and Ang (2014a), Zhang et al. (2014), Liu et al. (2015a) and Zhang and Tang (2015). In addition, there have been studies which use the structural decomposition analysis (SDA) to understand the driving forces behind the embodied

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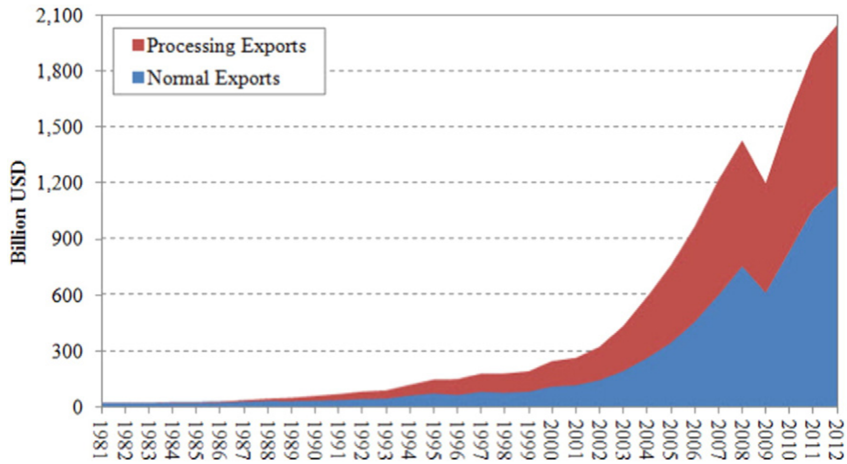

Fig. 1. China's normal and processing exports, 1981–2012.

emission changes. A review of SDA studies can be found at Su and Ang (2012a) and recent studies include Su and Ang (2012b, 2013, 2014b, 2015, 2016), Xu and Dietzenbacher (2014), Xia et al. (2015), and Zhang and Tang (2015).

There is another interesting feature in China's international exports. Fig. 1 shows that about half of China's exports are processing exports, meaning exports of end products made from imported assembling/processing intermediate inputs, and which are exempted from Chinese tariffs. The emissions embodied per dollar of processing exports are found to be much lower than emissions embodied per dollar of normal exports (Su et al., 2013). Differentiating the normal and processing exports requires the construction of the "new" extended input–output tables and models. Such analysis is far more complicated than the national and multi-regional embodied emission analysis for China. Some studies that used an extended framework include Dietzenbacher et al. (2012), Su et al. (2013), Weitzel and Ma (2014), Xia et al. (2015) and Jiang et al. (2015). Their results are summarized in Table 1. Among them, only two papers (Su et al., 2013; Xia et al., 2015) further applied the SDA analysis to study the driving forces behind the embodied emission changes in normal and processing exports.

As revealed in the report by WTO and IDE-JETRO (2011), some forms of processing trade can be found in over 130 countries. Due to data constraints, the studies shown in Table 1, generally use one or two years of data in the analysis. Currently, no study reports the time-series estimate of the embodiment in a country's normal and processing exports. In Table 1, the sector classification level is also found to vary from 28 to 104 sectors. Recent studies (e.g. Su et al., 2010) indicate that sector aggregation has significant impacts on the embodied emission estimates, especially at the sectoral level. Generally speaking, a higher sector disaggregation level is preferred in empirical studies (Su et al., 2010; Lenzen, 2013; Bouwmeester and Oosterhaven, 2013; De Koning et al., 2015). For SDA studies, it is also important to use the shorter time interval to reduce the potential impacts from temporal aggregation (Su and Ang, 2012b). Very few of the studies on China's energy and emissions use the time-series dataset in SDA analysis.

This paper is an attempt to construct time-series (2006–2012) estimates of China's embodied emissions in normal and processing exports at the detailed 135-sector level. With these estimates, we can further investigate the driving forces behind the embodied emission changes using the SDA, and also discuss the contributions to the emission efficiency improvements by sector and by export types. Section 2 of the paper explains the estimation of emissions embodied in trade using the extended I-O framework, and the driving forces behind the embodied emission changes using the additive SDA framework. The numerical results of the empirical study on China's embodied emissions from 2006 to 2012 are presented in Section 3. The final section summarizes the paper's main findings and conclusions.

2. Extended I-O framework

2.1. Emissions embodied in normal and processing exports

In order to account for processing trade in embodied emission studies, the traditional I-O table compiled by the National Department of Statistics must be disaggregated into the extended I-O table. Su and Ang (2013) further indicate that non-competitive imports assumptions should be included to avoid overestimating the embodied emissions in trade. Table 2 shows the structure of the extended I-O table with processing trade and non-competitive imports. This structure was first

Table 1
Summary of the estimates of China's CO_2 emissions embodied in processing trade.

Authors	Year studied	Number of sectors	CO_2 embodied in exports in Mt (% of total CO_2 emissions)		
			Total exports	Normal exports	Processing exports
Dietzenbacher et al. (2012)[a]	2002(a)	28	429 (12.6%)	358 (10.5%)	71 (2.1%)
	2002(b)	28	464 (13.6%)	368 (10.8%)	96 (2.8%)
Su et al. (2013)	1997	104	396.7 (12.6%)	349.0 (11.1%)	47.7 (1.5%)
	2002	104	563.6 (15.8%)	495.0 (13.9%)	68.6 (1.9%)
Weitzel and Ma (2014)	2007	42	1630 (28.3%)	1264 (21.9%)	366 (6.4%)
Xia et al. (2015)	2002	32	403 (15.5%)	329 (12.6%)	74 (2.8%)
	2007	32	1284 (27.2%)	1071 (22.7%)	213 (4.5%)
Jiang et al. (2015)[b]	2007	42	1596 (25.9%)	1309 (21.2%)	287 (4.7%)

[a] Dietzenbacher et al. (2012) utilize two different approaches, i.e. (a) separate coefficients and (b) identical coefficients, for estimating the emission coefficients of normal and processing exports productions.
[b] Jiang et al. (2015) further differentiate the contributions from the Chinese owned enterprises (COEs) and foreign-invested enterprises (FIEs) for each exporting type.