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FUEL FOR LIFE: DOMESTIC COOKING FUELS AND WOMEN'S HEALTH IN RURAL CHINA

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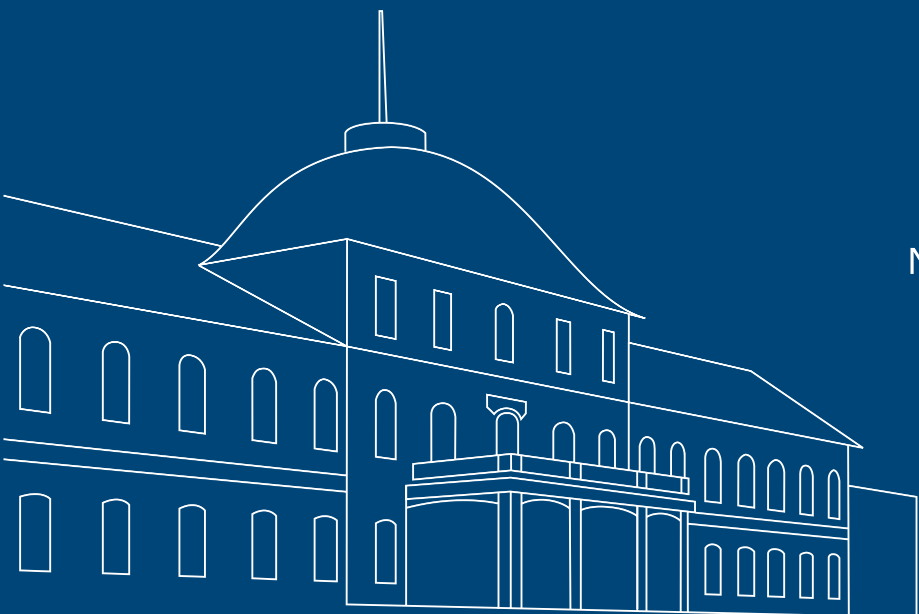

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Fuel for Life: Domestic Cooking Fuels and Women's Health in Rural China

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ABSTRACT

Using longitudinal and biomarker data from the China Family Panel Studies and the China Health and Nutrition Survey, this study examines the association between the type of domestic cooking fuel and the health of women aged ≥16 in rural China. Regarding three major domestic cooking fuels (wood/straw, coal and liquefied natural gas (LNG)), we find that, compared to women whose households cook with dirty fuels like wood/straw, women whose households cook with cleaner fuels like LNG have a significantly lower probability of chronic or acute diseases and are more likely to report better health. Even after controlling for unobserved individual heterogeneity, we find some evidence that women in households cooking with LNG are less likely to suffer from chronic/acute diseases. Cooking with domestic coal instead of wood or straw is also associated with elevated levels of having certain risks (such as systolic and diastolic blood pressure) related to cardiovascular diseases.

JEL Classification Codes: I10, D10, J10; Q53

Keywords: household cooking fuels; health; women; rural China

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Fuel for Life: Domestic Cooking Fuels and Women's Health in Rural China

1. Introduction

Globally, 40% of the population relies on solid fuels, including coal and biomass (e.g. wood, charcoal, agricultural residues and dung), for domestic cooking, thereby breathing in a large amount of particulate matter (PM) and pollutants that can be detrimental to health (United Nations Development Group, 2013). According to the 2010 Global Burden of Disease/Comparative Risk Assessment Project, for example, exposure to indoor air pollution (IAP) from cooking with solid fuels resulted in 3.5 million premature death and various other health problems (e.g. lung cancer) in 2010 (Lim et al., 2012; Reid et al., 2012). Yet despite unprecedented economic development in China, most rural Chinese still cook with solid fuels, 47.6% with biomass and 13.5% with coal in 2011 (Duan et al., 2014), and the use of solid fuels is likely to continue in the future (Zhang and Wu, 2012). As a result, IAP associated with solid fuels is estimated to be the largest single environmental risk contributor and ranks sixth among all risk factors examined for bad health in China (Zhang and Smith, 2007), resulting in over half a million premature deaths annually (World Health Organization and United Nations Development Programme, 2009). At the same time, although a relatively large body of epidemiological and environmental literature examines the effects of IAP on health in parts of China (Finkelman et al., 1999; Smith et al., 2004; Peabody et al., 2005; Zhao et al., 2006; Liu et al., 2007a; Zhang and Smith, 2007; Baumgartner et al., 2011; Kan et al., 2011; Jin et al., 2014), no studies assess this risk using nationally representative data and a longitudinal setting. Consequently, the evidence on IAP and health in China as a whole is scant, often narrowly focused (i.e. on certain provinces or cities) and usually based on cross-sectional analyses with limited generalizability and little ability to address confounders.

To address these shortcomings, this paper investigates the impacts of domestic cooking fuels on the health outcomes of rural women aged ≥16 using 2010–2012 data from the China Family Panel Studies (CFPS) and 1991–2009 data from the China Health and Nutrition Survey (CHNS). Specifically, it analyses the different health impacts associated with three major household cooking fuels: wood/straw, coal and liquefied natural gas (LNG). The research focuses on women in rural China because they are predominantly responsible for cooking and thus bear the brunt of the illness burdens associated with IAP (Zhang and Smith, 2007).

The study contributes to the existing literature in three ways: First, it provides a comprehensive analysis of the health impacts related to domestic cooking fuels by using the most recent nationally and regionally representative datasets (the CPFS and CHNS, respectively). Second, it assesses the impact of household cooking fuels on health within a panel setting capable of capturing time-invariant individual heterogeneity. Third, by using biomarker data from the 2009 CHNS, it more closely examines the association between IAP and certain risk predictors of cardiovascular disease, evidence for which has been primarily limited by a lack of reliable biomarker data (Fullerton et al., 2008).[1] This association can shed new light on the mechanisms by which IAP from household cooking fuels may influence health outcomes.

The remainder of the discussion proceeds as follows: Section 2 reviews the relevant research on this topic in China. Section 3 outlines the data and methodologies, and Section 4 reports the empirical results. Section 5 concludes the paper.

2. Prior studies

2.1. Fuel-based IAP and respiratory diseases

In the rapidly growing body of epidemiologic and environmental science literature on the association between fuel-based IAP and health in China, most studies present strong evidence that exposure to IAP is significantly related to an increased risk of bad health. With regard to the impact of fuel-based IAP on adult respiratory diseases, Liu et al. (2007b), using survey data for rural Yunyan in Guangdong province, show that cooking with biomass fuel, as compared with liquefied petroleum gas, increases the probability of chronic obstructive pulmonary disease (COPD) in non-smoking women aged ≥40. Similarly, using cross-sectional data for rural China (Shaanxi, Hubei and Zhejiang), Peabody et al. (2005) find that, compared with other types of fuel,[2] coal fuel is associated with an increased level of exhaled CO, an increased history of overall respiratory disease (including asthma, chronic bronchitis, emphysema,

[1] As emphasized by Balakrishnan et al. (2014) and Zhang et al. (2013), biomarkers are considered a very reliable source of information about absorbed doses of pollutants.

[2] Cooking fuels include wood, crop fuel (crop residues and other biomass like dung), coal, charcoal and cleaner fuels (electricity, liquefied petroleum gas and biogas) (Peabody et al., 2005).

COPD and tuberculosis) and decreased forced vital capacity (FVC)[3] among adults aged ≥18. Pan et al. (2002) also show that IAP from fuel combustion for cooking and heating has adverse effects on asthma attacks among respondents aged 15–65. These findings are confirmed by a recent meta-analysis of 33 international studies on IAP's detrimental respiratory impacts among those aged ≥65 (Bentayeb et al., 2013), which points to a generally significant association between IAP exposure and various short-term and long-term respiratory diseases, including wheezing, breathlessness, cough, phlegm, asthma and COPD. In contrast, Xu et al. (2007) find no association between domestic cooking fuels and COPD in individuals aged ≥35 in Nanjing city, while Kan et al.'s (2011) matched case-control analysis of respondents aged ≥15 in Huaiyuan county, Anhui province, identifies no link between cooking with solid fuel and tuberculosis in the presence of proper ventilation. This latter is supported by a recent review of 15 international studies (Lin et al., 2014), which suggests that the association between domestic use of solid fuels and tuberculosis is very low.

