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Transition of household cookfuels in China from 2010 to 2012

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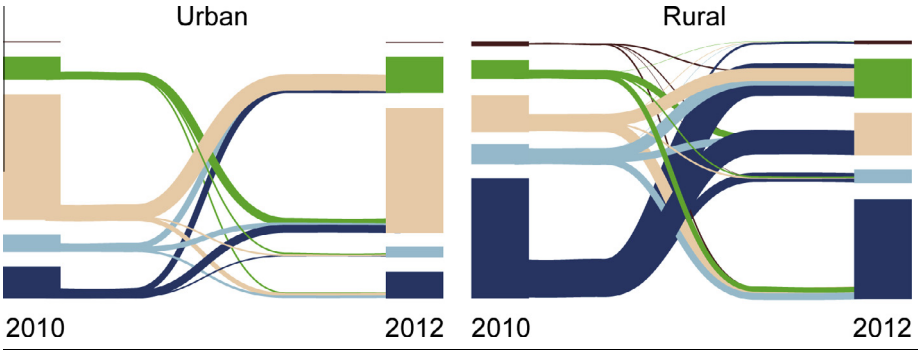
HIGHLIGHTS

- Transition of cookfuel in China was quantified based on a follow-up survey.
- Cookfuel transition was affected by various socioeconomic factors.
- Cookfuel transition simultaneously reduced emissions of both air pollutants and GHG.

GRAPHICAL ABSTRACT



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ABSTRACT

Emissions from household cookfuels strongly affect both air quality and climate change. China is undergoing a rapid transition of cookfuels due to its rapid development, which has significant consequences for environment and health. Unfortunately, detailed information on this transition is scarce. In this study, the trajectory and geographical variation of the cookfuel transition and the factors affecting it were investigated based on panel data on cookfuel choice from the China Family Panel Studies (CFPS) in 2010 and 2012 covering areas that include more than 90% of the national population and a large fraction of repeated households, thus reducing uncertainty. Over this short period, the proportion of Chinese households cooking with solid fuel dropped rapidly from 50% in 2010 to 39% in 2012; 9% and 18% of the solid fuel-using households in 2010 switched to clean energy in 2012, particularly electricity, in urban and rural areas, respectively, according to CFPS. The major forces driving the cookfuel transition include income, educational level, location, energy price, and fuel accessibility. Although switching from biomass to gas and electricity led to a slight increase in CO_2 emissions, the total residential emissions of CO, BC, OC, $PM_{2.5}$, and Hg decreased by more than 10% from 2010 to 2012. The warming effect of increased CO_2 emissions and reduced OC emissions was outweighed by the cooling effect achieved by the emissions reduction of air pollutants with warming impacts, including CO, BC and CH_4. Although this rapid transition is highly beneficial, it requires national action to accelerate and expand to a greater proportion of poor populations.

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1. Introduction

Household cooking in developing countries, which relies heavily on solid fuels, is a major concern because of its adverse impact on indoor and outdoor air quality [1,2], its significant contribution to disease [3,4], and its potential influence on climate change [5]. China houses one-fifth of the world's population that cooks with solid fuels [6], and thus 10% or more of the ambient primary $PM_{2.5}$ in China is estimated to be the product of solid-fuel household cooking [2,7]. In 2010, nearly 1 million premature deaths could be attributed to household air pollution from solid fuels [8], leading to significant socioeconomic losses [9]. Solid-fuel combustion is also responsible for large BC emissions (the dominant absorber of visible solar radiation) in China [10]. However, along with China's economic growth and rapid urbanization, rural residents are climbing the energy ladder, and the proportion of households cooking with solid fuels has decreased significantly since 1990 [11].

There has been ongoing discussion of the cookfuel transition in China; numerous socioeconomic variables such as income, educational levels, and energy costs have been identified as factors affecting cookfuel patterns [12–14]. However, limited by data availability, these studies were all based on provincial-level data from official statistics in China. Recently, the extent of the household fuel transition, and the factors influencing it, have been studied using cross-sectional survey data [15,16]. The results, though insightful with regard to quantifying the influencing variables, may be subject to large uncertainty when used to predict the future of the household fuel transition. Previous analysis of fuel switching based on household survey data from eight developing countries has proved that more information could be obtained by conducting detailed analyses using micro-level (e.g., household level) survey data [17]. Therefore, this paper aims to bridge the gap in knowledge about the direction of the cookfuel transition, the trajectory and speed of the transition, the geographical distribution pattern of the transition and most importantly, the major factors affecting the transition in China, using data from a newly published nationwide follow-up household survey.

