HHS Public Access

Author manuscript

J Dev Stud. Author manuscript; available in PMC 2021 January 01.

Published in final edited form as:

J Dev Stud. 2020 ; 56(7): 1309–1329. doi:10.1080/00220388.2019.1657571.

The Gendered Nature of Liquefied Petroleum Gas Stove Adoption and Use in Rural India

CARLOS F. GOULD,

Department of Environmental Health Sciences, Columbia University Mailman School of Public Health, New York, NY, USA

JOHANNES URPELAINEN

Johns Hopkins School of Advanced International Studies, Washington, DC, USA

Abstract

Clean cooking fuels promise substantial health benefits for rural households, but almost three billion people continue to rely on traditional biomass for their cooking needs. We explore the role of gender in the adoption of LPG, a clean cooking fuel, in rural India. Given that women are responsible for most households' cooking needs, we propose that gender inequality is an obstacle to LPG adoption because men may fail to appreciate the full benefits of clean cooking fuels. Using data for 8,563 households from the ACCESS survey, we demonstrate that households where women participant in decison-making are more likely to adopt LPG for cooking than households in which a man is the sole decision-maker. We extend our analytic framework to evaluate the relationship between household characteristics and LPG and firewood use. Access and cylinder costs were both negatively associated with LPG use and while LPG adoption reduced firewood use, fuel stacking remains the norm in study households. This study has implications for future policy designs to increase LPG adoption and use to obtain the multiple benefits of cleaner cooking.

Keywords

India; energy poverty; clean cooking; gender

1 Introduction

Clean cooking fuels promise substantial benefits to the 700 million households globally that still rely on solid fuels – primarily firewood, charcoal, dung, and crop residues – for their daily cooking and heating needs. The negative impacts of exposure to the household air pollution (HAP) resulting from the inefficient burning of solid fuels represent the largest energy-related health risk in the world (Smith et al., 2014). HAP exposure is a significant cause of morbidity and mortality globally, leading to an estimated 4 million premature deaths (3.9%−6.4% of global mortality) each year (Lim et al., 2013; Stanaway, Afshin, Gakidou, Lim, & et al., 2018). Recent estimates suggest one million premature deaths each

Correspondence Address: Johannes Urpelainen, Johns Hopkins School of Advanced International Studies, Johns Hopkins University, 1619 Massachusetts Avenue, NW, Washington, DC 20036, USA, JohannesU@jhu.edu.

year are attributable to HAP in India alone, with women bearing a disproportionate burden of disease because of the role as primary cooks (Balakrishnan, Dey, Gupta, Dhaliwal, & et al., 2019). The impacts of cooking with solid fuels in traditional stoves extend beyond health to economic costs, primarily through lost productive time dedicated to fuel collection (Lambe, Jürisoo, Wanjiru, & Senyagwa, 2015). Yet, the negative effects of solid fuel combustion are amenable to intervention through cleaner cooking, with increasing epidemiological evidence for improved health with reduced HAP exposure across a number of outcomes like birthweight (Alexander et al., 2018), child pneumonia (Smith et al., 2011), lung function in children and adults (Lee et al., 2019; Silwal & McKay, 2015), and blood pressure (Alexander et al., 2017). In this context, promoting household transitions from cooking with solid fuels to clean cooking fuels – the most promising approach for reducing HAP exposure – is paramount.

An important aspect of clean cooking fuels (gas and electricity primarily) is their gendered nature, with women primarily bearing the responsibility of cooking and associated tasks. However, the nature of the relationship between gender and fuel choice remain largely unexplained. In this empirical study we investigate whether women decision-makers adopt clean cooking fuels more than their man decision-maker counterparts in rural India. Interest in disentangling the energy-gender-poverty nexus has grown with greater understanding of the health hazards of HAP and their disproportionate impacts on women (Clancy, Skutsch, & Batchelor, 2003; Lambrou & Piana, 2006). In most societies with rural households still relying on traditional biomass, women are in charge of a household's cooking needs and other daily chores while men work outside (Bruce, Perez-Padilla, & Albalak, 2000; World Health Organization, 2018). This cooking responsibility leads to disproportionately high HAP exposure for women and, in turn, a high burden of disease. Furthermore, fuel collection and processing is often left to women and the collection and care of certain fuels – notably, firewood – can be particularly challenging (Behera, Rahut, Jeetendra, & Ali, 2015; World Health Organization, 2018). While women are likely to benefit from transitions to cleaner cooking fuels and therefore value these fuels more, decision-makers that are men may not see these benefits as worth the financial investment in acquiring a new stove and incurring regular fuel costs.

Our primary research question is whether households with women decision-makers had a higher probability of having LPG than households with men decision-makers, after accounting for other covariates of LPG adoption in rural North Indian households. To assess this research question, we use data from the 2014–2015 ACCESS survey on 8,563 households in six states of India (Madhya Pradesh, Uttar Pradesh, Bihar, Jharkhand, Odisha, and West Bengal). Controlling for known factors that influence household energy decisions, we examine the association between having a woman household decision-maker as compared to having a man household decision-maker and joint woman and man household decision-making and LPG adoption. Furthermore, we carry out an exploratory analysis of the covariates of fuel use, in terms of LPG as the primary cooking fuel, LPG use per capita, and firewood use per capita with and without LPG adoption. Around the world LPG use is increasing as the fuel becomes more affordable and the negative health effects of solid fuel combustion become more pressing. This study is timely, and relevant for designing

programs, policies, and materials to promote clean cooking fuel adoption in India and elsewhere in the world.

Briefly, we find that gendered decision-making plays a crucial role in LPG adoption. The positive association between having a woman decision-maker and the adoption of LPG remains robust even after controlling for other differences in economic status, household size, and caste. In additional analyses of the ACCESS survey, we discuss and analyze stated reasons households not having LPG in this sample, finding that high installation and fuel costs dominate. We also note that household heads that are men have higher levels of subjective satisfaction with their cooking arrangement *without* LPG, which is consistent with the notion that women face the greatest inconvenience and health problems associated with cooking on a traditional stove. Finally, we extend our framework to discuss the use of cooking fuels, analyzing determinants of both LPG use and continued firewood use in households with LPG. We find that increased education is positively associated with LPG use and that the costs of LPG – in terms of cylinder price and access – have a negative association with LPG use. While households with LPG use significantly less firewood than their non-LPG counterparts, solid fuels are a pervasive cooking fuel in rural Indian households. Nonetheless, we find suggestive evidence that households with women decision-makers use less firewood than those with man decision-makers, in addition to evidence for increased firewood use with increased LPG cylinder costs and difficulty in acquiring cylinders.

This study responds to the extant gaps in the gender and energy transitions literature, effectively leveraging a large regionally-representative survey to demonstrate the role of women decision-makers for LPG adoption in six rural Indian states. We crystallize the literature on gendered household decision-making for the adoption of clean cooking fuels and provide robust statistical analysis of the determinants of cooking fuel choice in rural Indian households. While clean fuels may have significant benefits in improving the quality of life of women – improved health, time savings, reduced drudgery, additional opportunities for income, education, or leisure – there has been limited success designing targeted projects that account for household decision-making processes. Our results suggest that effective strategies will incorporate not only gender but decision-making power to improve adoption.

2 Studies of Gender, Decision-Making, and Cooking Fuel Choice

In this analysis, we focus on gender and intra-household decision-making. Since women in large part bear the burden of cooking they are especially disadvantaged by a lack of clean fuels. At the same time that women face additional burdens from daily responsibilities – including firewood collection, cooking, cleaning, and child rearing (Blackden & Wodon, 2006) – they often have limited financial and decision-making power. Given these cultural constraints, women's preferences and health may not be adequately valued in household decisions around clean fuels (Köhlin, Sills, Pattanayak, & Wilfong, 2011). Pachauri and Rao (2013) outline central considerations in their review of gender and energy poverty literature on which we build: (i) women's control over household assets and resources, (ii) women's preferences for potential health benefits of cleaner cooking alternatives, and (iii) external institutions and norms that mediate the decision-making process. While in their review

Pachauri and Rao (2013) identify a lack of empirical evidence of women's power in decision-making, there has been some study of gender and decision-making of cooking fuel choice.

