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Greenhouse gas emissions in China 2007: Inventory and input–output analysis

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ABSTRACT

For greenhouse gas (GHG) emissions by the Chinese economy in 2007 with the most recent statistics availability, a concrete inventory covering CO_2, CH_4, and N_2O is composed and associated with an input–output analysis to reveal the emission embodiment in final consumption and international trade. The estimated total direct GHG emission amounts to 7456.12 Mt CO_2-eq by the commonly referred IPCC global warming potentials, with 63.39% from energy-related CO_2, 22.31% from non-energy-related CO_2, 11.15% from CH_4 and 3.15% from N_2O. Responsible for 81.32% of the total GHG emissions are the five sectors of the *Electric Power/Steam and Hot Water Production and Supply*, *Smelting and Pressing of Ferrous and Nonferrous Metals*, *Nonmetal Mineral Products*, *Agriculture*, and *Coal Mining and Dressing*, with distinctive emission structures. The sector of *Construction* holds the top GHG emissions embodied in both domestic production and consumption, and the emission embodied in gross capital formation is prominently more than those in other components of the final consumption characterized by extensive investment in contrast to limited household consumption. China is a net exporter of embodied GHG emissions, with emissions embodied in exports of 3060.18 Mt CO_2-eq, in magnitude up to 41.04% of the total direct emission.

1. Introduction

Among the largest carbon dioxide emitters in the world (IEA, 2009), China has been considered responsible for two thirds of the global increase in anthropogenic carbon dioxide emissions of 3.1% in 2007 (Yan and Yang, 2010). Though the Chinese government has committed to cut the carbon dioxide emission per unit of gross domestic product (GDP), by 40–45% by 2020 against the 2005 level (Xinhua net, 2009), in the future the total amount of carbon dioxide emissions in China is expected to increase further, due to the projected lasting economic growth and increase in energy demand and household consumption.

Non-CO_2 emissions are also remarkably important, as illustrated by the global inventory for 2004 with CH_4 comprising 14.3% of the total anthropogenic GHG emission (IPCC, 2007). According to the Initial National Communication on Climate Change of China (INCCCC, 2004), the GHG emission inventory for China 1994 reported that China's GHG emissions in 1994 totaled 3650 million tons of CO_2 equivalent (CO_2-eq), of which CO_2, CH_4, and N_2O contributed 73.05%, 19.73%, and 7.22%, respectively. Only considering the CO_2 emissions cannot reflect the real situation and full-scale picture of China's GHG emissions, especially in terms of sectoral structure and embodiment in final demand and international trade, and inclusive account of all the main GHG emissions in China remains to be carried out with more strength consistent with recent socio-economic development.

The direct anthropogenic GHG emissions in China have been widely explored. Early in 2005, China produced 2.2 billion tons of coal which represents 37% of total coal production in the world and accounts for 75.9% and 70% of China's total primary energy production and consumption, respectively (Cui, 2007). Over the years, the coal dominated energy and power structure has instigated a large number of studies on CO_2 emissions from fuel combustion in China (e.g., IEA, 2009; Ji and Chen, 2010; Liu et al., 2007; Peters et al., 2006; Wei et al., 2007; Yan and Yang, 2010; Zhang, 2000; Zhang et al., 2009). Notably, the calculation procedure provided in Peters et al. (2006) has been followed by Xu et al. (2009) and Yan and Yang (2010) in composing Chinese CO_2 emission inventories. Meanwhile, China is the largest producer of rice grain with the world's second-largest area of rice paddies and has a flourishing livestock production with a rapid increase in livestock numbers and the largest meat and egg yields in the world. In recent years, many empirical studies have focused on the estimation of CH_4, and N_2O emissions from agricultural activities (e.g., Cai, 1999; Cao et al., 1995; Guo and Zhou, 2007; Huang et al., 2006; Liu et al., 2000; Song et al., 1996; Verburg and Denier, 2001; Wang, 2001; Xing and Yan, 1999;

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Yamaji et al., 2003; Yan et al., 2003; Zheng et al., 2004; Zhou et al., 2007; Zou et al., 2010), fugitive CH_4 emissions from coal mining (e.g., Bibler et al., 1998; Li and Hu, 2008; Yang, 2009; Yuan et al., 2006; Zheng, 2002), and total CH_4 emissions in China (e.g., EPA, 2006; Khalil et al., 1993; Wang et al., 1993; Zhang and Chen, 2010a; Zhang et al., 1999). Many concrete efforts have been made to account GHG emissions from other sources such as waste treatment (e.g., Gao et al., 2006; Hou et al., 2006; Xu, 1997). In particular, GHG emission inventories of China in 1994 (INCCCC, 2004), 2005 (Cai, 2009; Chen et al., 2010), and 2006 (Zhang and Chen, 2010b) have been provided.

Input–output embodiment analysis which facilitates a deeper appreciation of the sectoral total emission requirements in terms of both the direct, visible and indirect, hidden emission costs (Leontief, 1970; Miller and Blair, 2009), has been popular as a main frontier method for benchmarking GHG emissions embodied in final consumption and international trade, as indicated by the rapid increase in the number of studies using different input–output models for several single countries (e.g., Andrew and Forgie, 2008; Chung et al., 2009; Ghertner and Fripp, 2007; Lenzen, 1998; Limmeechokchai and Suksuntornsiri, 2007; Mäenpää and Siikavirta, 2007; Weber and Matthews, 2008) as well as multiple countries and regions (e.g., Chen et al., 2009; Lenzen et al., 2007; Liu and Wang, 2009; Peters and Hertwich, 2008; Weber and Matthews, 2007; Wiedmann, 2009; Wiedmann et al., 2007), especially in CO_2 emissions with a single country framework due to its empirical applicability (e.g., for Japan see Kondo and Moriguchi, 1998; for Brazil see Machado et al., 2001; for Denmark see Munksgaard and Pedersen, 2001; for Spanish see Labandeira and Labeaga, 2002; Roca and Serrano, 2007; Sánchez Chóliz and Duarte, 2004; for Sweden see Kander and Lindmark, 2006; for Italy see Mongelli et al., 2006; for Norway see Peters and Hertwich, 2006; for Turkey see Tunç et al., 2007).

