Journal of Cleaner Production xxx (2014) 1–12

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Applying quantile regression and Shapley decomposition to analyzing the determinants of household embedded carbon emissions: evidence from urban China

Liyan Han [a], Xinkuo Xu [a,*], Lu Han [b]

[a] School of Economics and Management, Beihang University, Haidian, 100191 Beijing, China
[b] School of Management Science and Engineering, Central University of Finance & Economics, Haidian, 100191 Beijing, China

ARTICLE INFO

Article history:
Received 31 March 2014
Received in revised form
5 July 2014
Accepted 23 August 2014
Available online xxx

Keywords:
Embedded carbon emissions
Household
Mitigation policies
Urban China
Quantile regression
Shapley decomposition

ABSTRACT

As CO_2 emissions differ in households with different characteristics, mitigation policies still address the contributions of these characteristics and their effects on specific households. Using a representative resident survey in urban China, this paper compares how household characteristics differ in their associations with household embedded carbon emissions (HECEs) at different levels by quantile regression; then, this paper analyzes the contributions of these characteristics by Shapley decomposition. The findings include the following: (i) household income is the most important contributor to the difference of HECEs, and its positive effect increases as HECEs rise; (ii) the use of wealth has different effects on HECEs because household housing ownership and deposits contribute little to HECEs, but the positive effects of household car ownership contribute 25.8%; (iii) young people and children will emit more HECEs than adults; the employed emit more than persons who are unemployed or retired; (iv) education increases HECEs overall but mainly at the low quantiles; the negative effect of the marriage increases as HECEs rise; (v) income, car ownership, marital status, size and constitution of households with high HECEs should be addressed to reduce the inequality of HECEs. Indeed, education on the low-carbon concept is another way forward.

1. Introduction

The need for the household sector to reduce its energy use and CO_2 emissions has been emphasized recently in the debate on climate change policy, as a major part of the energy requirement and related carbon emissions in an economy is allocated to the household sector. Indeed, the proportion of this allocation for households is more than 80% for the U.S. (Bin and Dowlatabadi, 2005), 75% for India (Pachauri and Spreng, 2002), and approximately 74% for the UK (Baiocchi et al., 2010) (Hamamoto, 2013). The urbanization and the increasing domestic demand in China, which is the economy with the most carbon emissions, continuously increase the carbon emissions from households, and the embedded carbon emissions from urban households account most of the increase.

An understanding of the relevant factors to household CO_2 emissions is necessary to achieve effective climate policies aimed at reducing emissions (Honjo and Fujii, 2013). The literature on this subject can be divided into two categories. The first category consists of analyzing the differences in the carbon emissions among households in different groups. By dividing households into different income groups, Golley and Meng (2012) survey the per capita direct and indirect carbon dioxide emissions of Chinese urban households. In addition, the difference and variations of household energy consumption and the related CO_2 emissions in different income groups are discussed with other countries' data (e.g., Rosas et al., 2010; Andrich et al., 2013). The differences among household CO_2 emissions also exist in groups divided by more factors than income, for example, Duarte et al. (2012) survey the differences in the CO_2 emissions of groups classified by urban or rural location, education, social class and so on. For Chinese households, Wang and Shi (2009) observe the difference in consumption-induced CO_2 emissions across different regions

Abbreviations: HECEs, household embedded carbon emissions; per capita HECEs, household per capita embedded carbon emissions; OLS, ordinary least squares.

* Corresponding author. School of Economics and Management, Beihang University, Xueyuan Road, Haidian Distinct, 100191 Beijing, China. Tel.: +86 15910653325.
E-mail address: xxkuo@126.com (X. Xu).

http://dx.doi.org/10.1016/j.jclepro.2014.08.078
0959-6526/

during 1995–2004. Zhu et al. (2013) study the spatial and temporal variations in residential energy consumptions and air pollutant emissions in China, which are found to be driven by the ambient temperature and household income. Furthermore, Zhang et al. (2014b) estimate the carbon emissions from rural energy consumption in various regions of China, and they find significant regional disparities and similarities in the emissions due to the regions' climates and economic development levels. By grouping the provinces in mainland China into eight economic regions, Tian et al. (2014) estimate the sectional and regional CO_2 emissions in these regions and find that income growth and changes in consumption patterns are the main driving factors. An urban or rural location is also found to be the main determinant of residential direct or indirect carbon emissions in China (Fan et al., 2013; Wang and Yang, 2014).

