Science Bulletin 64 (2019) 351–353

Contents lists available at ScienceDirect

Science Bulletin

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

Science Bulletin
www.scibull.com

News & Views

The impact of income on household CO_2 emissions in China based on a large sample survey

Jiansheng Qu [a,b,*], Lina Liu [a], Jingjing Zeng [a,b], Zhiqiang Zhang [a], Jinping Wang [a,b], Huijuan Pei [a], Liping Dong [a], Qin Liao [a,b], Tek Maraseni [a,b,c]

[a] Information Center for Global Change Studies, Lanzhou Information Center, Chinese Academy of Sciences, Lanzhou 730000, China
[b] Key Laboratory of Western China's Environmental Systems (Ministry of Education), College of Earth and Environmental Sciences, Lanzhou University, Lanzhou 730000, China
[c] University of Southern Queensland, Toowoomba, Queensland 4350, Australia

Since reform and opening-up, China's energy consumption has been soaring largely due to the country's rapid economic development and urbanization [1]. As a result, CO_2 emissions from the household sector have been rapidly increasing [2]. China—now the second largest global economy and the largest CO_2 emitter [3]—has been making efforts to aggressively reduce CO_2 emissions and protect the environment. In line with the Paris Climate Change Agreement, China submitted its Nationally Determined Contribution (NDC) and pledged to achieve peak CO_2 emissions by 2030.

Climate change mitigation researchers have mainly focused on CO_2 emissions generated by the industrial sector, but attention has gradually shifted to the household sector in recent years [4–7]. Household CO_2 emissions (HCEs) come from both direct (e.g., coal, oil and gas, etc.) and indirect (e.g., food, clothing, medical, etc.) consumption of household goods and services. The CO_2 emissions related to these sources are referred to as direct and indirect HCEs, respectively.

In China, HCEs are a major sources of CO_2 emissions and are increasing exponentially—largely due to improvements in the economy and living standards—currently accounting for 35%–40% in total CO_2 emissions [8,9]. However, most global action frameworks for reducing CO_2 emissions are targeted at the national level and the individual differences in emission sources within nations are seldom considered [4,7].

Moreover, studies on HCEs have been mainly based on national statistical yearbook data, and many researchers have recommended the need to investigate regional disparity using sample surveys [10,11]. Comparison of HCEs based on household survey data could: (1) eliminate central tendency (average effect); (2) reveal disparities between different regions, provinces and urban and rural areas; (3) provide a more scientific basis for governments and policy-makers in designing a low carbon society; and (4) prioritize investment of scarce resources. In China, although there are a number of HCEs studies, these are limited both in terms of small sample sizes and areas surveyed. There have been virtually no large household surveys of HCEs conducted. This study, which assessed both direct and indirect HCEs from the mainland of China and analyzed the impact of income on HCEs, is a start in this direction.

Realizing the importance of comprehensive HCEs research, we did our project "Chinese Household CO_2 Emissions Assessment (CHCEA)" in 2011. Subsequently, we developed a questionnaire, pre-tested it and then implemented it through experienced and trained researchers during 2011–2013. The year 2012 was set as the research period since the data were mainly gathered in 2012. In total, 8,130 urban households and 7,513 rural households across 31 mainland provinces in China were randomly selected and interviewed. Assessment of HCEs was based on IPCC's Reference Approach, Input-output Analysis and Consumer Lifestyle Approach [4,7]. Other studies have indicated the impact of per capita income on per capita household CO_2 emissions in China [3,6]. Based on the collected data, this paper assesses the impact of income on indirect and indirect HCEs and basic and development HCEs. Moreover, it also classifies the provinces on the basis of their per capita income and HCEs.

In order to investigate the impact of income on HCEs, seven income group categories were identified according to the classification methods of China Statistical Yearbook. As shown in Fig. S1a (online), we found that there was a strong positive correlation between per capita income and per capita HCEs, with an R^2 value of 0.9395. Per capita HCEs of the highest income level households were 3.74 times than those of the lowest income level households.