First and foremost, the cost of clean fuels is an important barrier to adoption in households. Especially in rural poor communities, liquidity constraints limit uptake and sustained usage of clean fuels (Beltramo, Levine, & Blalock, 2014; Lewis & Pattanayak, 2012; Rehfuess, Puzzolo, Stanistreet, Pope, & Bruce, 2014). Therefore, the authority to make financial decisions within a household is central to a transition to cleaner cooking. Miller and Mobarak (2013) use a randomized control trial of two intervention wood-burning stoves, one a health-improving chimney stove and the other a money-saving efficient stove, to study gender and intra-household decision-making and find that women, while having stronger preferences for any improved stove, lack the authority to make purchases. The importance of household wealth and the gender of household heads has been studied extensively using large nationwide or even cross-country microeconomic data. A study by Kishore and Spears (2014) briefly discussed the role of having a first born male child and intra-household decision-making in an analysis of urban households in the National Family Health Survey (NFHS-3) conducted in 2005–2006, finding that urban Indian households with a male first child are more likely to use clean cooking fuels like LPG but the authors were unable to establish that increased clean cooking fuel ownership came from increased women's status. Behera et al. (2015) use household survey data from India, Bangladesh, and Nepal and show that having a woman household head is positively associated with having an LPG stove. Other studies have shown similar findings in Bangladesh (Mottaleb, Rahut, & Ali, 2017), Bhutan (Rahut, Das, Groote, & Behera, 2014), Bolivia (Israel, 2002), China (Hou, Liao, & Huang, 2018; Zhang & Hassen, 2017), Ghana (Mensah & Adu, 2015), Kenya (van der Kroon, Brouwer, & van Beukering, 2014), Kolkata, India (Gupta & Köhlin, 2006), in a study using data from Ethiopia, Malawi, and Tanzania (Rahut, Behera, & Ali, 2016) and in a study using data from eight developing countries (Heltberg, 2004). In a limited number of studies women headed households have been less likely to have a clean cooking fuel (Ogwumike, Ozughalu, & Abiona, 2014). These studies provide robust evidence for women headed households choosing clean cooking fuels more than male headed households, but there are limited because they do not directly account for decision-making in households with both male and female heads.

Other studies have sought to assess decision-making or women's household power using other measures, including education, the number of or presence of a women in a household, and women's involvement in the labor force. Several studies have shown that women's education level is positively associated with increased clean cooking fuel ownership across multiple contexts (Farsi, Filippini, & Pachauri, 2007; Laxmi, Parikh, Karmakar, & Dabrase, 2003; Pandey & Chaubal, 2011; Peng, Zerriffi, & Pan, 2010). Increased women's education is often discussed as leading to a greater opportunity cost of the burden of solid fuel collection (Heltberg, 2004). Others have shown that women's involvement in formal employment or generation of income, used as a proxy for financial decision-making power, is positively associated with households having a clean cooking fuel (Israel, 2002; Sehjpal, Ramji, Soni, & Kumar, 2014). In addition, other studies have sought to estimate the impact of women in decision-making through the inclusion of the number of women in a household

or the proportion of household members that are female in regression models; results have sometimes shown positive associations with clean cooking (Rahut et al., 2016) and other times a negative association (Heltberg, 2005). While these studies have strong designs and analytic approaches, they remain indirect – and perhaps even non-associated – measures of decision-making. In short, there is very limited published quantitative empirical study of the role of women's decision-making power in clean cooking fuel choice, but there have been a few qualitative efforts.

A study in rural Kenya leveraged qualitative interviews of 30 cleaner biomass cookstove purchasers to discuss the impact of gender-power roles on the decision to adopt the stoves (Person et al., 2012). While cost was the primary barrier to stove adoption, women participants discussed the way in which their decisions were shaped by their husbands – who had comparatively less motivation for stove adoption because they are not involved with cooking or firewood collection. A mixed-methods study in Guatemala discussed LPG use, finding again that wealth has an important relationship with increased sustained LPG use (Thompson, Hengstermann, Weinstein, & Diaz-Artiga, 2018). Furthermore, the study discusses the role of men and women decision-makers and LPG adoption and use. Indeed, results indicate that men are household decision-makers the majority of the time but do not value LPG fuel purchases or stove repairs because they largely avoid the negative effects associated with wood smoke. These studies offer important indications of the relevance of gender in cleaner cooking technology adoption.

While cooking energy, technology, and economy are commonly considered men-dominated domains, we hypothesize that because women are primary cooks they will obtain the majority of the socio-economic and health benefits of clean cooking energy. First and foremost, due to their increased air pollution exposure, we expect that women's health will see greater benefits from reduced cooking-attributable emissions and household air pollution exposure. Furthermore, having a clean cooking fuel – like LPG – may alleviate the burden of solid fuel acquisition and processing (Behera et al., 2015; Laxmi et al., 2003; Parikh, 2011). Access to clean fuels also makes cooking more convenient and faster. For example, if the woman cook needs to prepare *chai* for a guest, doing so is much faster and easier using LPG than the traditional *chulha*. Thus, besides the health benefits, women value LPG for the convenience and speed of cooking, as well as the comparative cleanliness of their pots and walls that no longer have to be cleaned of soot as frequently (Hollada et al., 2017). Therefore, in households where the decision-maker is a woman, we expect that LPG will be adopted at higher rates than where the decision-maker is a man. At the same time, we recognize that there may be differences between households where the decision-maker is a woman and other households. By accounting for the differences between households where the decision-maker is a woman (like different income or education levels) in statistical analyses, we can directly assess the preferences and proclivity of women's decision's for their household's cooking fuel. We submit our primary research question as a hypothesis to test.

Hypothesis

Holding other relevant covariates of cooking fuel choice equal, households with women decision-makers are more likely to adopt LPG than households with men decision-makers.

3 Methods

Our research design seeks to isolate the association between household decision-making and LPG adoption in rural India. To achieve this goal, we use freely available data from the Access to Clean Cooking Energy and Electricity: Survey of States (ACCESS) survey.

3.1 Data

The survey was administered by MORSEL India Research and Development Private Ltd. and developed as a collaboration between Columbia University and the Council on Energy, Environment and Water and has been described at length elsewhere (Aklin, Cheng, Ganesan, et al., 2016; Aklin, Cheng, Urpelainen, Ganesan, & Jain, 2016; Jain et al., 2015). Briefly, the ACCESS survey was administered in 8,568 households in 51 districts of six states in a statistically-representative manner between November 2014 and January 2015 in Madhya Pradesh, Uttar Pradesh, Bihar, Jharkhand, and West Bengal and in May 2015 in Odisha. The 45-minute survey contains information on household lighting, electricity, and cooking. The survey was administered to the household head, or chief wage earner, when available except for the cooking module during which questions were posed to the primary household cook. Here, our primary outcome is LPG ownership ($N = 3$ households lost do lack of data on LPG ownership). In sum, the data we use come from a survey that contains a wealth of data on a large number of households across six large states with a total population of about half a billion people. For further details on the survey, see Section A1. Throughout, we employ sampling weights to make findings statistically-representative of the six states as well as adjust standard errors for the village-clustered sampling strategy.

This study adds to previous discussions of cooking in the ACCESS data by applying a careful analytic framework to explore both LPG adoption and use. Previously, Jain et al. (2015) provided a high-level and timely description of the ACCESS survey. Elsewhere, we demonstrate that LPG is a popular fuel in rural Indian households and predictive of overall cooking satisfaction (Baquié & Urpelainen, 2017). Then, we used a holistic approach to describe how LPG is used in households, triangulating findings using several metrics of household fuel use like cylinder purchase patterns, dishes cooked with LPG, and perceptions of LPG and solid fuels to discuss the integration of LPG into a household's overall cooking arrangements (Gould & Urpelainen, 2018).