In 2010 and 2012, the China Family Panel Studies (CFPS) project was carried out to follow more than 12,000 households in 25 provinces. Although the survey generally aimed at other socioeconomic factors, a question about main cooking fuel was included in the surveys. Numerous topics (including economic condition, education, and family structure) are believed to be associated with cookfuel [18,19]. The results of this unique survey allow us to look into the cookfuel issue based on detailed information for a large number of households in most parts of China.

One immediate consequence of switching from solid fuels to clean energy is a positive impact on pollutant emissions, the air quality of household and ambient environments, and human exposure [20]. In contrast, the net impact of this fuel transition on climate change is more complex and uncertain depending on the species considered [21]. Again, the data derived from the survey provide us with an opportunity to quantitatively estimate the change in emissions of various air pollutants and greenhouse gases induced by the cookfuel transition and associated uncertainties. This information is required to conduct future cost-benefit analyses of any proposed policy to eliminate the residential use of solid fuel [22,23]. Due to data limitations, the fuel transition and associated environmental, health, and climate impacts in China has not previously been well quantified. Our results can provide a better understanding of this important issue, which can benefit not only China but also other developing countries undergoing economic transition.

In this study, cookfuel transition data from the CFPS survey were analyzed together with several socioeconomic parameters collected in the survey. Our aims are to identify the direction and trajectory of the cookfuel transition in China, to characterize the geographical distribution of the transition trends, to investigate the factors affecting cookfuel choice and cookfuel transition and to evaluate the impact of the transition on air pollutants and greenhouse-gas emissions.

Finally, the implication of the cookfuel transition on policy making is discussed. It is noted that the main limitation of this dataset is the relatively short duration between the two surveys. Therefore, the quantitative results of this study cannot be extrapolated. More surveys will be needed to address this issue in a fully quantitative manner.

2. Data and methodology

2.1. Study area

The survey covered 25 provinces in Mainland China except for the five western provinces of Ningxia, Qinghai, Neimenggu, Xinjiang, Xizang, and Hainan. For simplicity, the term "China" represents the 25 provinces discussed in this study (refer to Fig. S1 for a map of the study area). Excluding Hong Kong, Taiwan, and Macau, although the study area occupies approximately half of Mainland China's total land area (49.6%), the study area contains 92% of China's total population and 82% of total Gross Domestic Product (GDP) [24].

2.2. Data sources

The information used in this study was primarily obtained from CFPS surveys launched by Peking University. This is the first nearly nationwide longitudinal social survey designed to characterize China's ongoing social transformation using a range of factors. Sophisticated study design, the use of a standard computer-assisted person-to-person interview with a large sample size, and careful data management make this million-dollar survey one of the highest-quality surveys of its type in China [25]. Data from the baseline survey in 2010 and the first full-scale follow-up survey in 2012 were used in this study. Twelve thousand, five hundred and fifty-two families were followed up in 2010 and 2012; 68% were from rural areas. One question about major cookfuel was included in the questionnaires, which asked the respondents to make a single choice among biomass, coal, gas (including PCG, PNG, and LPG), electricity, biogas, and others as the primary cookfuel. Detailed original questionnaires for relevant variables were listed in the supplementary material. Because multiple cookfuels are used in many Chinese households over the course of the year, data collected this way impose certain limitations and create bias in the study.

Data for provincial cookfuel choice in 2000 (from the 2000 China census) [26] was used for comparison. Fuel consumption for total residential use in 2010 and 2012 was obtained from the China Energy Statistical Yearbook to calculate the relative contributions of cooking to total residential emissions of various air pollutants [24].

Fuel consumptions ($Fuel_{i,j,y}$, GJ) for cooking were estimated using the equation below:

$$Fuel_{i,j,y} = Frac_{i,y} P_{i,y} Ec / \eta_i$$

where Frac, P, Ec (GJ), and η are the fraction of households using certain types of cookfuel, population size, annual per capita energy consumption for cooking, and thermal efficiency (defined as thermal energy output percentage) for certain fuel types, respectively.

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