Because lung cancer is a serious health problem in China (see She et al., 2013; Chen et al., 2014), many studies focus on its association with fuel-based IAP. For example, one meta-analysis (Zhao et al., 2006) of 27 studies on air pollution and lung cancer risks in China provides evidence that the odds ratio (OR) of the lung cancer risk among women is 1.83 in households that use coal for heating and cooking. Another review by Smith et al. (2004) on the health effect of IAP from coal use in nine single-province/city/municipality studies (seven in China,[4] one in Japan and another in the U.S., with a focus either on women or on men and women separately) finds that the OR of lung cancer risks among women is 1.17. This risk of death from lung cancer for women almost doubles (OR = 1.94) in studies that adjust for smoking behaviour and a history of chronic respiratory disease. A more recent meta-analysis of 23 studies (Kurmi et al., 2012), including 17 carried out in China, also suggests that coal use is correlated with lung cancer and that the risk is more pronounced among females. Kim et al. (2014), using a prospective cohort of women in urban Shanghai from 1996 to 2009, demonstrate that cooking with coal is particularly harmful when the kitchen has poor ventilation, and Barone-Adesi et al. (2012), using a retrospective cohort of 37,272 individuals in Xuanwei county, Yunnan province, show that smoky coal is related to a higher lung cancer risk than smokeless coal. Coal use is also associated with general lung function impairment

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[3] FVC is the maximal volume of air exhaled with maximally forced effort from a maximal inspiration; that is, the vital capacity performed with a maximally forced expiratory effort (in liters at body temperature and ambient pressure saturated with water vapor) (see Miller et al., 2005).

[4] The cities/municipalities examined in those seven studies include Guangzhou, Harbin, Shenyang, Shanghai, Xuanwei and Taiwan.

(Jin et al., 1995; Zhou et al., 2000; Jie et al., 2014). For example, Zhou et al. (2014), in a nine-year prospective cohort study among rural residents aged ≥40 in southern China, find a correlation between using clean fuels like biogas (rather than biomass) and better lung function, as well as a decrease in risk for COPD.

2.2. Fuel-based IAP and non-respiratory diseases

A small body of literature for China does examine the association between fuel-based IAP and cardiovascular diseases (CVD), especially high blood pressure. Among these studies, Baumgartner et al. (2011) find that exposure to indoor biomass combustion is associated with an increase in systolic blood pressure (SBP) and diastolic blood pressure (DBP) among rural Chinese women aged >50. They find no such association, however, among younger cohorts aged 25–50. This latter finding is confirmed in Baumgartner et al. (2014) for 280 non-smoking women aged ≥25 living in a rural region of north-western Yunnan province whose exposure to pyrolytic biomass combustion is strongly associated with blood pressure issues.[5] Lee et al. (2012) also find that the use of in-home solid fuel is significantly correlated with an increase in the probabilities of hypertension, coronary heart disease, and diabetes among adults aged ≥18 at Putuo district of Shanghai.[6]

Domestic cooking fuels are also linked to certain poisonous endemics. For instance, in their study of arsenic exposure associated with coal-burning in a small village in Guizhou province, Shraim et al. (2003) find that females have higher dimethylarsinic acid levels but lower percentages of inorganic arsenic and monomethylarsonic acid than males. Several studies also confirm Finkelman et al.'s (1999) finding that domestic coal combustion results in selenium poisoning and potential mercury poisoning (Zheng et al., 2005; Li et al., 2006; Liu et al., 2007a). Li and Ma (2010) also identify a correlation between an increased incidence of CO poisoning and indoor coal burning, inadequate ventilation and/or inappropriate stove use.

In the context of our study, three aspects of the extant literature are particularly relevant: First, the empirical results for China generally suggest that fuel-based IAP has an adverse impact on both respiratory and non-respiratory health outcomes. Yet most existing studies for China cover only certain provinces or cities (see e.g. Peabody et al., 2005), and no studies use nationally representative data. Second, except for Barone-Adesi et al. (2012) and Zhou et al.

5 Epidemiological studies in Taiwan provide some evidence that pollutant-based IAP might be an emerging risk factor for CVD, including blood pressure and heart rate increments (see Chuang et al., 2010; Chuang et al., 2013; Lin et al., 2009).

6 It is worth noting that, although Lee et al. (2012) provide evidence for the association between in-home solid fuel use and cardiovascular diseases (CV), measures of CV are self-reported except for blood pressure. Their analysis is also based on cross-sectional data, and reported household solid fuels are used for both cooking and heating.

(2014), who use retrospective data to evaluate the impact of domestic cooking fuels on lung cancer and COPD, respectively, nearly all extant studies use cross-sectional data. Third, only a limited number of studies examine the association between fuel-based IAP and cardiovascular diseases (CVD) in China. Hence, despite recent findings on the association between IAP and blood pressure (see Baumgartner et al., 2011; Baumgartner et al., 2014), relatively little is known about how IAP exposure from domestic cooking fuels is related to other risk predictors of CVD such as inflammation. Furthermore, as emphasized by Baumgartner et al., (2011) and Baumgartner et al., (2014), the evidence on the association between blood pressure (BP) and domestic cooking fuels is exclusively based on cross-sectional data. A major contribution of our study, therefore, is the provision of nationally representative results based on panel data that allow us to control for unobserved heterogeneity. Given that high blood pressure results in around half of all CVD (Mackay and Mensa, 2004)[7], another contribution is our assessment of how domestic cooking fuels affect some major risk predictors of CVD (such as high blood pressure), which may shed light on the mechanisms through which IAP operates on health outcomes.

3. Data and methods

The China Family Panel Studies (CFPS), conducted by Peking University's Institute of Social Science Survey, currently comprises two waves, 2010 and 2012, which cover 25 provinces/municipalities/autonomous regions representing 95% of the Chinese population. Thus, CFPS is a nationally representative dataset. Additionally, the CFPS employs a multistage sampling design and aims to capture socio-economic development, as well as economic and non-economic well-being in Chinese households.[8] The CFPS sample for our study, taken from both waves, includes 12,901 rural women aged ≥16.

The China Health and Nutrition Survey (CHNS), administered in nine waves – 1989, 1991, 1993, 1997, 2000, 2004, 2004, 2009 and 2011 – covers nine provinces (Liaoning, Heilongjiang,[9] Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi and Guizhou) that are regionally representative but differ in geographic and economic conditions. The multistage random cluster design of this longitudinal dataset allows us to capture the spatio-temporal

7 It is worth highlighting that every 10-point increase in diastolic blood pressure or every 20 point increase in systolic blood pressure will lead to the doubled risks of cardiovascular diseases (Mackay and Mensa, 2004).

8 The CFPS excludes Hong Kong, Macao, Taiwan, Xinjiang, Qinghai, Inner Mongolia, Ningxia and Hainan (see Xie et al., 2014, for detailed information about the sampling design).

9 Heilongjiang province was added as the ninth province in 1997.

dynamics of the social, economic and health situations of the Chinese population.[10] Our CHNS sample, taken from the 1991 to 2009 waves, includes 15,539 rural women aged ≥16.

We use these CFPS and CHNS data to examine the impact of domestic cooking fuels on the health (including self-reported chronic or acute diseases and health status) of rural Chinese women. The advantage of the CFPS is that it is the first dataset that contains nationally representative information on health and cooking fuels. The CHNS, although not nationally representative, has three other advantages that we exploit in the analysis: a long-running panel, information on time exposure to cooking and, particularly important, biomarker information that allows a unique analysis of the association between cooking fuels and certain risk factors of CVDs.