3.2 Statistical Methods

We utilize regression analyses to test the association between the gender of the household decision-maker and LPG adoption. In our primary analyses, we utilize logistic regressions to investigate LPG adoption, accounting for possible overdispersion in the data using a quasi-binomial model, expressed in the following equation:

$$log\left(\frac{p}{1-p}\right)_{i,j,s} = \beta X_{i,j,s} + s + \epsilon_{i,j,s} \quad (1)$$

where β is the vector of coefficients, X is the vector of control variables described in Section 3.5, s is the vector of state dummy variables, ϵ is the error term with correlation structure based on the village-clustered sampling scheme. We specify models both with and without state dummy variables ($N = 6$), used to account for any systematic differences between states not captured in our covariates (for instance, stronger or weaker distribution networks). We observed no evidence of collinearity between covariates included in the models (see Section A2.2 for more information).

After presenting our main models, we carry out several supporting analyses (discussed further in Section 3.6). First, we assess the main results within each study state to assess heterogeneity in results across contexts. Second, we discuss reported reasons for not having LPG. Third, we report on overall satisfaction with cooking situations, by the gender of the respondent. Finally, we evaluate the use of LPG and firewood after LPG adoption.

For improved interpretability, we report regression results as average marginal effects, which can be interpreted as the effect of one-unit change in the covariate of interest (or if a binary variable the effect of that variable occurring as compared to not occurring) on the change of the probability of interest. For instance, an average marginal effect of 0.035 for having a woman decision-maker is interpreted as an 3.5 percentage point increase in the probability of a household having LPG as compared to not having a woman decision-maker.

All analyses were carried out in R (R Core Team, 2018). The package “survey” (Analysis of Complex Survey Samples) (Lumley, 2018) was used for survey-weighted analyses, the package “car” (Companion to Applied Regression) was used to calculate the Variance Inflation Factor for variables in regressions (Fox, 2018), and the package “margins” (Marginal Effects for Model Objects) (Leeper, 2018) was used to estimate and visualize model marginal effects.

3.3 Dependent Variable

The survey enumerators interviewed household heads and asked the following question: “Do you use domestic gas (LPG) for cooking?” In the full sample, 22% of all households have adopted LPG; Figure A2 shows a map of LPG adoption across study states and districts. The Indian national LPG program – now comprised of several distinct initiatives – began with Pratyaksh Hastantarit Labh (PAHAL) – Direct Benefits Transfer for LPG (DBTL) which enables a direct transfer of the LPG cylinder subsidy to bank accounts. The program was initially rolled out in November 2014 in some districts and then nationwide in January 2015. The subsidy has increased program efficiency, reduced leakage, and capped the purchase of subsidized cylinders at 12 per year per connection (Mittal, Mukherjee, & Gelb, 2017). Although increased program efficiency has freed up funds for the government to promote LPG through other programs, we do not expect that the program itself would have promoted LPG ownership in our study sample at the time of data collection. Nonetheless, any impacts

of the program would be limited to study households in Odisha, where data were collected in mid-2015, approximately five months after PAHAL–DBTL began in the state.

3.4 Explanatory Variables

To capture the effect of gender imbalances in decision-making, our primary explanatory variables are dummy variables for household decision-making by either (i) an adult woman or (ii) both an adult man and woman together. The original question from the survey is: "Who in your household makes decisions on purchase of durable goods?" The focus on durable goods is ideal for us, as an LPG connection and stove are essentially durable goods that have to be purchased by the household. This relationship between decision-making power and durable goods has been similarly utilized elsewhere (for example, (de Brauw, Gilligan, Hoddinott, & Roy, 2014; Doss, 2006; Li & Wu, 2011; Mohapatra & Simon, 2017)). In the sample, 5.6% of households have a woman decision-maker and 14.6% make decisions together. The rest are dominated by men. Importantly, this question captures a different subset than having a woman household head. Among study households, 5.0% of household heads were women (where the respondent reported to be a woman and the household head or where the respondent reported to be a man and the spouse of the household head), of which half were also sole decision-makers; similarly, half of reported women decision-makers were not household heads. In an additional analysis, we re-run our main analyses using a dummy variable for having a woman household head (reference: man household head) to test an alternative specification for capturing women's decision-making power.

3.5 Control Variables

Besides the primary variables of interest, we include the following explanatory variables to control for potential confounding. In selecting covariates, we draw on systematic reviews of improved and clean cookstove adoption literature (Lewis & Pattanayak, 2012; Muller & Yan, 2018; Rehfuess et al., 2014) and case studies.

- Monthly household expenditure (logarithmized): Previous studies have consistently demonstrated that wealthier households are more likely to use clean fuels (Muller & Yan, 2018). In the absence of accurate or representative monthly incomes, which are uncommon in rural poor population, monthly expenditure is often utilized as a proxy for wealth (Mobarak, Dwivedi, Bailis, Hildemann, & Miller, 2012). In our analysis, we utilize reported monthly expenditure, which has been logarithmized to account for the skewed data distribution.
- Number of adults living in the household: Household size can play an important role in defining cooking patterns and, as a result, decision-making regarding household energy choices. Household size is also an important factor in household economic models (Heltberg, 2004; Jan, 2012). In this dataset, adults are defined as over 18 years old.
- Number of children living in the household: In addition to the number of adults, the presence of children may play an important role in cooking patterns and decision-making around cooking practices, given the importance of child health

and the risks of the open burning of solid fuels (Mobarak et al., 2012; Pine et al., 2011). However, the direction of the association between the number of children and clean cooking fuel adoption remains context-dependent (Lewis & Pattanayak, 2012). In this dataset, children are defined as under 18 years old.

- Age of respondent: Age has been shown to affect household energy adoption decisions, though with inconsistent directions of associations (Jan, 2012; Muller & Yan, 2018). The respondent was the household head (74%) or their spouse (9%) in most cases.
- Hindu: Past studies in India have included religion as a covariate in cooking technology adoption (Bhojvaid et al., 2014; Kishore & Spears, 2014; Lewis & Pattanayak, 2012). Religion may define specific cooking patterns or dishes, as well as impact other important factors like socio-economic status and social networks. Baseline category is Muslim, a minority in India and in our sample.
- Caste group: scheduled caste, scheduled tribe, other backward caste.[1] The caste system has wide-reaching impacts on households in terms of defining economic status factors as well as socio-cultural context that could mediate the clean cooking technology adoption process (Bhojvaid et al., 2014). The baseline category is the government category of general/forward caste.
- Household head education: up to 5th standard, more than 5th standard. Education is a potentially powerful covariate in household energy decision-making (Lewis & Pattanayak, 2012; Mobarak et al., 2012). Educational achievement can be tied to socio-economic status as well as greater knowledge of the health risks of solid fuel burning. Baseline category is no formal education at all. The ACCESS survey collected three additional categories of educational achievement (up to 10th standard, 12th standard or diploma, and Graduate and above) that have been collapsed into the single indicator “more than 5th standard” due to similarity in other household characteristics and small sample sizes in higher educational categories.

As the Table 1 shows, the sample has considerable variation along demographics, economic variables, and indicators of social status. Three-quarters of the study households derive their primary source of income from agriculture on their own land or as day laborers. About two-fifths of the study sample have a Below Poverty Line ration card, with an equal number having an Above Poverty Line ration card. Two-thirds of study households used grid electricity for lighting, one-third reported to have a toilet, and less than one in ten households had piped water. Aklin, Cheng, Urpelainen, et al. (2016) compare the sample to representative household surveys conducted by the National Sample Survey Organization of India and find that the ACCESS survey adequately represents the population.