As shown in Fig. S1b (online), per capita HCEs from direct and indirect carbon emission sources as well as basic (related to basic needs) and development (related to development needs) demands, increased with greater per capita income. The HCEs from direct and indirect household consumption accounted for 33.33% and 66.67% in the lowest income level households, and for 19.11% and 80.89% in the highest income level households, respectively. Similarly, HCEs from basic and development energy usage accounted for 82.44% and 17.56% in the lowest income level households, and for 71.49% and 28.51% in the highest income level households, respectively. With an increase in income, indirect and basic HCEs were identified as the major contributors to total HCEs. This

* Corresponding author.
E-mail address: jsqu@lzb.ac.cn (J. Qu).

https://doi.org/10.1016/j.scib.2019.02.001

finding is concurrent with Qu et al. [7], who reported that energy consumption due to the use of indirect goods and services is 2.44 times greater than that for the use of direct goods and services.

Per capita direct and indirect HCEs for the highest income level households were 2.14 times and 4.53 times higher, respectively, than those for the lowest income level households. Similarly, per capita basic and development HCEs for the highest income level households were 3.24 times and 6.07 times higher, respectively, than those for the lowest income level households. The higher direct and indirect HCEs at higher income levels meant that more goods and services were consumed. Higher per capita HCEs from basic and development demands for higher income levels was mainly caused by their improving living standards. The results in this work are consistent with the findings of Qu et al. [4].

Using entire dataset from 31 provinces, we first estimated the average per capita income and average per capita HCEs. We then classified all the provinces into four different groups on the basis of this information: (1) "HH"—provinces whose per capita income and per capita HCEs were both higher than the average levels; (2) "HL"—provinces whose per capita income was higher and HCEs was lower than the average levels; (3) "LH"—provinces whose per capita income was lower and HCEs was higher than the average levels; (4) "LL"—provinces whose per capita income and per capita HCEs were lower than the average levels.

As shown in Fig. 1, 10 provinces were in the "HH" category, including: (1) four municipalities (Shanghai, Beijing, Tianjin and Chongqing); (2) three of the wealthiest provinces (Jiangsu, Guangdong and Shandong); and (3) three industrial (higher concentration of energy industries) provinces (Liaoning, Jilin and Inner Mongolia). The five provinces with "LH" type (Xinjiang, Shanxi, Heilongjiang, Hebei and Qinghai) were concentrated in northern China. Fourteen provinces belonged to "LL" type, which included northwest China (Gansu, Ningxia and Shaanxi), southwest China (Yunnan, Sichuan, Guizhou and Tibet), south China (Guangxi, Hainan and Fujian), and the central China (Henan, Anhui, Hunan and Jiangxi), where had low-level per capita income and HCEs. Two provinces, Hubei and Zhejiang, were grouped under the "HL" type.