3.1. Health measures

The CFPS captures illness or disease with the following question: *"Have you felt any physical discomfort during the preceding two weeks"*, which is coded 1 if the answer is yes, and 0 otherwise. Similarly, the CHNS captures general health as follows: *"Have you suffered from a chronic or acute disease during the past 4 weeks?*", which is represented by a dummy coded 1 if the answer is yes, and 0 otherwise. The CFPS also assesses self-reported health (SRH) status on a 5-point scale: *"How would you rate your health status? 1 = excellent, 2 = very good, 3 = good, 4 = fair and 5 = poor"*. We rescale these values from 1 = *poor* to 5 = *excellent* to bring them into line with the corresponding 4-point CHNS item, which appears only in the 1997 to 2006 waves: "*Right now, how would you describe your health compared to that of other people your age? 1 = bad; 2 = fair; 3 = good; 4 = excellent.*" It should be noted that SRH covers not only mental and physical health but also subjective experience of acute and chronic diseases and overall feelings of well-being (Xie and Mo, 2014).

For the risk predictors of CVD, we use CHNS data on systolic and diastolic blood pressure (SBP/DBP) and inflammation (C-reactive protein, CRP) as proxies. In the CHNS, blood pressure information is available for the 1991 to 2009 waves[11] based on three successive pairs of blood pressure measurements taken by a health professional using a mercury sphygmomanometer at intervals of at least one minute. We calculate the average values of SBP and DBP based on the second and third measurements to overcome potential measurement biases (Lei et al., 2012). We follow the conventional way of dealing with CRP values and

[10] See Zhang et al. (2014) for more detailed information on the CHNS.
[11] See Lei et al. (2012) for a detailed overview of the blood pressure measurements in the CHNS.

remove those with values beyond 10 mg/dl (Pearson et al., 2004). Inflammation is only available in the 2009 CHNS wave and it captured by a dummy variable equal to 1 if the high sensitivity C-reactive protein (CRP) $\geq$ 3 mg/dl and 0 otherwise (Yan et al., 2012) mainly because values above 3 mg/L are associated with high risk of future cardiovascular events (Pearson et al., 2004).

We also test for several other major disease symptoms potentially related to fuel-based IAP using binary dummies. In the CFPS data, these are fever, pain, diarrhoea, cough and palpitation, whereas in the CHNS, they are fever, cough, diarrhoea, asthma, eye disease and heart disease/chest pain.

3.2. Household cooking fuels (HCF)

As in Peabody et al. (2005), we investigate three major household cooking fuels – wood/straw, coal and liquefied natural gas – which account for 84% of total household fuel consumption in the CFPS and 88% in the CHNS. The household cooking fuel variable can thus take three values: 0 = wood/straw, 1 = coal and 2 = liquefied natural gas (LNG), with wood/straw as the reference group. As noted by Peabody et al. (2005), fuel types might be better proxies for pollution exposure than the type of stove used in the household, although both are only indirect measures of exposure to IAP. The fuel-based approach is, however, regarded as the most accurate technique for assessing IAP in developing countries (Mestl and Edwards, 2011).

Regarding possible mechanisms of how different cooking fuels operate on health, exposure to biomass fuel use (like wood/straw) is associated with chronic bronchitis or chronic obstructive pulmonary disease mainly through reduced mucociliary clearance and macrophage response (Bruce et al., 2000). In addition, exposure to biomass smoke for cooking is also a potential risk factor for lung cancer because some carcinogenic compounds are generated via polycyclic aromatic hydrocarbons (Bruce et al., 2000). Use of biomass fuel also leads to cataracts since oxidative changes happen with the absorption of toxins into the lens (Bruce et al., 2000).

As Zhang and Smith (2007) have highlighted, coal contains intrinsic contaminants such as sulphur, and coal burning for cooking generally takes longer than LNG or other gas combustion (Zhang, 1996). More importantly, the concentrations of particulate matter (PM) and sulphur dioxide (SO2) are highest in the kitchen when coal is used for cooking (Zhang and Smith, 2007), thereby giving rise to some cardiovascular diseases (Bruce et al., 2000; Baumgartner et al., 2011).

Lastly, we categorize the independent variables into three subgroups – individual, family and community characteristics – discussed separately below:

3.3. Individual characteristics

Individual controls include age, age squared, educational level, marital status, job status and current smoking behaviour. Education is measured on a 6-point scale recoded as a dummy variable: 1 = illiterate, 2 = primary school, 3 = middle school, 4 = high school, 5 = vocational school and 6 = university or higher. Marital status is a dichotomous variable equal to 1 if the respondent is married and 0 if the respondent is living together with a partner, divorced or widowed. Job status is a dummy variable equal to 1 if the respondent is currently employed and 0 otherwise. Current smoking behaviour is a binary variable equal to 1 if the respondent has smoked in the past month and 0 otherwise. The definitions of the individual variables are the same for both the CFPS and the CHNS except for time spent cooking, which is only available in the CHNS data as measured by the following question: *"During the previous week, how much time (in hours) did you spend per day, on average, cooking food for the household?"*

3.4. Family characteristics

The family controls are household size and household income, which for ease of comparability is adjusted to 2012 in the CFPS and to 2011 in the CHNS. In addition, we also introduce the availability of safe drinking water, existence of flushing toilets, clean trash treatment (for the CFPS), existence of excreta around the living place (for the CHNS) and availability of electricity. Regarding the CFPS, the safe drinking water is defined as 1 if the household's drinking source is tap water or mineral/purified water, 0 otherwise. Flushing toilet facility equals 1 if the household mostly use an indoor/outdoor flushing toilet, 0 otherwise. The electricity variable equals 1 if the household has occasional or no power outage, 0 otherwise. As with the CHNS, safe drinking water variable is a binary variable equal to 1 if the household's water source is a water plant or ground water above 5 meter deep, 0 otherwise. The flushing toilet variable equals 1 if the household can access an in-house/out-house flushing toilet facility, 0 otherwise. Excreta dummy equals 1 if there is no excreta around the dwelling place, 0 otherwise. Availability of electricity is a dummy variable equal to 1 if electric facilities are accessible for the household, 0 otherwise.

3.5. Community characteristics

In the CFPS, we employ the distance in the community to the nearest hospital/medical center, which is a continuous variable measured in kilometres. In the CHNS, the availability of health facilities in the community is defined by a dummy variable equal to 1 if a health facility is located in the village/neighbourhood and 0 if in another village/town/city or in the respondent's city but in a different neighbourhood. Similarly, we also add the distance to the health facility measured in kilometres.

3.6. Estimation approaches

To investigate the association between domestic cooking fuels and general disease (or specific symptoms) in a cross-sectional setting in the CFPS and the CHNS, we adopt a probit regression model of the following form:

$$GD_i = \alpha_0 + \alpha_1 HCF + \alpha_2 I_i + \alpha_3 F + \alpha_4 C + \alpha_5 Y + \alpha_6 P + \varepsilon_i \quad (1)$$

where GD_i is a binary variable indicating general chronic or acute disease or a specific disease symptom of individual i, and *HCF* denotes dummies for the three household cooking fuels, wood/straw, coal and liquefied natural gas, with wood/straw as the reference group (applied to both the CFPS and the CHNS). I_i is a vector of individual i's characteristics, F is a vector of family characteristics and C is a vector of community characteristics. Y is a vector of year dummies (with 2010 and 1991 as the reference year in the CFPS and CHNS, respectively), and P is a vector of provincial dummy variables (with Liaoning as the reference province in both datasets). α_1 is the key coefficient of interest, and ε_i is the error term. Because both surveys use a multistage sampling design, we take into account clustering at the village/neighbourhood (CFPS) or community (CHNS) level.

To assess the effects of household cooking fuels on certain risk predictors of cardiovascular diseases (using the CHNS measure of inflammation), we use a specification similar to equation (1) but without year dummies. For SRH (measured on a 4-point scale in the CHNS and a 5-point scale in the CFPS), we estimate the impact of household cooking fuels with an ordered probit model using data from the CFPS and the CHNS and specifications similar to equation (1).