In turn, Figure 1 shows the distribution of LPG adoption by different categorical explanatory variables. Variables such as education, high caste status (general caste), and women decision-makers are associated with higher LPG adoption.

[1]Muslims in the study sample also have castes: 61% self-report as other backward caste and 39% as general caste.

Next, Figure 2 shows the distribution of LPG adoption for different continuous explanatory variables. The household head's age shows little association with LPG adoption; however, the number of adults as well as household expenditure are positively association with LPG adoption.

We then investigated variations between households with different decision-making structures. Table 2 shows relative similarities between these households. Notably, households with women decision-makers are less educated than their man decision-maker counterparts.

3.6 Supporting Analyses of LPG Adoption Across States, LPG Non-Adoption, Cooking Satisfaction, and Fuel Use

We carried out four additional analyses to discuss LPG adoption, non-adoption, cooking satisfaction, and cooking fuel use (see Section A2.1 for full discussion of methods):

State-by-State Analysis—A strength of the ACCESS data is the wide variety of socio-economic, cultural, and geographic contexts captured across the six study states. We assess the heterogeneity of findings across study states by carrying out the main results' analysis within each study state.

LPG Non-Adoption—The factors related to the non-adoption of LPG have received much attention recently, including in a recent effort to analyze efforts to scale-up clean cooking fuels around the world through 11 distinct country case studies and a systematic review (Puzzolo, Pope, Stanistreet, Rehfuess, & Bruce, 2016; Quinn et al., 2018). We describe the distribution of reported reasons for not having LPG by household decision-maker, the total number of reasons reported, and extend our regression framework to explore potential associations of covariates with individual reasons for not having LPG.

Overall Cooking Satisfaction—We describe the associations that gender and LPG use have with overall cooking satisfaction to help describe the changes that occur with LPG in a household. Respondents were asked: "Overall, how satisfied are you with your primary cooking arrangement?" Responses were coded into Unsatisfied (1), Neutral (2), and Satisfied (3).

Cooking Fuel Use—Finally, we discuss the determinants of cooking fuel use using three outcomes. First, do households owning LPG report it to be their primary cooking fuel? Second, how much LPG is used in adopting households? Third, how much firewood is used in households? First, we assess the association of our regression covariates with each of the three primary outcomes, accounting for State dummy variables. Then, we incorporate into our regression analyses additional covariates that describe the various costs of each cooking fuel: cost of a large LPG cylinder purchased from the market, one-way distance to acquire an LPG cylinder (in kilometers), one-way distance to collect firewood (in kilometers), and whether a household mostly collects firewood as compared with mostly purchasing firewood. Further information about these analyses is available in Section A7.

4 Results

Having described the data, we now turn to the regression results, which are summarized in Table 3 showing average marginal effects and Figure A1 showing conditional marginal effects, which visualize the distribution of the marginal effects across the distribution of the covariate of interest. The six models differ only depending on the inclusion of different variables and dummy variables for all but one state (Jharkhand is the reference because it has the lowest fraction of households owning LPG).

The results provide robust support for the importance of gender-equal decision-making norms. In models 1–2, when control variables are not included, the coefficient for a woman decision-maker is positive, with an increase in the probability of LPG adoption of 3.5 percentage points relative to a man-dominated household. For households that share decision-making, the probability of LPG adoption is indistinguishable from men-dominated households. In models 3–4, we include only the control variables to set the stage for a multi-variable evaluation. Here we see that our models replicate the standard predictions from the literature. A household's monthly expenditure is very strongly positively associated with LPG adoption – especially evidenced in conditional probability plots in Figure A1 – as are higher levels of education. The traditionally disadvantaged groups, in particular scheduled caste and scheduled tribe populations, have much lower probabilities of using LPG. We also see small positive associations with the number of adults and small negative associations with the number of children, as well as a positive but weak association between the household head's age and LPG adoption. When we include all variables in models 5–6, we see that the inclusion of control variables actually *strengthens* the association between gender-equal decision-making and LPG adoption. The coefficients are now higher, such that probability of LPG adoption increases between 3.1–5.4 percentage points for shared decision-making and between 8.0–9.1 percentage points for women-led households.

To summarize, we show that households with women decision-makers have an 8 percentage points higher probability of having LPG as compared to households with men decision-makers, after controlling for a number of covariates and state dummy variables. Furthermore, the coefficients for the control variables do not change much, suggesting that our results are stable regardless of how we specify the models. We additionally demonstrate the robustness of our findings by including village dummy variables ($N = 714$) with no significant effect to the main results (Section A4 of Supplementary Information). Using an alternative specification of women's decision-making power in the household, Table A2 show very comparable results to our main analyses where having a woman household head is associated with a 8.0–9.9 percentage point increase in the probability of having LPG as compared to having a man household head.

4.1 State-by-State Results

The inclusion of state dummy variables demonstrates the stability of our results to potential uncontrolled state-level confounding. Furthermore, the results shown in Table 3 show that the state dummy variables have large and statistically significant average marginal effects, suggesting that their inclusion is paramount for achieving accurate assessments of the associations between decision-making covariates and LPG adoption across the study states.

Re-assessing our main results within each study state reveals heterogeneity in our findings (Table A4). Having a woman decision-maker increases the probability of LPG adoption between 4.8–17.9 percentage points across five study states, though in some of the states the association did not reach statistical significance at $P < 0.05$. In Bihar there is a small negative association, perhaps owing to inherent state-level differences in women's status and empowerment that are not captured in the data. Higher monthly expenditure and increased educational attainment of the household head remained strongly positively associated with LPG adoption in all study states.

4.2 Reasons for LPG Non-Adoption

High installation and fuel costs are overwhelmingly reported as reasons for LPG non-adoption (Table 4). We observe the households with women decision-makers have a lower probability of reporting any reason for LPG non-adoption as compared to their man-led decision-making counterparts (Table A5). Households with women decision-makers report fewer reasons overall for LPG non-adoption in comparison to the other types of households (Table A6). These lower numbers likely explain negative associations between having a woman decision-maker and reported reasons for non-adoption. In addition, households with higher monthly expenditure and greater educational attainment have a lower probability of having reported high installation cost or high monthly fuel costs as a reason for LPG non-adoption. Importantly, we also observe that households where the household head has obtained "up to 5th Standard" and "more than 5th Standard" education have a 15 percentage point and 49 percentage point lower probability of citing a lack of information as a reason for LPG non-adoption as compared to households with no formal education, respectively.

The clear importance of financial barriers to LPG adoption – both installation and fuel costs – has been noted in India. Since the data for the present study were collected in 2014–2015, several national efforts to promote LPG have become fully operational, the largest of which is *Pradhan Mantri Ujjawala Yojana* that offers free LPG connections to below poverty line households (Smith, 2018). Still, there is some evidence that households may remain limited by financial constraints and continue to use solid fuels after the adoption of LPG. The results shown in Table A5 show important geographic heterogeneity, with dummy variables showing that the reasons for not having LPG vary across study states. For example, with Jharkhand as the reference state, a household being in Madhya Pradesh has a lower probability of reporting that LPG is unavailable or that they lack information about how to acquire LPG but a higher probability of reporting the monthly cost of LPG cylinders as a reason for not having LPG. Finally, we suggest that the negative association between increased education and reporting lack of information as a reason for not having LPG is an indication of education leading to greater acquisition of health-improving knowledge.

4.3 Overall Cooking Satisfaction

Results shown in Table 5 demonstrate that men are more satisfied with their primary cooking arrangement than women (LPG households: $P = 0.001$, non-LPG households: $P = 0.011$) and that LPG users are more satisfied than non-LPG users ($P < 0.001$). Higher baseline (non-LPG households) cooking satisfaction may be important to explaining why men-dominated households are less likely to adopt LPG. Given that men-dominated

households are more satisfied with their cooking arrangement even in the absence of LPG, we may hypothesize that they have comparatively fewer reasons to incur the cost of adopting LPG. Somewhat surprisingly, though, we do not observe differential improvements in satisfaction with LPG usage among women as compared to men. When men-dominated households do adopt LPG, they report the same amount of improvement from the clean fuel as households with equal or woman-dominated decision-making.