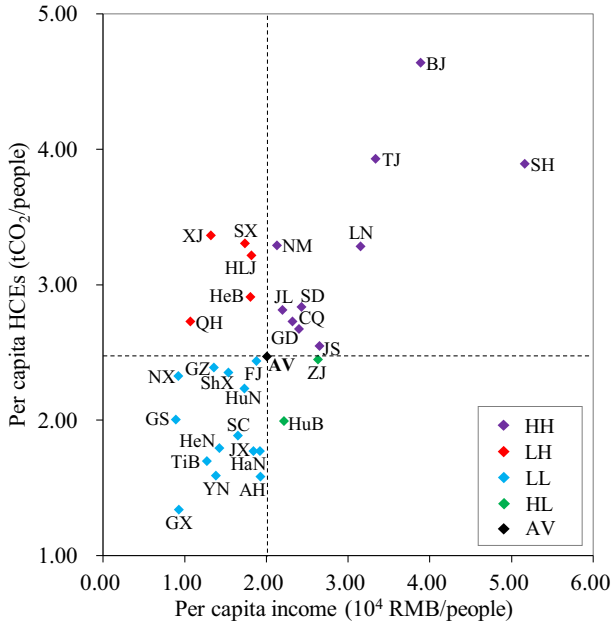

Fig. 1. Classification of 31 provinces on the basis of per capita income and per capita HCEs. Dotted lines indicate average values for per capita income and per capita HCEs, respectively. Here, AV represents average. AH, BJ, FJ, GS, GD, GX, GZ, HaN, HeB, HeN, HLJ, HuB, HuN, JL, JS, JX, LN, NM, NX, QH, SD, SX, ShX, SH, SC, TJ, TiB, XJ, YN, ZJ, and CQ represent Anhui, Beijing, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hainan, Hebei, Henan, Heilongjiang, Hubei, Hunan, Jilin, Jiangsu, Jiangxi, Liaoning, Inner Mongolia, Ningxia, Qianghai, Shandong, Shanxi, Shaanxi, Shanghai, Sichuan, Tianjin, Tibet, Xinjiang, Yunnan, Zhejiang, and Chongqing, respectively.

As noted, there was a direct relationship between per capita income and HCEs from different carbon emission sources. As shown in Fig. S2 (online), we divided HCEs based on whether they were from direct, indirect, basic and development energy consumption, and then analyzed the influence of per capita income on them. We found that Shanghai, Beijing, Tianjin, and Inner Mongolia were all in "HH" type, Shanxi was in "LH" type, Guangxi, Anhui, Yunnan, Henan, and Sichuan were all in "LL" type, and Hubei was in "LH" type. It was evident that per capita HCEs of the different carbon emission structure of different provinces was unequal. For example, the rich cities such as Shanghai, Beijing, and Tianjin still had high-level per capita direct and indirect, basic and development HCEs, while the less affluent provinces such as Guangxi, Anhui, Henan and Sichuan had with lower per capita HCEs from different sources. Zhejiang's per capita income was high, while it also had low-level direct and basic per capita HCEs, resulting in low-level per capita HCEs. At the same time, these less affluent provinces such as Xinjiang, Shanxi, Heilongjiang and Hebei had higher per capita direct and basic HCEs, leading to higher overall HCEs.

With increased income, the biggest increase in HCEs occurred in indirect and development demands for the different provinces. At even finer scales, within both direct and indirect carbon emission structure as well as basic and development demands, per capita HCEs varied by the household size and age structure, education level and income level of the occupants. In China, overall, indirect consumption of goods and services is the main source of HCEs [8]. This is further validated by our study. As noted, per capita indirect HCEs were higher than those of direct HCEs for all income groups. When we looked at the trend over the 17-year period from 1995 to 2011, indirect HCEs in rural areas increased more rapidly than those in urban areas [10,11]. This suggests that indirect sources of HCEs should be equally scrutinized.

Per capita HCEs were relatively higher in a couple of less affluent provinces such as Xinjiang, Shanxi, Heilongjiang and Hebei; there are two main reasons for this: (1) northern areas experience freezing temperatures in winter and the government provides free coal powered heating for homes and offices, while such heating systems did not exist in southern China; and (2) the government has developed a district heating system in north China but not in south China. Due to rapid urbanization, the area served by district heating system has increased exponentially in recent years, accounting for more than 4% of total carbon emissions in China [10].

In general, in all provinces, the living standard of people in China is expected to grow which may lead to increasing HCEs due to direct and indirect, basic and development energy demand. However, people's lifestyle, household size, age structure, household equipment and energy sources vary between different provinces, resulting in different levels of energy consumption/efficiency and thus HCEs. Similarly, different ways of heating, cooling and cooking also lead to a significant provincial differences in HCEs. Further, geographical factors, such as geographical location, climatic condition, topography and altitude, vary widely among different provinces. Such provincial differences are reflected in the way that the energy is used and the amount of the energy usage from the different categories (direct and indirect, basic and development) of energy demand, leading to significant difference in HCEs.

