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CO_2 emissions from China's power sector at the provincial level: Consumption versus production perspectives

Soeren Lindner [a,b], Zhu Liu [a,c], Dabo Guan [d,e], Yong Geng [a,*], Xin Li [d]

[a] Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, China
[b] Department of Land Economy, University of Cambridge, Cambridge CB3 9EP, United Kingdom
[c] Graduate University of Chinese Academy of Sciences, Beijing 100049, China
[d] School of Earth and Environment, University of Leeds, Leeds LS2 9JT, United Kingdom
[e] St Edmund's College, University of Cambridge, Cambridge CB3 0BN, United Kingdom

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ABSTRACT

The Chinese electricity sector plays an important role in domestic CO_2 mitigation efforts due to its large contribution to overall emissions. However, primary energy resources used for electricity generation are not evenly distributed across the country. Such a supply and demand mismatch in reality results in large parts of electricity to be transferred from economically less developed provinces in the west to economic growth centres in the east. A literature review shows that the emissions embodied in electricity transfer within China have not been explicitly studied, although in fact they cause a shift of environmental pollution away from economically well-off provinces to resource-rich, and less developed provinces. Therefore, it is critical for policy makers to address this issue. Under such a circumstance, a bottom-up model is developed to calculate direct CO_2 emissions embodied in electricity export and import between Chinese provinces. It helps quantifying emissions from the power sector associated with both production and consumption perspectives and sheds lights on the environmental impact of regional supply and demand mismatch in China. Results show that the difference between consumption and production based CO_2 emissions from electricity sector in some provinces were higher than the total CO_2 emissions from electricity sector in Netherlands (in the case of Beijing), or as high as the total CO_2 emission from France's electricity sector (in the case of Guangdong). Based upon Chinese realities, policy implications and suggestions are made, such as how to set up appropriate emission reduction targets for electricity sector at provincial level, and the inclusion of consumption emissions in designing China's cap-and-trade mechanism. The methodology and findings may be useful for investigation of embodied emissions throughout various regions of the world.

Contents

* Corresponding author.
E-mail address: gengyong@iae.ac.cn (Y. Geng).

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1. Introduction

Due to rapid industrialization and urbanization in the last three decades China has become the largest CO_2 emitter in the world, accounting for 25% of global CO_2 emission and 20.3% of global primary energy consumption [1–3]. China plays a key role in the global effort to reduce anthropogenic greenhouse gases (GHG) emissions. The electricity sector is highly relevant for domestic energy- and climate policy because about 60% of the China's total CO_2 emissions stem from coal combustion for electricity production [4]. China's installed capacity of electricity generation has experienced rapid growth in the past decade, with a capacity increase from 380 GW (2003) to 793 GW (2008) and a total capacity of over 900 GW in 2010 [5]. In order to match the predicted annual economic growth of 8%, total electricity demand will have to increase to 4000 billion kW h by the year 2020, which requires addition of about 90 GW of new generating capacity every year [2,6,7].

The central government has acknowledged the importance of reducing GHG emissions and decided to implement a voluntary reduction target of 40–45% reduction of CO_2 emission intensity compared to the level of the year 2005 [2]. As outlined in the 12th Five-Year Plan the national target is going to be allocated to individual reduction responsibilities of provinces according to the principle of "shared but differentiated responsibilities" [1,8]. Allocation is not a straightforward task. With different economic structures and socio-economic development priorities, different provinces have different absolute and per capita emissions, as well as different drivers of emissions [9–11]. Thus, reduction responsibilities need to be decided by considering different development stages in provinces in order to reach fairness of allocation [12,13].

As we show in this paper, the emissions from the electricity sector also play an important role for allocating emissions reduction obligations at the provincial level. More specifically, two features of the electricity sector are analysed in this paper:

2. Provincial fuel mix disparity

The fuel mix used for electricity production is not equal in each province [14]. In fact, while some provinces in north China generate about 95% of electricity by coal combustion, some provinces in central China and the south produce less than 30% of electricity with coal, and instead most of it with hydro power and wind (Table 1). The distribution of primary energy fuels for electricity production in China has been well documented (see [3,5,15,16]). According to these references 58% of the hydropower generated in China stems from Sichuan, Yunnan, Guizhou and Hubei province, located in south-west China. The geographical distribution of wind power is rather uneven as well: Inner Mongolia ranks first with an installed capacity of 1.5 GW, followed by Jilin, Liaoning and Hebei, all locating in north China. By the end of 2008 total cumulative installed wind power was 12.5 GW and it is planned to make wind power the third largest power resource after coal and hydropower in 2020. Eleven nuclear power plants with a generation capacity of 8.6 GW and 62.86 TW h power output were installed at the end of 2008. These are all located in the fast-growing eastern-coastal provinces in Guangdong, Zhejiang and Jiangsu. Due to rapid growth in electricity demand and power structure adjustment, the Chinese government has recently announced to speed up nuclear development. 450 billion RMB will be invested for installing 40 GW of new capacity until 2020 [3]. Solar energy and biomass, as well as natural gas power plants (gas currently contributes less than 1%), only play a minor role in electricity generation in China.

2.1. Regional supply and demand mismatch

China has a domestic mismatch of electricity demand and supply [17]. Major primary energy sources (i.e., coal and hydro) for electricity generation are located in economically less developed regions, whereas the electricity demand is concentrated in fast growing regions along the eastern coast. Coal is concentrated

Table 1
Grouping of provinces according to fuel mix.
Source: NBS, 2009.

Region	Provinces with more than 90% of power generation by fossil fuels	Provinces between 50 and 80% of power generation by fossil fuels	Provinces with less than 50% of power generation by fossil fuels
Central China		Henan, Hunan, Jiangxi, Chongqing	Hubei, Sichuan
Eastern China	Shanghai, Jiangsu, Anhui	Fujian, Zhejiang	
North-east	Jilin, Heilongjiang, Liaoning		
North-west	Ningxia, Shaanxi	Gansu, Xinjiang	Qinghai
South China		Guizhou, Guangdong	Yunnan, Guangxi
North China	Shanxi, Shandong, Beijing, Inner Mongolia, Tianjing, Hebei		