4.4 Cooking Fuel Use

Having discussed LPG adoption and cooking satisfaction, we now discuss cooking fuel use and explore associations of covariates with fuel use after LPG adoption. LPG was reported to be the primary fuel in 59% of LPG-owning households. Figure A3 shows the distribution of kilograms of LPG and firewood used per month per person in study households. After adoption, households use a median of 1.29 kg/month/capita of LPG (1.69 kg/month/capita when it is a primary cooking fuel and 0.89 kg/month/capita when it is a supplemental fuel). As expected, households with LPG reported to use significantly less firewood per capita than households without LPG (Has LPG: 4.67 kg/week/capita; No LPG: 7.14 kg/week/capita). Nevertheless, exclusive clean cooking fuel remains rare in the study sample (4%).

Table 6 hows the results of our regression analyses with cooking fuel use outcomes. We see that among LPG-owning households, having a woman decision-maker is not statistically significant association with using LPG as the primary cooking fuel (Regressions 1–2). We see that increased education of the household head is also positively associated with using LPG as the primary cooking fuel. We observe similar trends when exploring associations of covariates with LPG use: a positive association between having a woman decision-maker and LPG use that does not reach statistical significance ($P = 0.12$ and $P = 0.16$) and a significant positive relationship between increased education and LPG use. Education of the household head is significantly negatively associated with firewood use (10% lower kilograms of firewood used per week). Household size (in terms of number of adults and number of children as distinct variables) is negatively associated with using LPG as the primary cooking fuel, but positively associated with overall measures of fuel use both for LPG and firewood.

In Tables A7 and A8, we introduce two important factors to LPG use as covariates: the cost of a large LPG cylinder (in 100 Indian rupee increments) and the one-way distance to acquire LPG cylinders (in kilometers). Results show that cylinder cost and access do not appear to be significantly associated with a household's decision to elevate LPG to the primary cooking fuel in a household and display a weak negative association with LPG use in kilograms per month. Having a woman decision-maker was not statistically significantly associated with using LPG as the primary cooking fuel ($P = 0.25$) and or LPG used in a month ($P = 0.11$). Increased education remains significantly associated with increased LPG use after accounting for these cost variables (13.1% more LPG kilograms per month, $P = 0.01$).

We turn to the use of firewood in Tables A9 and A10. Having LPG is significantly negatively associated with firewood use (kg/month) even after including covariates that account for socio-economic differences between LPG-owning and non-LPG owning

households (37.6% less kilograms of firewood per month). Furthermore, having a woman decision-maker was associated with using 6.8% less firewood per month among all firewood-using households. Among households without LPG, though, gender of the decision-maker was not significantly associated with overall firewood use. Next, we assess the associations between various measures of fuel costs – both LPG and firewood fuel costs and access – with overall firewood use. Increased burden of LPG acquisition – per one-kilometer increase in travel distance to acquire an LPG cylinder – was suggestively associated with a 0.7% increase in overall firewood use ($P = 0.06$) in univariate regressions, with the magnitude of association unchanged in multivariable models. Remarkably, households with women decision-makers used 20.6% less firewood per month in comparison to men decision-maker households ($P = 0.03$).

5 Conclusion

Most analysis of energy poverty focuses on the household level, but different household members reap varying gains from investing in modern energy. We use household survey data from rural India to investigate how decision-making structures within households influence the adoption of LPG. We have found robust evidence that households with traditional, man-dominated decision-making are less likely to adopt LPG stoves than households with equal or woman-dominated decision-making on durable goods. Consistent with other assessments of the determinants of LPG adoption, we also show that wealthier households and households where the head of household is more educated are more likely to adopt LPG.

The results from this study add an important and previously under-appreciated explanation for variation in LPG adoption. In rural areas, many households follow the traditional patriarchal society, with a man household head controlling the assets and important decisions of all household members. Because the man decision-maker is typically not responsible for cooking and often works outside the house, he has less incentive to adopt modern cooking fuels that are clean and convenient to use. Furthermore, we show that men have greater overall satisfaction with their cooking arrangement than women among households with no LPG usage, providing suggestive evidence that they may be less inclined to invest in a clean cooking stove. While we do not explicitly explore the reasons for higher overall satisfaction among men, elsewhere it has been reported that men may not perceive women's daily duties, like firewood collection, to be as challenging as their own labor duties (Jackson, 1999); in short, men may not feel the burden of cooking with solid fuels as much as women. Our results show that accounting for household decision-making structures can explain variation in LPG adoption, and thus provide new insights into why almost three billion people continue to live in households that rely on traditional biomass.

We also explore the determinants of cooking fuel use in households, a crucial aspect of obtaining the benefits of a clean cooking transition in the long-term. Here, several narratives emerge. First, although having a woman decision-maker is significantly positively associated with LPG adoption, the weak positive association between gender of the decision-maker is not statistically significantly associated with increased LPG use – either in terms of LPG being the household's primary cooking fuel or in terms of kilograms per month purchased. However, we do observe that increased education of the head of the household and monthly

expenditures are consistently positively associated with increased LPG use. Second, the cost of LPG in terms of cylinder direct costs and one-way distance to acquire LPG cylinders are marginally negatively associated with LPG use. Importantly, even after accounting for these clean cooking fuel costs, we see that education remains positively associated with increased LPG use. In addition, consistent with expectations, we observe that households with LPG report to consume significantly less firewood than non-LPG households, accounting for all covariates. Remarkably, we also observe that having a woman decision-maker is associated with decreased firewood use after the adoption of LPG, as is increased education of the household head. We also find that measures of the cost of LPG – including the cost of a cylinder and the distance required to acquire a cylinder – are positively associated with reported firewood use, indicating that high economic burdens of clean fuel use may be associated with higher continued reliance on traditional stoves, as reported elsewhere in India and around the world (Gould et al., 2018; Krishnapriya & Somanathan, 2016; Puzzolo et al., 2016). Many of the benefits of clean cooking fuel adoption are only reaped when clean cooking fuels are used long-term as the primary household cooking fuel, and in tandem with a substantial reduction or elimination of the use of traditional biomass-burning stoves. Here we provide preliminary evidence for reduced firewood use after LPG adoption, which may lead to time use savings, reduced drudgery, and improvements in overall well being from reduced firewood collection burdens, cooking times, and cleaning tasks.

A limitation of this study is that the primary explanatory variable is derived from a single self-reported question. However, we consider this question to be a valid indicator of women's decision-making power in relevant context because we expect LPG stoves to be purchased similarly to other durable goods because they are long-term investments and that decisions to purchase durable goods are consistent across different goods. Furthermore, we demonstrate that an alternative specification using a dummy variable for having a women household head yields very similar results to our main approach despite women household heads being decision-makers only in half of study households. Still, a binary measure of women's involvement in decision-making is limited (Munoz Boudet et al., 2018). Alternative approaches to assessing women's decision-making, agency, and empowerment may be useful for future studies of gender and cooking fuel choice (Ballon & Yalonetzky, 2018). Elsewhere, studies have sought to capture the demographic and economic dimensions of household decision-making and intra-household bargaining, such as accounting for marital status, parenthood, individual asset ownership, individual consumption, or nutrition (Munoz Boudet et al., 2018). Some ongoing studies in Ghana (Carrión et al., 2018) and Guatemala (Thompson, Diaz-Artiga, Weinstein, & Handley, 2018) are taking alternative approaches to assess household decision-making, including directly asking about decisions to purchase LPG stoves and LPG cylinders or defining household decision-making through experimental designs assessing intra-household bargaining and/or resource allocation.

