



## Heterogeneous impacts of households on carbon dioxide emissions in Chinese provinces



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### HIGHLIGHTS

- Spatial heterogeneous impacts of households on CO<sub>2</sub> emissions are analyzed.
- Clarify the responsibility of CO<sub>2</sub> emissions reduction in Chinese provinces.
- Unequal impacts on CO<sub>2</sub> emissions among different income households are identified.
- The Chinese provinces demanding high-income household specific policies are listed.
- Key sectors for shrinking unequal impacts of households on emissions are identified.

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### ABSTRACT

As unequal carbon dioxide emissions exist among households with diverse consumption patterns resulting from different income and spatial contexts, the same carbon emission reduction policies for households will go against the principle of social equality. Though a lot of attention has been paid to estimating the emissions from different income households in previous literature, the full impacts of households on carbon emissions of production sectors through changing income are not well captured. Therefore, for better supporting the fair but different carbon emission reduction policy design for households and provinces, this paper investigates the unequal impacts of households on total emissions and sectoral emissions by specifically taking into account the heterogeneity among different income households in different provinces under the empirical context of China. A combination of semi-closed input-output model and hypothetical extraction method is used here to quantify the unique effect of each income class of households. We find five aspects of seriously unequal impacts of different income households among Chinese provinces: (1) the more responsibility for reducing carbon emissions should be allocated to Shandong, Hebei, Jiangsu, Inner Mongolia, Henan, Guangdong, Shanxi and Liaoning; (2) more unequal impacts on total provincial emissions between urban and rural households in Beijing, Tianjin, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Zhejiang, Guangdong and Chongqing; (3) unequal impacts of urban (or rural) households on total provincial emissions exist among provinces; (4) unequal impacts of households on total provincial emissions exist among income classes and among provinces; (5) unequal impacts of urban households on emissions of sectors exist among provinces. These pictures of the inequality can provide more evidence for making fair but distinguishing carbon emission reduction policies for different income households across Chinese provinces.

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## 1. Introduction

The growing household income, as one of the important factors affecting household energy consumption and carbon emissions [1], drives a dramatic increase in the household consumption and subsequently carbon emissions, especially in China. For example, in China, with an obvious nominal increase rate of 78.2%<sup>1</sup> in the household income, household direct energy-related and indirect consumption-embedded emissions had increased by 28.8% during 2007 and 2012 [2]. Serious inequality of household income exists not only among households in the same province in China, but also among households in different provinces, as shown in Fig. 1. A large deviation exists between provincial income level and national average income level<sup>2</sup> [3]. On the other hand, the consumption expenditure and consumption structure also exhibit serious disparity among different provinces. Such kind of heterogeneity might lead to very unequal household carbon emissions among households with different income levels and among households in different provinces. Previous literature, such as Liu et al. [4] and Wiedenhofer et al. [5], has sketched a picture of unequal household emissions among different income households in the whole China. However, the differences in the income and consumption structure may aggravate the inequality of household carbon emissions across different provinces [6]. In this regard, it might be promising to evaluate and compare the impacts of consumption on carbon emissions among different income households in different provinces so as to provide evidence for designing fair but distinguishing carbon emission reduction policies. Consequently, in this study we pay specific attention on investigating the nexus between household consumption and carbon emissions among different income households in different provinces, and further answering how much disparity exists in their contribution to total emissions and sectoral emissions. These pictures of inequality are informative for policymakers to explicitly make consumption-based carbon emission reduction policies and allocate carbon dioxide reduction quotas fairly among poor, middle and rich households and among different provinces.

