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Regional household carbon footprint in China: a case of Liaoning province

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ABSTRACT

With the rapid development, household energy consumption has become major driving force inducing higher energy consumption and corresponding carbon emissions. As the largest developing country, China's household energy consumption has grown quickly over the last two decades due to improved living standards and rapid urbanization. Thus, it is necessary to study household carbon footprint and identity the key driving forces so that appropriate mitigation policies can be raised. Under such a circumstance, this paper aims to uncover household carbon footprints in Liaoning province so that household carbon footprint characteristics and driving forces for the years of 1997, 2002 and 2007 can be quantified. Our results show that urban households have higher carbon footprints than their rural counterparts and indirect carbon footprints are higher than direct carbon footprints. Also, population size and per capita consumption are the main factors to contribute the increase of household carbon footprints, while carbon intensity had negative effect on the increase of household carbon footprints. Finally, we provide our policy recommendations in order to help local decision makers prepare their low carbon development strategies. The research outcomes from this study can also facilitate decision-makers in other provinces to mitigate the overall carbon emissions from their household sector by considering their local situations.

1. Introduction

Energy consumption is a global issue due to decreasing fossil-fuel reserves and increasing air pollution emissions and recent attentions on climate change (Revesz et al., 2014). In order to reduce the overall energy consumption, both demand and supply perspectives should be considered, particularly from household consumption since more households continue to increase their incomes and thus have more energy demand. In the late 1980s, researchers began to pay attentions on the impacts of household energy consumption (Schipper et al., 1989; Vringer and Blok, 1995). Later on, more studies confirmed that household energy consumption played a dominant role in energy consumption and corresponding carbon emissions. For example, household energy consumption accounted for 75% of total energy consumption in India (Pachauri and Spreng, 2002), more than 80% in the United States (Bin and Dowlatabadi, 2005), and 52% in the Republic of Korea (Park and Heo, 2007). At the global level, household energy consumption induced 72% of global greenhouse gas emissions (Hertwich and Peters, 2009). Under such a circumstance, it is critical to study how to mitigate the overall carbon emissions from household sector.

China is the largest developing country and has experienced fast urbanization during the last two decades. Such a rapid development induced higher household energy consumption, leading to that primary energy consumption from households increased from 987.03 million tons of coal equivalent (Mtce) in 1990 to 3617.30 Mtce in 2012 (Li et al., 2012; Liu, 2009; Parikh and Shukla, 1995; Sun

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et al., 2014). Since China has a coal-dominated energy structure, this means that such large energy consumption also resulted in more carbon emissions, putting a lot of pressures on China's efforts for responding climate change. Furthermore, with increasing household incomes, a lot of Chinese residents spent more money on improving their life quality, such as purchasing energy intensive products (such as purchasing imported luxurious products and private vehicles with higher energy consumption and emissions) and enjoying high carbon life style (such as taking overseas travel and using air conditioners for longer time) (Hubacek et al., 2009; Tian et al., 2014). One recent study revealed that household consumption accounted for more than 40% of total carbon emissions from primary energy utilization in China during the period of 1992–2007 (Liu et al., 2011), while another study revealed that CO_2, SO_2, COD, NOx, and ammonia-nitrogen emissions from household consumption accounted for 42.17%, 33.67%, 33.11%, 28.83% and 30.38% of the total corresponding national emissions in China, respectively (Liu and Wu, 2013). Under such a circumstance, it is necessary to uncover household energy consumption patterns and corresponding carbon footprints so that appropriate energy saving and greenhouse gas emission reduction policies can be raised for household sector.