An additional limitation is that while the consistency of LPG cylinder sizes means that assessing the amount of LPG used in household is precise, assessing the use of firewood in a continuous measure through self-reported measures may be challenging for participants. An alternative approach may be for studies to determine locally-appropriate measures of firewood amounts (e.g., armful) that can be weighed to establish a conversion factor to kilograms (Adrianzén, 2013). In this study we include access to fuels as a continuous

covariate, with our implicit assumption being that the further a household has to travel the greater the inconvenience and cost. Therefore, whether it be LPG or firewood, households for whom access is more limited will seek to reduce their use of the fuel in favor of an alternative. While in many places it is reported that fuel collection is a time-consuming and burdensome activity (World Health Organization, 2018), elsewhere it has been reported that instead fuel collection is spent enjoying friends and family (Thompson, Hengstermann, et al., 2018). Future studies may ask participants to discuss their experiences with fuel collection to assess its potential positive, neutral, or negative impacts.

From a practical perspective, changing gender norms within households in rural communities is a difficult and slow-moving process. For example, we observe differential associations between gendered decision-making and LPG adoption across study states, which could indicate that having a role in decision-making may imply different levels of bargaining power or agency for women across geographic contexts. When gender imbalances in decision-making power within households impede LPG adoption, profound socio-cultural changes are necessary to remove this impediment to adoption. Such changes are difficult and take a long time. In this regard, the robust association between gender equality and LPG adoption does not mean that interventions for women's empowerment would necessarily solve the clean cooking fuel problem in the short or medium run. And yet, recognizing the importance of gender in the adoption of household energy technologies can inform interventions to promote the use of clean cooking fuels. Such interventions would benefit from engaging the women beneficiaries of clean cooking fuels, perhaps by offering subsidies or loans to them for cookstove adoption and use (e.g., (Pillarisetti et al., 2018)) or through agency-based empowerment training to increase women's involvement in the clean cooking sector (e.g., (Shankar, Onyura, & Alderman, 2015)). The interventions could also specifically target women in marketing and consumer awareness campaigns. Indeed, a key tenet of India's national LPG program – especially Pradhan Mantri Ujjwala Yojana (PMUY) which has reached more than 70 million households since 2016 – is enhancing women's status and the alleviation of drudgery through cleaner cooking (Ministry of Petroleum & Natural Gas & Government of India, 2019). Through PMUY, women are qualified to receive a subsidized LPG connection, cylinder, and regulator to set up LPG in their household. As long as LPG remains a product that people find appealing, spreading information and awareness can make a positive difference. Even in villages and households with patriarchal gender norms, interventions that specifically empower women to make decisions related to cooking and other gendered aspects of daily life hold promise. Future studies and subsequent rounds of the ACCESS survey can directly assess the impacts of gendered decision-making on LPG adoption and use within the parameters of the Indian LPG program.

Clean cooking fuel use is receiving more attention around the world in the form of government programs, policies, and research. Indeed, access and use of LPG is being transformed in India through substantial government investment. This study is timely and shows that LPG promotion should respond to the gendered nature of cooking in rural households. Furthermore, we show that LPG use may increase with improved access and reduced cylinder costs. Although LPG adoption is significantly associated with reduced firewood use, fuel stacking remains the norm among study households. Future studies may

carefully investigate the motivations for continued solid fuel use after clean cooking fuel adoption and study enablers of reduced solid fuel use.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors recognize support from NIH grants #R25GM62454 and #T32ES023770 to CFG. We thank Sandra Baquié for excellent comments. Replication data and code for this publication is available.

References

Adrianzén MA (2013, 5). Improved cooking stoves and firewood consumption: Quasi-experimental evidence from the northern peruvian andes. Ecological Economics, 89 , 135–143.

Aklin M, Cheng C, Ganesan K, Jain A, Urpelainen J, & Council on Energy, Environment and Water. (2016). Access to clean cooking energy and electricity: Survey of states in India (ACCESS). (Harvard Dataverse, V1 10.7910/DVN/0NV9LF)

Aklin M, Cheng C, Urpelainen J, Ganesan K, & Jain A (2016). Factors affecting household satisfaction with electricity supply in rural India. Nature Energy , 1 , 16170.

Alexander DA, Northcross A, Karrison T, Morhasson-Bello O, Wilson N, Atalabi OM, . . . Olopade CO (2018, 2). Pregnancy outcomes and ethanol cook stove intervention: A randomized- controlled trial in Ibadan, Nigeria. Environment International , 111 , 152–163. [PubMed: 29216559]

Alexander DA, Northcross A, Wilson N, Dutta A, Pandya R, Ibigbami T, . . . Olopade CO (2017, 6). Randomized controlled ethanol cookstove intervention and blood pressure in pregnant Nigerian women. American Journal of Respiratory and Critical Care Medicine, 195 (12), 1629–1639. [PubMed: 28081369]

Balakrishnan K, Dey S, Gupta T, Dhaliwal RS, & et al., M. B. (2019, 1). The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: The Global Burden of Disease Study 2017. The Lancet Planetary Health, 3 (1), e26–e39. [PubMed: 30528905]

Ballon P, & Yalonetzky G (2018, 5). Introduction to special section: Quantitative approaches to the measurement and analysis of female empowerment and agency. The Journal of Development Studies, 54 (8), 1279–1283.

Baquié S, & Urpelainen J (2017). Access to modern fuels and satisfaction with cooking arrangements: Survey evidence from rural India. Energy for Sustainable Development , 38 , 34–47.

Behera B, Rahut DB, Jeetendra A, & Ali A (2015, 6). Household collection and use of biomass energy sources in south Asia. Energy , 85 , 468–480.

Beltramo T, Levine DI, & Blalock G (2014). The effect of marketing messages, liquidity constraints, and household bargaining on willingness to pay for a nontraditional cookstove. University of California, Berkeley (Center for Effective Global Action Working Paper Series No. WPS-035)

Bhojvaid V, Jeuland M, Kar A, Lewis JJ, Pattanayak SK, Ramanathan N, . . . Rehman IH (2014). How do people in rural India perceive improved stoves and clean fuel? Evidence from Uttar Pradesh and Uttarakhand. International Journal of Environmental Research and Public Health, 11 (2), 1341–1358. [PubMed: 24473110]

Blackden CM, & Wodon Q (2006). Gender, time use, and poverty in sub-Saharan Africa (Vol. 73). Washington, DC, USA: World Bank Publications.

Bruce N, Perez-Padilla R, & Albalak R (2000). Indoor air pollution in developing countries: A major environmental and public health challenge. Bulletin of the World Health Organization, 78 , 1078–1092. [PubMed: 11019457]

Carrión D, Dwommoh R, Tawiah T, Agyei O, Agbokey F, Twumasi M, . . . Asante KP (2018, 6). Enhancing LPG adoption in Ghana (ELAG): A factorial cluster-randomized controlled trial to

enhance LPG adoption & sustained use. BMC Public Health, 18 (1), 689–701. [PubMed: 29866127]

Clancy JS, Skutsch M, & Batchelor S (2003). The gender-energy-poverty nexus. United Kingdom (United Kingdom Department for International Development Project)

de Brauw A, Gilligan DO, Hoddinott J, & Roy S (2014, 7). The impact of Bolsa Família on women's decision-making power. World Development , 59 , 487–504.

Doss C (2006, 3). The effects of intrahousehold property ownership on expenditure patterns in Ghana. Journal of African Economies, 15 (1), 149–180.

Farsi M, Filippini M, & Pachauri S (2007, 11). Fuel choices in urban Indian households. Environment and Development Economics, 12 (06).