Lots of previous literature has investigated direct and indirect emissions from households at provincial level [6–8]. Though the evident disparity of household carbon emissions among provinces has been revealed [6], the quantified changes in carbon emissions from production sectors along with changing household income are generally neglected. It is thought that a two-way relationship on emissions exists between production sectors and households (see Fig. 2), including (1) households affect the productive activity through their changed consumption which will further affect the emissions of production sectors; and (2) changing consumption will alter the revenues of production sectors, which in turn acts on the income and consumption of households, and therefore changes household emissions. Household indirect emissions calculated by existing methods in the previous literature, including input-output model (IOM), life cycle assessment (LCA), consumer lifestyle approach (CLA) and emission coefficient method (ECM) [1], can only reflect the first channel from households to production sectors, namely household consumption change resulting in the change of energy for producing these consumed goods and services, and consequently the carbon emissions. However, the feedback from production sectors to households, namely sectors affecting consumption through the compensation for employees and further affecting direct and indirect household emissions, is always neglected. Therefore, we should also dig deep into more information on the impact of households on emissions considering the income-consumption relationship

between households and production sectors.

Based on the research background and literature gap, this paper aims to provide comprehensive insights for making fair but different carbon emission reduction policies for different income households and different provinces, according to the impacts of households on provincial total carbon emissions and emissions of production sectors. To that end, the following two research works are accomplished in this paper: (i) measure the unequal impacts of household consumption on carbon emissions across different income households in each province; (ii) measure the unequal impacts of household consumption on carbon emissions across different provinces. To take the two-way relationship into account and fulfill this analysis, we use the semi-closed IO model to analyze the interdependent nexus between sectors and households through moving the household consumption and compensation of employees from the final uses and primary inputs to the intermediate uses in the IO table. Meanwhile, as we have different income households in the semi-closed IO table, we apply the hypothetical extraction method to investigate the relative importance of household consumption structure of each income level on carbon emissions through hypothetically extracting the household consumption of each income level in the IO table.

The remaining parts of this paper are structured as following: Section 2 summarizes some previous literature on household consumption, energy consumption and carbon emissions. Section 3 describes the semi-closed input-output model, hypothetical extraction method and data. Section 4 presents the main results of unequal impacts of different income household consumption on carbon emissions in different provinces. Conclusions and policy implications are presented in Section 5.

## 2. Literature review

Household consumption has become one of the most popular topics in environmental problems [9]. Household energy consumption and carbon dioxide emissions are not only coming from consumer activities related to direct energy use (such as car use, heating and cooling, etc.), but also related to consumption patterns (food, clothing, residence, etc.) [10–12]. Household consumption has a positive relationship with energy consumption and carbon emissions [4,8,13–16]. And estimating direct and indirect energy consumption and carbon emissions is common in previous literature, such as Bin and Dowlatabadi [17], Brizga et al. [18], Das and Paul [19], Zhang et al. [1], Long and Yoshida [20], and Allinson et al. [21].

Household income has been identified to be one important household characteristic affecting direct and indirect household emissions in previous literature [1,10,22]. With household income increase, energy requirements and carbon emissions will intend to increase due to the increasing consumption [1,23]. Duarte et al. [24] applied a social accounting matrix (SAM) to analyze the relationship between the household consumption pattern and CO<sub>2</sub> emissions in Spain, and found an upward trend existing in consumption emissions as the income rose, and total carbon emissions from the highest income households were above five times higher than those from the lowest income households. Shammin and Bullard [25] estimated direct and indirect carbon emissions from different income households, and assessed effects of cap-and-trade policies on the costs of reducing GHG emissions of different income households. They showed that carbon emissions from the lowest income households were 10,414 pounds of carbon per year, and emissions from the highest income households were 40,751 pounds of carbon per year. Wiedenhofer et al. [5] used a carbon-footprint-Gini coefficient and estimated household carbon footprints across different income households in China, and found the serious inequality in the distribution of household carbon footprints. They calculated the average Chinese household footprints were 1.7 tCO<sub>2</sub>/cap, and household footprints from the highest and lowest income urban households were 2.4 and 0.8 tCO<sub>2</sub>/cap, respectively.

<sup>1</sup> The nominal growth rate of urban per capita disposable income was 78.2% between 2007 and 2012, while the nominal growth rate of rural per capita net income was 91.2% during this period [3].

<sup>2</sup> The national average annual household income for urban and rural households was respectively 23,392 and 8588 CNY/person in 2012.

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