As regards the association between domestic cooking fuels and disease in general (or specific symptoms), since domestic cooking fuels in a household would not change within a short-term period, we account for the potential biases associated with individual unobservables by estimating the following random effects probit model with data from the CFPS and the CHNS:

$$GD_{it} = I(X'_{it}\beta + F_t + \alpha_i + \varepsilon_{it} \geq 0) \quad (2)$$

where GD_{it} denotes general chronic or acute disease of individual i at time t, $I(\cdot)$ is an indicator function that equals 1 if its argument is true (0 otherwise), and X_{it} is a vector of individual characteristics including age and time spent on cooking. F_t captures the two family characteristics, household income and household size, while α_i is assumed to be a random variable.

Because self-reported health is ordinal in both data sets under consideration, for this variable we adopt a random effects ordered probit estimation that uses a specification similar to equation (2):

$$SRH^*_{it} = X_{it}\beta + \alpha_i + \varepsilon_{it} \quad (3)$$

$$SRH_{it} = \begin{cases} 1, if\ SRH^*_{it} \leq c_1 \\ 2, if\ c_1 < SRH^*_{it} \leq c_2 \\ \vdots \\ K, if\ c_{K-1} < SRH^*_{it} \end{cases} \quad (4)$$

where SRH^*_{it} (linked to the observed ordinal response categories SRH_{it}) is a latent variable of self-reported health for individual i at time t. X_{it} represents observed characteristics, α_i is a random variable, c is a set of cut-off points c_1, c_2 …, c_{K-1} and K is the number of possible outcomes.[12]

We use a balanced panel in the CFPS and an unbalanced panel in the CHNS. In order to test for possible attrition bias in the CHNS, we employ the variable addition test proposed by Verbeek and Nijman (1992). The test adds a variable to the right side of equations (2) and (3) that counts the number of surveyed years that each respondent is present in the survey. The test of attrition bias is evaluated on the significance of this added variable, and insignificance denotes the nonexistence of attrition bias.

To analyse the association between household cooking fuels and SBP or DBP levels in the CHNS data, we employ the following ordinary least squares estimation (OLS):

[12] See Alsakka and Gwilym (2010) for a specific application of the random effects ordered probit approach to examine the sources of heterogeneity in sovereign credit ratings in emerging economies.

$$CVD_i = \beta_0 + \beta_1 HCF + \beta_2 I_i + \beta_3 F + \beta_4 C + \beta_5 P + \beta_6 Y + \varepsilon_i \qquad (5)$$

where CVD_i is a continuous variable denoting the SBP/DBP level of individual i, and HCF is a dummy for household cooking fuel. I_i is a vector of individual i's characteristics, F is a vector of family characteristics and C is a vector of community characteristics. P is a vector of provincial dummy variables (with Liaoning as the reference), and Y is a vector of year dummies (with 1991 as the reference year). β_1 is the key coefficient of interest and ε_i is the error term. Because the CHNS uses a multistage sampling design, we also take into account clustering at the community level. All the health measures, together with the data and methods used, are summarized in Table 1. In order to take account of individual unobserved heterogeneity, we also estimate a corresponding panel model using data from the CHNS.

Table 1. Summary of health measures, data and methods

Health measures	Description	Definition	Data source	Years	Methodology
Self-reported acute/chronic disease	Have you felt any physical discomfort during the preceding two weeks?	A binary variable equal to 1 if the respondent has felt discomfort, and 0 otherwise.	CFPS	2010-2012	Probit model Random-effect probit model
	Have you suffered from a chronic or acute disease during the past 4 weeks?	A dummy that equals 1 if the respondent has suffered from a chronic or acute disease, and 0 otherwise	CHNS	1991-2009	Probit model Random-effect probit model
Self-reported health (SRH)	How would you rate your health status? 1=excellent, 2=very good, 3=good, 4=fair and 5=poor	A 5-point scale ranging from 1=poor to 5=excellent	CFPS	2010-2012	Ordered probit model Random effect ordered probit model
	Right now, how would you describe your health compared to that of other people your age? 1=bad; 2=fair; 3=good; 4=excellent.	A 4-point scale ranging from 1=bad to 4=excellent	CHNS	1997-2006	Ordered probit model Random effect ordered probit model
Systolic blood pressure (SBP)	Measurements are taken three times by a health professional using a mercury sphygmomanometer	The average value of SBP based on the second and third measurements	CHNS	1991-2009	Ordinary least squares model Fixed effect model
Diastolic blood pressure (DBP)	Measurements are taken three times by a health professional using a mercury sphygmomanometer	The average value of SBP based on the second and third measurements	CHNS	1991-2009	Ordinary least square model Fixed effect model
Inflammation	Using high sensitivity C-reactive protein	A dummy equal to 1 if the high sensitivity C-	CHNS	2009	Probit model

		reactive protein exceeds 3 mg/dl, 0 otherwise			

4. Results

4.1. Descriptive statistics

As Appendix Table A1 shows, the average age of rural women in the CFPS is around 46, which is quite similar to the 45 years in the CHNS (see Table A2). Wood/straw is more predominant as a cooking fuel (CFPS: 63.7%; CHNS: 40.9%) than either coal or LNG (see Appendix Tables A1 and A2). The proportion of LNG, one of the cleaner fuel types, is higher in the CFPS (25.7%) than in the CHNS (17.1%), but this outcome could result from the different periods covered by each survey (2010–2012 and 1991–2009, respectively). The differences between the two datasets could also be attributed to the different geographic regions they cover. Additionally, the trends of domestic cooking fuels from 1991 to 2009 are illustrated in the Appendix Figure A1. Two points are worth highlighting: First, the patterns of domestic cooking fuels have shifted dramatically. Specifically, wood/straw use for household cooking has declined, from 36.9% in 1991 to 17.8% in 2009. Similarly, coal use also has experienced a decrease during the same period, from 36% to 23.2%. However, the use of LNG for domestic cooking has increased significantly, from 15.2% to 22.4%. Second, although the use of wood/straw, coal has declined but LNG has increased steadily during the last decade, those three fuels are still the predominant types for household cooking fuels. Such temporal changes in our sample are very comparable to the results from Duan et al. (2014) based on the data from the CHNS 1991 to 2006.

4.2. Cross-sectional evidence of HCF and health: the CFPS and the CHNS

According to the pooled cross-sectional results for the CFPS (Table 2), women whose households rely on LNG are less likely to suffer from chronic or acute disease than those whose households rely on wood/straw (CFPS: marginal effect (ME) = -4.4%, column 1). Likewise, women in households using either coal or LNG are more likely to self-report better health status than those in households using wood/straw.[13] Nevertheless, the point estimates for LNG are larger than those for coal (2.9% for LNG versus 1.9% for coal, respectively, column 2),

[13] When evaluating the impact of domestic cooking fuels on health outcomes, we also introduce a dummy variable indicating whether any highly polluting enterprises (e.g. a chemical plant) within a 5-kilometer radius centered at the village or residential level exist. The results are quite similar and are available from the authors upon request.

suggesting that cleaner cooking fuels like LNG are beneficial to health. Interestingly, as for the CHNS, we also cannot observe any association between coal/LNG and chronic/acute disease (column 3). Nonetheless, we indeed find that, relative to wood/straw, LNG use is associated with better self-reported health (ME=2.1%, column 4).[14]

Table 2. (Ordered) probit estimates for the effect of household cooking fuels on women's health in rural area: CFPS 2010–2012 and CHNS 1991–2009

Variables	CFPS		CHNS	
	(1)	(2)	(3)	(4)
	Chronic/acute disease	SRH (excellent)	Chronic/acute disease	SRH (excellent)
Coal	0.010	0.019*	-0.008	0.009
	(0.020)	(0.011)	(0.008)	(0.007)
LNG	-0.044***	0.029***	-0.009	0.021***
	(0.015)	(0.009)	(0.010)	(0.008)
N	12901	12901	15539	8409
Pseudo R^2	0.065	0.147	0.090	0.081

Notes: The dependent variable is a dummy variable for whether the respondent has suffered from a chronic or acute disease (1 = yes, 0 = no) or self-reported health (SRH) measured on a 5-point scale from 1 = poor to 5 = excellent in the CFPS and a 4-point scale from 1 = poor to 4 = excellent in the CHNS. Controls include a dummy for household cooking fuel (0 = wood/straw, 1 = coal, 2 = LNG, with wood/straw as the referent), individual characteristics, family characteristics, community characteristics, provincial dummies (with Liaoning as the referent in both the CFPS and CHNS) and year dummies (with 2010 and 1991 as the referents in the CFPS and CHNS, respectively). Also reported are marginal effects, which for SRH indicate the probability of excellent health. Village/neighbour or community-level clustered standard errors are in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

To check possible effects of domestic cooking fuels on health among different age cohorts, we split the sample into two groups: women aged 16-50 and 50+. The results demonstrate that, relative to wood/straw, women aged 16-50 in households using LNG are more likely to self-report better health in the CFPS. However, this is not the case for those women aged 16-50 in the CHNS. Interestingly, we can consistently find that LNG use for cooking is associated with improved self-rated health among women aged 50+ in both the CFPS and the CHNS (see Table A3 in the Appendix).