Fox J (2018). Package 'car': Companion to applied regression. Retrieved from https://cran.r-project.org/web/packages/car/index.html

Gould CF, Schlesinger S, Toasa AO, Thurber M, Waters WF, Graham JP, & Jack DW (2018, 10). Government policy, clean fuel access, and persistent fuel stacking in Ecuador. Energy for Sustainable Development , 46 , 111–122. [PubMed: 30294142]

Gould CF, & Urpelainen J (2018, 11). LPG as a clean cooking fuel: Adoption, use, and impact in rural India. Energy Policy , 122 , 395–408.

Gupta G, & Köhlin G (2006, 4). Preferences for domestic fuel: Analysis with socio-economic factors and rankings in Kolkata, India. Ecological Economics, 57 (1), 107–121.

Heltberg R (2004). Fuel switching: Evidence from eight developing countries. Energy Economics, 26 (5), 869–887.

Heltberg R (2005, 6). Factors determining household fuel choice in Guatemala. Environment and Development Economics, 10 (3), 337–361.

Hollada J, Williams K, Miele C, Danz D, Harvey S, & Checkley W (2017, 2). Perceptions of improved biomass and liquefied petroleum gas stoves in Puno, Peru: Implications for promoting sustained and exclusive adoption of clean cooking technologies. International Journal of Environmental Research and Public Health, 14 (2), 182.

Hou B, Liao H, & Huang J (2018, 5). Household cooking fuel choice and economic poverty: Evidence from a nationwide survey in China. Energy and Buildings, 166 , 319–329.

Israel D (2002). Fuel choice in developing countries: Evidence from Bolivia. Economic Development and Cultural Change, 50 (4), 865–890.

Jackson C (1999, 10). Mens work, masculinities and gender divisions of labour. Journal of Development Studies, 36 (1), 89–108.

Jain A, Ray S, Ganesan K, Aklin M, Cheng C, & Urpelainen J (2015). Access to clean cooking energy and electricity: Survey of states. New Delhi, India (Council on Energy, Environment and Water)

Jan I (2012). What maked people adopt improved cookstoves? Empirical evidence from rural Northwest Pakistan. Renewable and Sustainable Energy Reviews, 16 (5), 3200–3205.

Kishore A, & Spears D (2014). Having a son promotes clean cooking fuel use in urban India: Women's status and son preference. Economic Development and Cultural Change, 62 (4), 673–699.

Köhlin G, Sills EO, Pattanayak SK, & Wilfong C (2011). Energy, gender and development: What are the linkages? Where is the evidence? Washington, DC, USA (Policy Research Working Papers (no. WPS 5800), World Bank)

Krishnapriya P, & Somanathan R (2016). Fuel choices and respiratory health in India. The Indian Journal of Economics, 97 (384), 75–86.

Lambe F, Jürisoo M, Wanjiru H, & Senyagwa J (2015). Bringing clean, safe, affordable cooking energy to households across Africa: An agenda for action. Stockholm, Sweden and Nairobi, Kenya Retrieved from https://newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2016/04/NCE-SEI-2015-Transforming-household-energy-sub-Saharan-Africa.pdf (Prepared by the Stockholm Environment Institute Paper for the New Climate Economy)

Lambrou Y, & Piana G (2006). Energy and gender issues in rural sustainable development. Rome, Italy Retrieved from http://www.fao.org/docrep/pdf/010/ai021e/ai021e00.pdf (Food and Agriculture Organization of the United Nations)

Laxmi V, Parikh J, Karmakar S, & Dabrase P (2003, 3). Household energy, womens hardship and health impacts in rural Rajasthan, India: Need for sustainable energy solutions. Energy for Sustainable Development , 7 (1), 50–68.

Lee AG, Kaali S, Quinn A, Delimini R, Burkart K, Opoku-Mensah J, . . . Asante KP (2019, 3). Prenatal household air pollution is associated with impaired infant lung function with sex-specific effects: Evidence from GRAPHS, a cluster randomized cookstove intervention trial. American Journal of Respiratory and Critical Care Medicine, 199 (6), 738–746. [PubMed: 30256656]

Leeper TJ (2018). margins: Marginal effects for model objects. (R package version 0.3.23)

Lewis JJ, & Pattanayak SK (2012). Who adopts improved fuels and cookstoves? A systematic review. Environmental Health Perspectives, 120 (5), 637. [PubMed: 22296719]

Li L, & Wu X (2011). Gender of children, bargaining power, and intrahousehold resource allocation in China. Journal of Human Resources, 46 (2), 295–316.

Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, . . . others (2013). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: A systematic analysis for the Global Burden of Disease Study 2010. The Lancet , 380 (9859), 2224–2260.

Lumley T (2018). Package 'survey': Analysis of complex survey samples. Retrieved from http://r-survey.r-forge.r-project.org/survey/

Mensah JT, & Adu G (2015). An empirical analysis of household energy choice in Ghana. Renewable and Sustainable Energy Reviews, 51 , 1402–1411.

Miller G, & Mobarak AM (2013). Gender differences in preferences, intra-household externalities, and low demand for improved cookstoves. Cambridge, MA, USA (National Bureau of Economic Research Working Paper Series)

Ministry of Petroleum & Natural Gas, & Government of India. (2019). Pradhan mantri ujjwala yojana. Retrieved from http://www.pmujjwalayojana.com/ (Official Website)

Mittal N, Mukherjee A, & Gelb A (2017, 12). Fuel subsidy reform in developing countries: Direct benefit transfer of lpg cooking gas subsidy in India. Retrieved from https://www.cgdev.org/sites/default/files/fuel-subsidy-reform-developing-countries-india.pdf (Center for Global Development Policy Paper)

Mobarak AM, Dwivedi P, Bailis R, Hildemann L, & Miller G (2012). Low demand for nontraditional cookstove technologies. Proceedings of the National Academy of Sciences, 109 (27), 10815–10820.

Mohapatra S, & Simon L (2017). Intra-household bargaining over household technology adoption. Review of Economics of the Household , 15 (4), 1263–1290.

Mottaleb KA, Rahut DB, & Ali A (2017, 9). An exploration into the household energy choice and expenditure in Bangladesh. Energy , 135 , 767–776.

Muller C, & Yan H (2018, 2). Household fuel use in developing countries: Review of theory and evidence. Energy Economics, 70 , 429–439.

Munoz Boudet AM, Buitrago P, Leroy De La Briere B, Newhouse DL, Rubiano Matulevich EC, Scott K, & Suarez Becerra P (2018). Gender differences in poverty and household composition through the life-cycle: A global perspective (No. WPS8360). Retrieved from http://documents.worldbank.org/curated/en/135731520343670750/Gender-differences-in-poverty-and-household-composition-through-the-life-cycle-a-global-perspective

Ogwumike FO, Ozughalu UM, & Abiona GA (2014). Household energy use and determinants: Evidence from Nigeria. International Journal of Energy Economics and Policy , 4 (2), 248–262.

Pachauri S, & Rao ND (2013). Gender impacts and determinants of energy poverty: Are we asking the right questions? Current Opinion in Environmental Sustainability , 5 (2), 205–215.

Pandey VL, & Chaubal A (2011, 11). Comprehending household cooking energy choice in rural India. Biomass and Bioenergy , 35 (11), 4724–4731.

Parikh J (2011, 12). Hardships and health impacts on women due to traditional cooking fuels: A case study of Himachal Pradesh, India. Energy Policy , 39 (12), 7587–7594.

Peng W, Zerriffi H, & Pan J (2010, 9). Household level fuel switching in rural Hubei. Energy for Sustainable Development , 14 (3), 238–244.

Person B, Loo JD, Owuor M, Ogange L, Jefferds MED, & Cohen AL (2012, 4). “It is good for my family’s health and cooks food in a way that my heart loves”: Qualitative findings and implications for scaling up an improved cookstove project in rural Kenya. International Journal of Environmental Research and Public Health, 9 (5), 1566–1580. [PubMed: 22754457]

Pillarisetti A, Gill M, Allen T, Madhavan S, Dhongade A, Ghorpade M, . . . Smith KR (2018, 10). A low-cost stove use monitor to enable conditional cash transfers. EcoHealth, 15 (4), 768–776. [PubMed: 30315510]

Pine K, Edwards R, Masera O, Schilmann A, Marrón-Mares A, & Riojas-Rodríguez H (2011). Adoption and use of improved biomass stoves in rural Mexico. Energy for Sustainable Development , 15 (2), 176–183.