According to the different household carbon emissions in groups with different characteristics, mitigation policies can both target the groups with high carbon emissions and be implemented more specifically according to the characteristics of the groups. However, the differences between carbon emissions in households in the same group are ignored when analyzing household carbon emissions only by groups, though assigning a household to multiple groups with different household characteristics can alleviate this problem to a certain extent. As a result, uniform migration policies will induce unequal results among households in the same group. To solve this problem, a regression approach is applied to depict the relations between household carbon emissions and multiple household characteristics in a single model.

Using the ordinary least squares (OLS) regression approach, scholars have studied the relationships between different types of household carbon emissions and household characteristics with the micro survey data from several different countries. Using their respective survey data, Baiocchi et al. (2010), Büchs and Schnepf (2013) and Brand et al. (2013) estimate the associations between household socioeconomic factors and household direct or indirect CO_2 emissions in the United Kingdom. Wilson et al. (2013) find that the household size, income, community zone, age, and marital status are all statistically significant predictors of the direct GHG emissions for 1920 respondents in Canada. Furthermore, Graham et al. (2013) investigate the way climatic and socio-demographic characteristics affect household CO_2 emissions in Australia. Golley and Meng (2012) survey the impact of household demographic characteristics on the per capita direct and indirect carbon dioxide emissions of Chinese urban households. Liu et al. (2013) survey the impact of household characteristics, including income, size, age, education and lifestyles, on the carbon emissions of rural households in North China. Lee and Lee (2014) survey the influence of the urban form on GHG emissions in the U.S. household sector based on their analysis of the relationship between household characteristics and GHG emissions. In addition, Sun et al. (2014) adopt the Tobit and OLS models to explore the factors that influence different types of direct energy expenditure in China; they find that urbanization and its effect on residential lifestyles are the main driving factors.

As the OLS regression approach makes a great contribution to understanding the significant factors that affect the carbon emissions for each household, there are still two shortcomings for mitigation policies. Firstly, the OLS regression approach as a type of mean reversion treats the effects of each household characteristic as the same with respect to the carbon emissions from all households. However, it seems very unlikely that high-carbon households and low-carbon households have the same sensitivity to changes in the household characteristics. Secondly, the OLS regression approach cannot show the size of the contributions of household characteristics to the differences among household carbon emissions. Nevertheless, the effect of one household characteristic is modified by the characteristic's dimension as well as by its range and distribution.

We are motivated by previous studies to revisit the subject by employing quantile regression to examine how household characteristics affect household embedded carbon emissions (HECEs) from representative residents in Chinese cities. The application of quantile regression will uncover the differences in the effects of the probable determinants, which have been advanced by previous studies, to HECEs at different quantiles. Moreover, we use the Shapley decomposition method to discern the contributions of the determinants to the differences between the HECEs. The combination analysis can tell us which determinants are important to HECEs and which groups they affect. The methodology and its findings are useful for policy makers to identify the households that need to cut their emissions and the way to make them do so.

The rest of the paper is structured as follows: Section 2 introduces the survey data used in this paper and the approach to calculating HECEs. In addition, Section 2 details how to apply the methodologies of quantile regression and Shapley decomposition to analyze the factors that affect HECEs. Section 3 reports the effects of household characteristics on HECEs at different quantiles, and these effects are the results of the quantile regression compared with the results of the OLS regression. Section 3 also reports the contributions of the determinant variables, which are the results of Shapley decomposition. Then, Section 4 discusses the implications by comprehensively analyzing the results of the quantile regression and Shapley decomposition. Section 5 concludes.

2. Data and method

2.1. Data sources

The survey data we use in this paper come from the Consumer Finance Survey performed in 2011 by the China Center for Financial Research (CCFR), Tsinghua University. The contents of this survey contain household demographic characteristics, the quota of household income and categories of spending, household financial characteristics and some other socio-economic characteristics of households. The survey has considered the differences of the cities the sample households live in, which are about the size, and the cities' economic development levels, saving levels, consumption levels, and consumption conditions. The 5772 samples selected cover the representative households in urban China, who live in 24 cities all around the country, including Beijing, Jinan, Shenyang, Shanghai, Gguangzhou, Chongqing, Xian, Wuhan, Baotou, Jilin, Xuzhou, Nanchang, Haikou, Kunming, Urumqi, Luoyang, Shuozhou, Yichun, Anqing, Quanzhou, Guilin, Panzhihua, Baiyin and Zhuzhou. Table 1 shows the distribution of household locations, and Table 2 shows the distribution of household annual after-tax income. In addition, Table 3 shows the population share and the summary statistics of the household per capita income and consumption for the different cities in the survey.

Table 1
The distribution of household locations.

Region	Proportion of households (%)
Northeast China	10.04
North China	11.11
East China	26.02
South China	9.40
Central China	10.18
Northwest China	22.71
Northeast China	10.54