4.3. Panel evidence for HCF and health: the CFPS

[14] We also find that, in the CFPS, having a large household and clean rubbish treatment are correlated with a lower probability of chronic/acute disease. Interestingly, having a higher education and household income are related to better health status. However, a longer distance to health facilities is negatively associated with reporting better health. Regarding the CHNS, being employed, having a large household size, better sanitation conditions (e.g. having a flushing toilet in the household) and no excreta around the dwelling place are associated with lower levels of chronic/acute disease. Additionally, having a higher household income and no excreta around the dwelling place are positively related to reporting better health. Also note that age is positively associated with the probability of chronic/acute diseases but negatively correlated with reporting better health in both datasets.

Given the possible existence of individual unobservables or omitted factors, we also estimate random effects (ordered) probit estimates based on the CFPS data, which reveal a significantly negative association between the probability of chronic/acute diseases and cooking with LNG (ME=-5.2%, Table 3, column 1).[15] They also reveal a significantly positive association between self-reported health and cooking with coal or LNG (ME: 2.0% for LNG versus 2.3% for coal, respectively, column 2), which implies that both these fuels are less detrimental than wood.[16]

Table 3. Random effects (ordered) probit estimates for the effect of household cooking fuels on women's health in rural areas: CFPS 2010–2012

Variables	(1) Chronic/acute disease Random effects probit	(2) Self-reported health (excellent) Random effects ordered probit
Coal	-0.006	0.023**
	(0.020)	(0.010)
LNG	-0.052***	0.020***
	(0.015)	(0.007)
N	9770	10000

Notes: The dependent variable is either a dummy for whether the respondent has suffered from a chronic or acute illness (1 = yes, 0 = no) or a 5-point measure of self-reported health problems (from 1 = poor to 5 = excellent). The controls are domestic cooking fuel (0 = wood/straw, 1 = coal, 2 = liquefied natural gas (LNG), with wood/straw as the referent), age, age squared, household income and household size. Also reported are marginal effects, which for SRH indicate the probability of excellent health. Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Our analysis for the two age groups (15-50 and 50+) shows that, compared with wood/straw, LNG use for cooking is strongly associated with better self-reported health among women aged 50+, but not for those aged 16-50. Thus, older rural women are more likely to benefit from positive effects of cleaner fuels like LNG (see Table A4 in the Appendix).

4.4. Panel evidence for HCF and health: the CHNS

We perform a similar panel analysis with the CHNS but introduce an additional control for the time a woman spends cooking (TSC), which is divided into four categories: 1 = TSC<1 hour/day, 2 = 1≤TSC<2 hours/day, 3 = 2≤TSC<3 hours/day, and 4 = TSC≥3 hours/day, with

[15] Note that we also employ a likelihood-ratio test to check the appropriateness of random effects (ordered) probit estimates and results demonstrate that there is enough variability between individuals to favor random effects (ordered) probit estimates instead of (ordered) probit estimates. This is also the case for the CHNS estimation. The results are not reported here, but available from the authors upon request.

[16] It is also interesting to note that, for self-reported health, age is negatively associated with better health while having a higher household income is positively correlated with improved health.

TSC<1 hour/day as the reference.[17] Two of the findings are worth emphasizing: First, the random effects probit estimations (Table 4, column 1) reveal no significantly negative association between domestic LNG use and chronic/acute diseases while the random effects ordered probit estimations (column 2) show a significant positive effect of LNG use on self-reported health (ME=2.2%). Taken together, these results suggest that LNG may lead to better health outcomes. Second, none of the coefficients on time spent cooking are significant (columns 1 and 2), which could imply that the mere use of a specific fuel may lead to IAP persistency. In other words, the spatio-temporal distribution of pollutant concentrations could be affected by house structure, room layout and ventilation (Zhang and Smith, 2007). [18] For the test of attrition bias, the results from random effect probit and order probit estimates indicate that this additional variable is insignificant (not reported here). Thus, it suggests that endogenous attrition bias is not a serious issue in our case.[19]

Table 4. Random effects (ordered) probit estimates for the effect of household cooking fuels on women's health in rural areas: CHNS 1991-2009

Variables	(1) Chronic/acute disease Random effects probit	(2) Self-reported health (excellent) Random effects ordered probit
Coal	-0.007	0.002
	(0.006)	(0.005)
LNG	-0.013	0.022^{***}
	(0.008)	(0.006)
1≤TSC<2 hours/day	-0.003	-0.005
	(0.008)	(0.006)
2≤TSC<3 hours/day	-0.011	0.003
	(0.008)	(0.006)
TSC≥3 hours/day	-0.012	-0.011
	(0.009)	(0.008)
N	10090	7023

Notes: The dependent variable is either a dummy for whether or not the respondent has suffered from a chronic or acute disease or a 4-point measure of self-reported health (1 = poor, 2 = fair, 3 = good and 4 = excellent). The controls are cooking fuel (0 = wood, 1 = coal, 2 = liquefied natural gas (LNG), with wood/straw as the referent), a dummy for time spent cooking (TSC, 1 = TSC<1 hour/day, 2 = 1≤TSC<2 hours/day, 3 = 2≤TSC<3 hours/day, 4 = TSC≥3 hours/day, with group 1 as the referent), age, age squared, household income (inflated to 2011) and household size. Also reported are marginal effects, which for SRH indicate the probability of excellent health. Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[17] Similar to the results from the CFPS, we also find that age is negatively related to improved health and having a higher level of household income is positively correlated with better health.

[18] We also interact fuel type with TSC, but the estimated coefficients remains insignificant.

[19] To capture some potential effects of seasonal changes for cooking fuel use within a household, we also introduce interviewed month into our estimates. The results, available upon request, are qualitatively very similar to those without controlling for seasonal changes.

To detect the possible heterogeneity of domestic cooking fuel use on various different age groups, we rerun the estimates for rural women aged 15-50 and 50+ separately. The results indicate that in both age groups, relative to wood/straw, LNG use is associated with a higher probability of self-reported improved health. One interesting point to emphasize is that, for those women aged 50+, time spent cooking above 3 hours/day is correlated with a lower probability of reporting better health status, perhaps suggesting that older women are more likely to suffer from longer exposure to IAP (see Table A5 in the Appendix).

4.5. HCF and major risk predictors of cardiovascular diseases (CVD): the CHNS

Even though China is facing a major increase in cardiovascular diseases (Gordon-Larsen et al., 2013; Yan et al., 2012), empirical evidence of the possible effects of household cooking fuels on CVD is quite limited (Fullerton et al., 2008). High blood pressure is one of the major risk contributors for CVD (Mackay and Mensa, 2004). Following Baumgartner et al., (2011), we analyse the levels of systolic blood pressure (SBP) and diastolic blood pressure (DBP). We dichotomize the whole sample into two age groups, namely 16-50 and 50+, because the relative increased risk in cardiovascular diseases begin usually in the fifth decade of life (see for instance Mackay and Mensa, 2004). In our analysis of the CHNS data, we note that, relative to wood/straw, cooking with coal is associated with an increase in raised levels of SBP and DBP among rural women aged 50+ (see columns 2 and 4 in Table 5), but no significance is found for those women aged 16-50. This result supports Baumgartner et al.'s (2011) conclusion that indoor solid fuel combustion is related to a higher level of SBP among women aged 50+ in rural Yunnan, China. We also introduce inflammation as another potential risk factor for CVD. Nevertheless, we find no association between domestic cooking fuels and inflammation (see column 5).