As to China's GHG emissions, much of the existing research has applied the input–output model to perform embodiment analysis of CO_2 emissions. Prominent studies about China's CO_2 emissions were conducted by Weber, Peters and their colleagues in their series work (e.g., Guan et al., 2008, 2009; Peters et al., 2007; Weber et al., 2008). Peters et al. (2007) analyzed the effects of changes in China's technology, economic structure, urbanization, and lifestyles on CO_2 emissions. According to them, 32% of China's emission was embodied in exports and 34% avoided by imports in 2002. Weber et al. (2008) first presented a systematic study on the contribution of exports to China's CO_2 emissions during 1987–2005. Around one-third of Chinese emissions were estimated due to production of exports in 2005 (Weber et al., 2008). Guan et al. (2008) assessed the driving forces of China's CO_2 emissions from 1980 to 2030 are the household consumption, capital investment and growth in exports. Wang and Watson (2007) valuated the net exports as up to 23% of the total CO_2 emissions in China in 2004. Zhang (2010) adopted the Ghosh input–output model to investigate supply-side structure effect on production-related carbon emissions in China from 1992 to 2005. Lin and Sun (2010) reported that China is a net exporter of CO_2 emissions in 2005. Using 1997 input–output table and purchasing power parity index, Yan and Yang (2010) estimated that 10.03–26.54% of China's annual CO_2 emissions are embodied in China's exports, in contrast to only 4.40–9.05% in China's imports during 1997–2007. The CO_2 emissions embodied in bilateral trade such as China–Japan (Liu et al., 2010), China–US (Shui and Harriss, 2006; Xu, et al., 2009; Guo et al., 2010), China–UK (Li and Hewitt, 2008) were also studied.

The embodiment of all the main GHG emissions in terms of CO_2, CH_4, and N_2O, both distinctively and as a whole, in the Chinese economy by its statistical industrial sectors and final use categories have been systematically accounted by Chen and his fellows in their multi-scale ecological input–output analysis of environmental emissions and resources use: in his doctoral dissertation Zhou (2008) presented two sets of databases for embodiment intensity of GHG emissions, one for Chinese economy 1992 under the Material Product System (MPS) for planed economies of the socialist Soviet style and another for Chinese economy 2002 under the System of National Accounts (SNA) for marketing economies; Chen et al. (2010) accounted the GHG emission embodiment in Chinese economy 2005; Zhou et al. (2010) provided the GHG embodiment intensity in the regional urban economy of Beijing 2002.

The target of the present work is to present a GHG emission inventory by economic sector in 2007 covering main emission sources including energy production, fuel combustion, industrial processes, agricultural activities, waste treatment, etc., and to systematically reveal the GHG emission embodiment in final consumption and international trade of the Chinese economy, with the most recently available input–output table and relevant environmental resource statistics.

2. Methodology and data

2.1. Direct emission estimate

In this study, taken into consideration are all the three main GHG emissions of CO_2, CH_4, and N_2O, with CO_2 due to fuel combustion and industrial processes for raw chemicals, nonmetal mineral products, smelting and pressing for ferrous and non-ferrous metals; CH_4 from remarkable sources as agricultural activities (manure management, enteric fermentation, rice cultivation, field burning of plant residues), coal mining, oil and natural gas leakage, fossil fuel burning, industrial wastewater, domestic sewage and municipal solid waste treatment; and N_2O from fuel combustion, agricultural activities (manure management, planting soils, field burning of plant residues), and industrial processes.

The calculation of CO_2 emissions from fuel combustion is based on the energy consumption data and the emission factors of various fuels with different processes. The energy consumption data source from CESY (2008), with Energy Balance Sheet in 2007 in raw units, Industrial Final Energy Consumption in 2007 in raw units, and Net Calorific Values of all energy sources. Based on the quantity of various types of fossil fuel consumptions in 2007, data processing for energy-related emissions can be referred to Peters et al. (2006), with the adoption of CO_2 emission factors by IPCC (2006). In addition to the combustion of fuels, the production processes of cement, ammonia, calcium carbide, soda ash, glass, iron and steel also cause considerable CO_2 emissions. For CO_2 emissions from industrial processes, the data of industrial products can be found in CSY (2008), CIESY (2008) and other sources, and corresponding emission factors are also adopted from IPCC (2006) and Peters et al. (2006).

As to non-CO_2 emissions, previous researches about CH_4 and N_2O emission factors of different sources are reviewed, and specific emission factors are adopted to suit the Chinese situation. Since some specific emission factors are not available, the default emission factors provided in IPCC (2006) are adopted directly. As the direct calculation of some other emissions is difficult, as a preliminary approximation, appropriate assumptions associated with some recent studies for CH_4 and N_2O emissions will be reasonably made.

2.2. Input–output analysis and emission embodiment

For the input–output table in China, the basic row balance can be expressed as

$$X = AX + F - X^m \tag{1}$$