Our results indicate that per capita income had a strong positive effect on HCEs before the development needs are saturated. Understanding the trends and magnitude of income impact on HCEs is crucial in developing and refining climate change adaptation and

mitigation policies, including local adaptation policy, economic policy and low carbon policy. Such analysis will assist governments to identify problematic areas and prioritize scarce resources. For example, governments can promote economic policies by enhancing people's awareness of saving and mastering low-carbon construction systems. Meanwhile, LPG and electricity generated from renewable sources should gradually replace coal and petrol as energy sources. Governments can then also focus on research to improve energy efficiency and thereby reduce energy demand.

This study provides insights into the impact of income on HCEs from different regions of China. However, it is still a preliminary research owing to a number of limitations: (1) while this work enabled the benchmarking of HCEs and preliminary analysis of income inequality, it was insufficient to provide the rationale behind the disparities; and (2) being a large country, there are vast variations in climatic conditions, heating systems, household size, and the affordability and accessibility of fuels across China, thus, significant differences in the consumption of good and services. This research could not examine all potential determinants of HCEs at different temporal and spatial scales. Our follow-up research will address these issues.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

This work was supported by the National Key Research and Development Program of China (2016YFA0602803) and "Strategic Priority Research Program—Climate Change: Carbon Budget and Related Issues" of the Chinese Academy of Sciences (XDA05140100).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scib.2019.02.001.

References

[1] Liu MM, Liu XY, Huang YN, et al. Epidemic transition of environmental health risk during China's urbanization. Sci Bull 2017;62:92–8.
[2] Liu LN, Qu JS, Zhang ZQ, et al. Assessment and determinants of per capita household CO_2 emissions (PHCEs) based on capital city level in China. J Geogr Sci 2018;28:1467–84.
[3] Guan DB, Peters GP, Weber CL, et al. Journey to world top emitter: an analysis of the driving forces of China's recent CO_2 emissions surge. Geophys Res Lett 2009;36:1–5.
[4] Qu JS, Zeng JJ, Li Y, et al. Household carbon dioxide emissions from peasants and herdsmen in northwestern arid-alpine regions, China. Energy Policy 2013;57:133–40.
[5] Wiedenhofer D, Guan DB, Liu Z, et al. Unequal household carbon footprints in China. Nat Clim Change 2017;7:75–80.
[6] Liu LN, Qu JS, Clarke-Sather A, et al. Spatial variations and determinants of per capita household CO_2 emissions (PHCEs) in China. Sustainability 2017;9:1277.
[7] Qu JS, Liu LN, Zeng JJ, et al. China's household CO_2 emissions: an assessment based a large sample survey in China. Chin Sci Bull 2018;63:547–57 [in Chinese].
[8] Liu LC, Wu G, Wang JN, et al. China's carbon emissions from urban and rural households during 1992–2007. J Clean Prod 2011;19:1754–62.
[9] Tian X, Chang M, Lin C, et al. China's carbon footprint: a regional perspective on the effect of transitions in consumption and production patterns. Appl Energy 2014;123:19–28.
[10] Maraseni TN, Qu J, Yue B, et al. Dynamism of household carbon emissions (HCEs) from rural and urban regions of northern and southern China. Environ Sci Pollut Res Int 2016;23:20553–66.
[11] Qu J, Maraseni TN, Liu L, et al. A comparison of household carbon emission patterns of urban and rural China over the 17 Year Period (1995–2011). Energies 2015;8:10537–57.

Jiansheng Qu holds his Ph.D. degree on Geography and Environment Change from Lanzhou University. He is the director of Scientific Information Center for Resources and Environment of Chinese Academy of Sciences. He also serves as professor of the Information Center for Global Change Studies, and adjunct professor at College of Earth and Environmental Sciences in Lanzhou University. His current research focuses on the ecological and environmental strategy, climate policy analysis, greenhouse gas emissions assessment, and low-carbon society development.