Table 5. OLS/probit estimates for the effect of household cooking fuels on women's blood pressure/inflammation in rural areas: CHNS

	OLS estimates				Probit estimate
Variables	(1) Systolic blood pressure 16-50	(2) Systolic blood pressure 50+	(3) Diastolic blood pressure 16-50	(4) Diastolic blood pressure 50+	(5) Inflammation
Coal	0.070	1.809**	0.520	0.912*	0.016
	(0.589)	(0.747)	(0.390)	(0.464)	(0.032)
LNG	0.335	1.133	0.358	0.484	0.005
	(0.616)	(0.891)	(0.419)	(0.572)	(0.031)

N	6288	9251	6288	9251	1637
Pseudo R^2/ Adjusted R^2	0.108	0.174	0.102	0.093	0.109

Notes: The dependent variable is a dummy for whether the respondent has suffered from inflammation (1 = yes, 0 = no) or from levels of systolic and diastolic blood pressure. The information on blood pressure is available from 1991 to 2009; that on inflammation, only in 2009. The controls include a dummy for household cooking fuel (0 = wood, 1 = coal, 2 = liquefied natural gas, with wood as the referent), individual characteristics, family characteristics, community characteristics, provincial dummies (with Liaoning as the referent) and year dummies (with 1991 as the referent). Marginal effects are reported for the probit estimate of inflammation. Community clustered standard errors are in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

To assess the possible existence of some unobserved or omitted factors, we also estimate a fixed effects model.[20] As Table 6 demonstrates, coal use for domestic cooking is still significantly and positively correlated with an elevated level of systolic blood pressure among women aged 50+ (see column 2), which is quite similar to that of the OLS estimates in the Table 5. Additionally, longer time exposure is also associated with raised levels of SBP among women aged 50+ (>3 hours/day) and DBP among those aged 16-50 (1-3 hours/day) (columns 2 and 3).

Table 6. Fixed effects estimates for the effect of household cooking fuels on women' blood pressure in rural area: CHNS 1991-2009

Variables	Systolic blood pressure		Diastolic blood pressure	
	(1) 16-50	(2) 50+	(3) 16-50	(4) 50+
Coal	-0.599	2.267*	0.288	0.079
	(0.669)	(1.229)	(0.481)	(0.707)
LNG	-0.131	-0.573	0.654	-0.215
	(0.768)	(1.438)	(0.553)	(0.827)
1-2 hours	0.524	1.536	1.076**	-0.111
	(0.612)	(1.006)	(0.440)	(0.579)
2-3 hours	-0.036	1.731	0.920*	-0.110
	(0.664)	(1.129)	(0.478)	(0.649)
>3 hours	-1.064	2.603**	-0.008	0.417
	(0.726)	(1.300)	(0.523)	(0.748)
N	6252	3838	6252	3838
R^2	0.088	0.102	0.066	0.028

Notes: The dependent variables are levels of systolic/diastolic blood pressure. Controls are cooking fuel choices (0=wood, 1=coal, 2=liquefied natural gas (LNG), wood/straw as the reference), dummies of time spent cooking (1=<1 hour/day, 2=1<= & <2 hours/day, 3=2<= & <3 hours/day, 4=>=3 & <4, and 5=>=4 & <5 hours/day, with group 1 as the reference groups), age, age squared, household income (inflated to 2011) and household size. Standard errors are in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01.

4.6. HCF and specific symptoms of chronic or acute diseases

[20] We performed a Hausman test to detect the appropriateness of fixed effects over a random effects model. Results are clearly in favor of a fixed effects model.

Finally, as Table 7 shows, we find no significant association between coal/LNG (with wood/straw as the referent) and specific disease symptoms except for significantly negative associations with palpitation in the CFPS, and with eye disease but significantly positive association with heart/chest pain in the CHNS.

Table 7. Probit estimates for the effect of domestic cooking fuels on women's health (specific symptoms) in rural areas: CFPS 2010-2012 & CHNS 1991-2009

Variables	CFPS				
	Fever	Diarrhoea	Cough	Pain	Palpitation
Coal	-0.003	0.003	0.003	0.007	0.006
	(0.005)	(0.002)	(0.004)	(0.015)	(0.005)
LNG	0.001	-0.001	0.003	-0.018	-0.008*
	(0.004)	(0.002)	(0.003)	(0.012)	(0.004)
N	12637	10713	12623	12901	12901
Pseudo R^2	0.023	0.055	0.031	0.059	0.072
Variables	CHNS				
	Fever/cough	Diarrhoea	Asthma	Eye	Heart/chest
Coal	-0.003	0.003	-0.007	-0.003*	0.004*
	(0.005)	(0.003)	(0.007)	(0.002)	(0.002)
LNG	-0.001	-0.002	-0.007	-0.004**	0.003
	(0.006)	(0.004)	(0.010)	(0.002)	(0.002)
N	15539	15539	1078	14299	15539
Pseudo R^2	0.081	0.069	0.297	0.208	0.172

Notes: The dependent variable is a dummy for whether the respondent has suffered from fever, diarrhoea, cough, asthma, pain, palpitation, eye or heart disease/chest pain (1 = yes, 0 = no). Asthma is only available in the year of 2009 for the CHNS. The controls are a dummy for household cooking fuel (0 = wood/straw, 1 = coal, 2 = liquefied natural gas, with wood/straw as the referent), individual characteristics, family characteristics, community characteristics, provincial dummies (with Liaoning as the referent in both the CFPS and CHNS) and year dummies (with 2010 and 1991 as the referent in the CFPS and CHNS, respectively). Marginal effects are reported. Village/neighbour or community-level clustered standard errors are in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01.

The results from the random effects probit model are illustrated in the Table 8. Two points are worth noting: First, when taking wood/straw as the reference category, we mostly fail to observe any significant association between coal/LNG and specific disease symptoms, which is consistent with the previous cross-sectional results in Table 7. Second, in the CFPS, compared with wood/straw, LNG is associated with a lower probability of diarrhoea (ME=-2.6%). Nonetheless, coal or LNG use for cooking is related to a decreased probability of fever in the CHNS (ME: -1.2% for LNG versus -0.8% for coal, respectively).[21]

[21] When adding the interview month into the estimates, we find that the results are qualitatively similar.

Table 8. Random effects probit estimates for the effect of domestic cooking fuels on women's health (specific symptoms) in rural areas: CFPS 2010-2012 & CHNS 1991-2009

Variables	CFPS				
	Fever	Diarrhoea	Cough	Pain	Palpitation
Coal	-0.002	-0.005	0.003	0.001	0.003
	(0.004)	(0.013)	(0.002)	(0.001)	(0.003)
LNG	0.002	-0.026***	-0.002	0.002	-0.003
	(0.003)	(0.009)	(0.002)	(0.001)	(0.002)
N	10002	10002	10002	10002	10002
			CHNS		
Variables	Fever	Diarrhoea	Eye	Heart/chest pain	
Coal	-0.008*	-0.001	-0.001	0.001	
	(0.004)	(0.002)	(0.001)	(0.001)	
LNG	-0.012**	-0.003	-0.001	0.001	
	(0.006)	(0.003)	(0.001)	(0.001)	
1-2 hours	-0.005	0.003	0.0002	0.0004	
	(0.005)	(0.003)	(0.001)	(0.001)	
2-3 hours	-0.012**	-0.001	-0.001	-0.002	
	(0.006)	(0.003)	(0.001)	(0.002)	
>3 hours	-0.022***	-0.004	-0.0001	-0.0004	
	(0.007)	(0.003)	(0.001)	(0.001)	
N	10090	10090	10090	10090	

Notes: The dependent variable is a dummy for whether the respondent has suffered from fever, diarrhoea, cough, pain, palpitation, eye or heart disease/chest pain (1 = yes, 0 = no). In the CFPS, the controls are a dummy for household cooking fuel (0 = wood/straw, 1 = coal, 2 = liquefied natural gas, with wood/straw as the referent), age, age squared, household income (inflated to 2012) and household size. For the CHNS, controls are similar to those in the CFPS but add dummies of time spent cooking (1=<1 hour/day, 2=1<= & <2 hours/day, 3=2<= & <3 hours/day, 4=>=3 & <4, and 5=>=4 & <5 hours/day. Marginal effects are reported. Standard errors are in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01.