Carbon footprint is one widely accepted method on assessing both direct and indirect carbon emissions, caused by an activity or product during its lifecycle (Wiedmann and Barrett, 2010). Direct household carbon footprint is defined as the carbon emissions caused by direct use of energy (coal, gas, oil, electricity and heat) for lighting, cooking, heating and cooling, and transportation (Dong and Geng, 2012). One special note is that emissions from electricity and heat are usually regarded as indirect emissions in regional carbon emission studies because the emissions are caused during the production process and not the final consumption process. However, it is usually regarded as direct carbon footprint in household carbon footprint studies because it is an important household energy use and quite different from other expenditures such as food, clothes and buildings (Bin and Dowlatabadi, 2005; Wei et al., 2007). Indirect household carbon footprint is defined as those embodied carbon emissions associated with the production of all other commodities consumed by households, i.e. emissions from the manufacture of furniture, food, clothes, services, etc. (Wier et al., 2001). From academic point of view, many related studies have been undertaken during recent years, focusing mainly at the national level (Donglan et al., 2010; Reinders et al., 2003; Zhu et al., 2012), at the city level (Gu et al., 2013; Yang et al., 2013; Zheng et al., 2011) and at the regional level (Qu et al., 2013a). Among all of them, several studies revealed that indirect household carbon footprint is higher than direct household carbon footprint (Feng et al., 2011; Wei et al., 2007; Zhang, 2013), and urban household carbon footprint is more than rural household carbon footprint (Fan et al., 2012; Wang and Yang, 2014). Also, in order to quantify the key factors on inducing higher household carbon footprint, decomposition analysis method has been widely applied, in which population increase, urban area expansion and per capita household consumption increase are key factors contributing to more indirect carbon emissions, while the decrease of carbon intensity mitigates the growth of carbon emissions (Liu et al., 2011; Munksgaard et al., 2000). However, few studies focused on one province in a developing country that is experiencing both industrialization and urbanization, as well as on the comparisons between direct and indirect household carbon footprints and also between urban and rural households within one province (Dai et al., 2012; Liu et al., 2013). Consequently, it is crucial to initiate such a study so that complete carbon footprint profile at one provincial level can be presented. Such research findings can facilitate those provincial decision-makers for preparing rational mitigation policies on household sector by considering the regional situations.

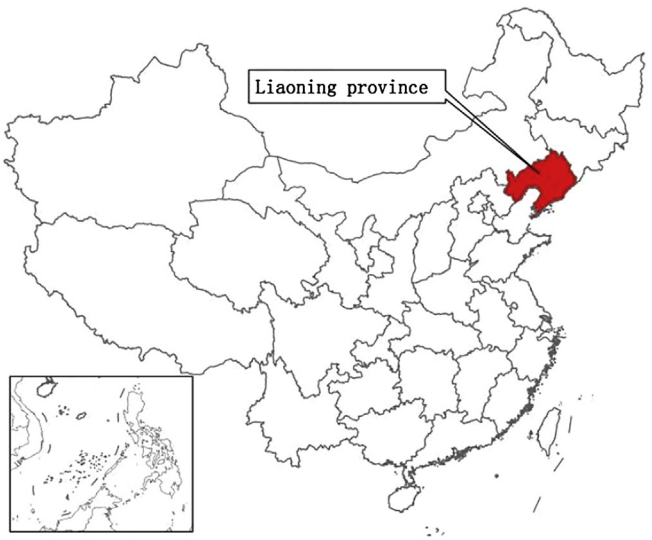

Fig. 1. The location of Liaoning province in China.

Under such a circumstance, this paper aims to study household carbon footprint at the provincial level by employing a case study approach. Liaoning Province in the northeastern part of China was selected as the case study region. Fig. 1 shows its location in China. The total area of this province is 148,000 km^2, with a total population of 43.9 million in 2013 (including 27.2 million urban residents and 16.7 rural residents). This province is one of China's most heavily industrialized provinces and has many state-owned enterprises (Dong et al., 2013a). It has played a key role on promoting China's industrialization. To date, this province is one of the leading provinces in terms of economic development and its total GDP reached 2860 billion RMB (1 USD = 6.2 RMB) in 2014, which means that provincial per capita GDP reached 10,518 USD, much higher than 7485 USD, the national per capita GDP in 2014. However, such rapid development also induced higher carbon emissions. According to Li et al. (2012), Liaoning's carbon emission experienced an annual increase rate of 5.2% from 1985 to 2009, particularly with an annual increase rate of 7.6% from 2005 to 2009, bringing a great pressure to the provincial government to response climate change. In order to achieve low-carbon development, the Liaoning provincial government initiated several innovative projects, such as cleaner production audits (Geng et al., 2010a), eco-industrial parks (Geng et al., 2014), integrated watershed management (Geng et al., 2010b), etc. More recently, in order to respond China's continuous attention on carbon emission reduction, the provincial government of Liaoning is actively promoting carbon emission reduction. In this regard, the Liaoning provincial government has released regional regulations on energy saving and emission reduction and also is responsible for enforcing related national regulations in the territory of Liaoning.

At the national level, National Development Reform Commission (NDRC, a ministry leveled agency in charge of all planning issues) initiated its first national low carbon development demonstration projects in August 2010, in which five provinces (Liaoning, Hubei, Yunnan, Guangdong and Shaanxi) and eight cities (Chongqing, Baoding, Tianjin, Nanchang, Hangzhou, Xiamen, Guiyang and Shenzhen) were chosen for provincial or municipal level demonstration (Dong et al., 2013b). This means that Liaoning province is the only province in the northeast China region for such a demonstration project. Consequently, the Liaoning provincial government initiated its overall low carbon efforts. Many of such

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