5. Conclusions

This analysis of data from the China Family Panel Studies (CFPS) and the China Health and Nutrition Survey (CHNS) examines the association between the type of domestic cooking fuel and women's health in rural China. Not only does it expand the extant literature by using the most recent nationally and regionally representative datasets within panel settings, it also explores how household cooking fuels are related to the health impairments associated with certain risk predictor for cardiovascular disease. Our results indicate that, relative to those who use traditional biomass fuels like wood/straw, women in rural households who cook with liquefied natural gas are less likely to suffer from chronic or acute diseases and more likely to report better health outcomes. They also associate the use of coal with increased levels of systolic and diastolic blood pressure, suggesting that solid fuel use could be affecting the risk predictors for cardiovascular disease in rural China. This finding is consistent with previous epidemiological studies in rural China (see Baumgartner et al., 2011; Baumgartner et al., 2014).

Such incomplete combustion of solid fuels like biomass and coal emits several pollutants like PM and other toxic compounds (Smith et al., 2004). In particular, PM inhalation results in oxidative stress and systematic inflammation as well (Barregard et al., 2006; Pope and Dockery, 2006), thereby leading to elevated blood pressure levels (Bautista et al., 2005).

Admittedly, however, the observed effects are generally small in magnitude, perhaps because of certain study limitations. One important constraint is that even though a significant proportion of rural households use a mixture of fuels (Zhang and Smith, 2007), our dataset only permits an analysis of primary fuel use, which makes it difficult to isolate the effect of a specific fuel type. Another potential problem is the endogeneity encountered in virtually all studies on this topic (Dulfo et al., 2008), which in the absence of adequate instruments is difficult to solve.[22] Nevertheless, despite these limitations, our analysis does provide evidence for an association between fuel type and health problems among women in rural China. Any such evidence implies that shifting from dirty fuels such as biomass to cleaner choices like liquefied natural gas or electricity could improve health outcomes. This shift, however, is inherently a long-term process, one likely to be hampered by the affordability and availability of cleaner fuels in rural areas (see Baumgartner et al., 2012).

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[22] We also estimate a special regressor model (SRM) meant for binary choice model estimation when one or more regressors are endogenous or mismeasured (Lewbel et al., 2012). Following Lewbel et al. (2012), we adopt age as the special regressor mainly because it is both continuous and exogenous. In our case, the instrument candidates include 2011-adjusted prices of coal briquettes and liquefied natural gas at the community level. Taking wood/straw and coal as the referent, we do observe a negative yet insignificant association between LNG and chronic/acute diseases. Based on the Hansen J-test and Wald F-test, our instruments appear to be reasonable (results available from the authors upon request). Nevertheless, as Lewbel et al. (2012) emphasize, such an instrumental technique can be problematic if the association between special regressors and other endogenous variables leads to violation of the special regressor's conditional independence from the error term. In addition, the fact that the model imposes fewer assumptions on error term distribution leads to larger standard errors (Lewbel et al., 2012).

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Appendix:

Table A1. Descriptive statistics: CFPS 2010–2012

Variables	Obs	Mean	Std. Dev.	Min	Max
Dependent variables					
Chronic/acute disease	12901	0.347	0.476	0	1
Fever	12901	0.022	0.147	0	1
Pain	12901	0.156	0.363	0	1
Diarrhoea	12901	0.005	0.072	0	1
Cough	12901	0.015	0.121	0	1
Palpitation	12901	0.033	0.177	0	1
Self-reported health (SRH)					
Poor	12901	0.146	0.353	0	1
Fair	12901	0.154	0.361	0	1
Good	12901	0.171	0.376	0	1
Very good	12901	0.262	0.440	0	1
Excellent	12901	0.267	0.443	0	1
Household cooking fuels					
Wood/straw	12901	0.637	0.481	0	1
Coal	12901	0.106	0.308	0	1
Liquefied natural gas (LNG)	12901	0.257	0.437	0	1
Individual characteristics					
Age	12901	46.059	16.053	16	97
Working status	12901	0.490	0.500	0	1
Education levels					
Illiterate	12901	0.516	0.500	0	1
Primary school	12901	0.220	0.414	0	1
Middle school	12901	0.194	0.395	0	1
High school	12901	0.052	0.223	0	1
Vocational school	12901	0.012	0.110	0	1
University or higher	12901	0.005	0.073	0	1
Marital status	12901	0.834	0.372	0	1
Currently smoking	12901	0.039	0.195	0	1
Family characteristics					
Household income (log)	12901	9.877	1.148	0.693	14.253
Household size	12901	4.674	1.922	1	26
Drinking water	12901	0.421	0.494	0	1
Electricity	12901	0.944	0.230	0	1
Flushing toilet	12901	0.209	0.407	0	1
Clean trash treatment	12901	0.148	0.355	0	1
Community Characteristics					
Distance to the health facility (km)	12901	1.247	1.670	0.001	9.500

Notes: Self-reported health (SRH) is measured on a 5-point-scale (1 = poor, 2 = fair, 3= good, 4 = very good and 5 = excellent). The household cooking fuels are wood/straw, coal and liquefied natural gas (0 = wood/straw, 1 = coal, 2 = liquefied natural gas (LNG)). The education level dummy is measured on a 6-point scale (1= illiterate, 2 = primary school, 3 = middle school, 4 = high school, 5 = vocational school and 6 = university or higher). Dummies are also included for marital status (1 = married, 0 = others), working status (1 = currently employed, 0 = currently unemployed) and smoking behaviour at the time of interview (1 if the respondent had smoked for the past month, 0 otherwise).
Source: China Family Panel Studies 2010 and 2012.

Table A2. Descriptive statistics: CHNS 1991-2009

Variables	Obs	Mean	Std. Dev.	Min	Max
Dependent variables					
Chronic/acute disease	15539	0.109	0.311	0	1
Fever	15539	0.046	0.210	0	1
Diarrhoea	15539	0.017	0.130	0	1
Asthma	1078	0.001	0.031	0	1
Eye disease	15539	0.004	0.066	0	1
Heart disease/chest pain	15539	0.009	0.092	0	1
Self-reported health (SRH)					
Bad	8409	0.070	0.256	0	1
Fair	8409	0.317	0.465	0	1
Good	8409	0.492	0.500	0	1
Excellent	8409	0.121	0.326	0	1
Household cooking fuels					
Wood/straw	15539	0.409	0.492	0	1
Coal	15539	0.420	0.494	0	1
Liquefied natural gas (LNG)	15539	0.171	0.377	0	1
Individual characteristics					
Age	15539	44.959	15.728	16	97.84
Working status	15539	0.705	0.456	0	1
Education levels					
Illiterate	15539	0.300	0.458	0	1
Primary school	15539	0.337	0.473	0	1
Middle school	15539	0.263	0.440	0	1
High school	15539	0.073	0.260	0	1
Vocational school	15539	0.020	0.140	0	1
University or higher	15539	0.007	0.083	0	1
Marital status	15539	0.799	0.400	0	1
Currently smoking	15539	0.037	0.189	0	1
Time spent cooking (hours/day)	10227	1.728	0.932	0.017	4.667
Family characteristics					
Household income (log)	15539	9.390	1.011	1.156	13.414
Household size	15539	4.198	1.591	1	13
Water	15539	0.827	0.378	0	1
Flushing toilet	15539	0.207	0.405	0	1
No excreta around the dwelling place	15539	0.568	0.495	0	1
Electricity	15539	0.984	0.127	0	1
Community characteristics					
Location of health facility	15539	0.752	0.432	0	1
Distance to the health facility (km)	15539	0.923	3.573	0	60

Notes: Self-reported health (SRH), which is only available from 1997 to 2006, is measured on a 4-point scale (1 = poor, 2 = fair, 3 = good and 4 = excellent). Asthma is only available in the year of 2009. The household cooking fuels are wood, coal and liquefied natural gas (0 = wood, 1 = coal, 2 = liquefied natural gas (LNG)). The education level dummy is measured on a 6-point scale (0 = illiterate, 1 = primary school, 2 = middle school, 3 = high school, 4 = vocational school and 5 = university or higher). Dummies are also included for marital status (1 = married, 0 = other), working status (1 = currently employed, 0 = currently unemployed) and smoking behaviour at the time of interview (1 if the respondent was currently smoking cigarettes, 0 otherwise).
Source: China Health and Nutrition Survey 1991, 1993, 1997, 2000, 2004, 2006 and 2009.

Table A3. Ordered probit estimates for cooking fuel choice on women self-reported health in rural area: CFPS 2010-2012 and CHNS 1991-2009

Variables	CFPS		CHNS	
	(1)	(2)	(3)	(4)
	16-50	50+	16-50	50+
Coal	0.010	0.027^{**}	0.016	0.003
	(0.015)	(0.012)	(0.012)	(0.006)
LNG	0.025^{**}	0.035^{***}	0.014	0.022^{***}
	(0.012)	(0.011)	(0.013)	(0.007)
N	7958	4945	5107	3302
Pseudo R^2	0.140	0.109	0.052	0.042

Notes: The dependent variable is self-reported health (SRH) measured on a 5-point scale from 1 = poor to 5 = excellent in the CFPS or a 4-point scale from 1 = poor to 4 = excellent in the CHNS. Controls include dummies of household cooking fuel choices (0=wood, 1=coal, 2=liquefied natural gas, wood as the reference), individual characteristics (including age, age squared, education level, marital status, job status, current smoking behavior, participation into food preparation and cooking), family characteristics (translog household income inflated to 2011, household size, the availability of safe drinking water, sanitation and clean trash treatment), community characteristics (distance to the health facility), provincial dummies (Liaoning as the reference) and year dummies (2010 as the reference). Also reported are marginal effects, which for SRH indicate the probability of excellent health. Village/neighbour clustered standard errors are in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01.

Table A4. Random effects ordered probit estimates for cooking fuel choice on women self-reported health in rural area: CFPS 2010-2012

Variables	Random effects ordered probit: 16-50	Random effects ordered probit: 50+
Coal	0.021	0.024^{*}
	(0.016)	(0.013)
LNG	0.012	0.027^{***}
	(0.011)	(0.009)
N	6011	3989

Notes: The dependent variable is self-reported health (SRH) measured on a 5-point-scale variable of self-reported health status (from 1=very unhealthy to 5=very healthy). Controls include cooking fuel choices (0=wood, 1=coal, 2=liquefied natural gas, wood as the reference), age, age squared, household income (inflated to 2011) and household size. Also reported are marginal effects, which for SRH indicate the probability of excellent health. Standard errors are in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01.

Table A5. Random effects ordered probit estimates for household cooking fuels on women self-reported health in rural area: CHNS 1991-2009

Variables	Random effects ordered probit: 16-50	Random effects ordered probit: 50+
Coal	-0.001	0.005
	(0.009)	(0.004)
LNG	0.020*	0.020***
	(0.011)	(0.006)
1-2 hours	0.001	-0.007
	(0.010)	(0.005)
2-3 hours	0.007	-0.001
	(0.011)	(0.005)
>3 hours	-0.001	-0.014**
	(0.013)	(0.007)
N	4085	2938

Notes: The dependent variable is self-reported health (SRH) measured on a 4-point scale from 1 = poor to 4 = excellent. Controls include cooking fuel choices (0=wood, 1=coal, 2=liquefied natural gas (LNG), wood/straw as the reference), dummies of time spent cooking (1=<1 hour/day, 2=1<= & <2 hours/day, 3=2<= & <3 hours/day, 4=>=3 & <4, and 5=>=4 & <5 hours/day, with group 1 as the reference groups), age, age squared, household income (inflated to 2011) and household size. Also reported are marginal effects, which for SRH indicate the probability of excellent health. Standard errors are in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01.

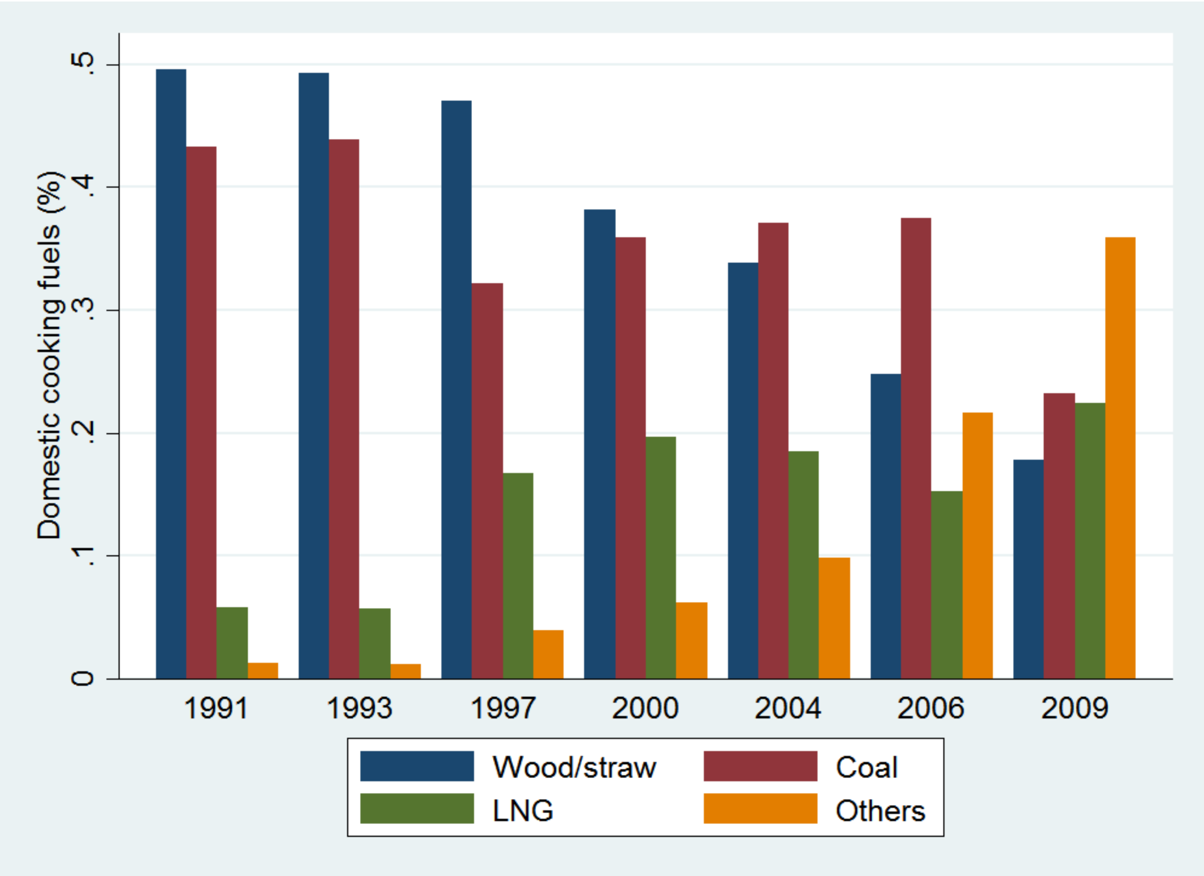

Figure A1. Temporal change of domestic cooking fuels from 1991 to 2009, China Health and Nutrition Survey

Notes: LNG denotes liquefied natural gas.

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