Puzzolo E, Pope D, Stanistreet D, Rehfuess EA, & Bruce NG (2016). Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use. Environmental Research, 146 , 218–234. [PubMed: 26775003]

Quinn AK, Bruce N, Puzzolo E, Dickinson K, Sturke R, Jack DW, . . . Rosenthal JP (2018). An analysis of efforts to scale up clean household energy for cooking around the world. Energy for Sustainable Development .

R Core Team. (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria Retrieved from https://www.R-project.org/

Rahut DB, Behera B, & Ali A (2016, 12). Patterns and determinants of household use of fuels for cooking: Empirical evidence from Sub-Saharan Africa. Energy , 117 , 93–104.

Rahut DB, Das S, Groote HD, & Behera B (2014, 5). Determinants of household energy use in Bhutan. Energy , 69 , 661–672.

Rehfuess EA, Puzzolo E, Stanistreet D, Pope D, & Bruce NG (2014). Enablers and barriers to large-scale uptake of improved solid fuel stoves: A systematic review. Environmental Health Perspectives, 122 (2), 120. [PubMed: 24300100]

Sehjpal R, Ramji A, Soni A, & Kumar A (2014, 4). Going beyond incomes: Dimensions of cooking energy transitions in rural India. Energy , 68 , 470–477.

Shankar AV, Onyura M, & Alderman J (2015). Agency-based empowerment training enhances sales capacity of female energy entrepreneurs in Kenya. Journal of Health Communication, 20 (Sup1), 67–75. [PubMed: 25839204]

Silwal AR, & McKay A (2015, 8). The impact of cooking with firewood on respiratory health: Evidence from Indonesia. Journal of Development Studies, 51 (12), 1619–1633.

Smith KR (2018). Making of new India: Transformation under modi government. In Bibek Debroy KD Anirban Ganguly (Ed.), (pp. 401–410). Wisdom Tree.

Smith KR, Bruce N, Balakrishnan K, Adair-Rohani H, Balmes J, Chafe Z, . . . others (2014). Millions dead: How do we know and what does it mean? Methods used in the Comparitive Risk Assessment of household air pollution. Annual Review of Public Health, 35 , 185–206.

Smith KR, McCracken JP, Weber MW, Hubbard A, Jenny A, Thompson LM, . . . Bruce N (2011). Effect of reduction in household air pollution on childhood pneumonia in guatemala (respire): A randomised controlled trial. The Lancet , 378 (9804), 1717–1726.

Stanaway JD, Afshin A, Gakidou E, Lim SS, & et al., D. A. (2018, 11). Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. The Lancet , 392 (10159), 1923–1994.

Thompson LM, Diaz-Artiga A, Weinstein JR, & Handley MA (2018, 2). Designing a behavioral intervention using the COM-b model and the theoretical domains framework to promote gas stove use in rural Guatemala: A formative research study. BMC Public Health, 18 (1).

Thompson LM, Hengstermann M, Weinstein JR, & Diaz-Artiga A (2018, 9). Adoption of liquefied petroleum gas stoves in Guatemala: A mixed-methods study. EcoHealth.

van der Kroon B, Brouwer R, & van Beukering PJ (2014, 7). The impact of the household decision environment on fuel choice behavior. Energy Economics, 44 , 236–247.

World Health Organization. (2018, 5). Household air pollution and health. Geneva, Switzerland Retrieved from http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health (World Health Organization Fact Sheet)

Zhang X-B, & Hassen S (2017, 4). Household fuel choice in urban China: Evidence from panel data. Environment and Development Economics, 22 (04), 392–413.

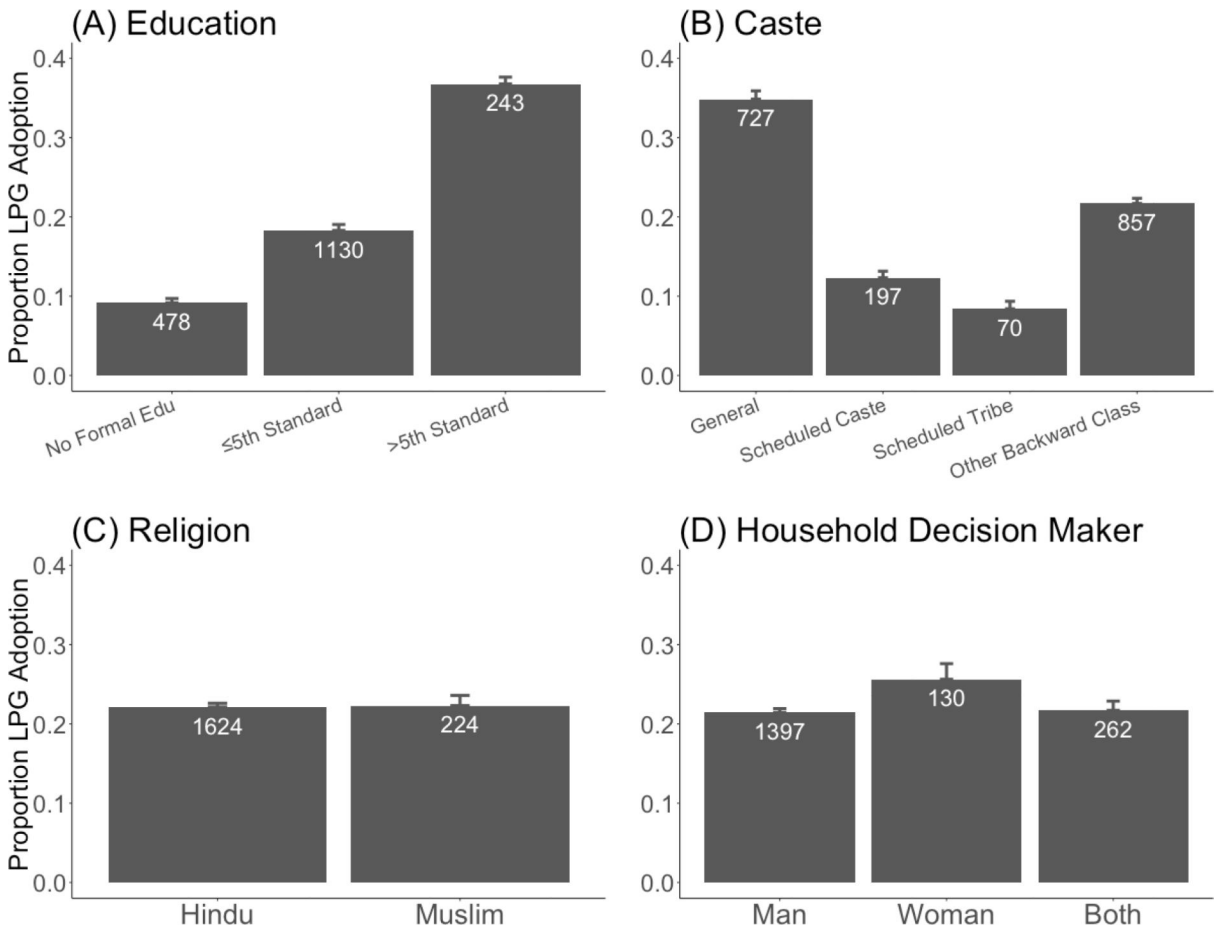

Figure 1:

For categorical covariates of LPG adoption, the proportion of households with LPG is shown along with values in each bar showing the number of participants in each category with LPG. Whiskers indicate the standard errors. Estimates use the ACCESS data employing survey weights to account for village-clustered sampling scheme.

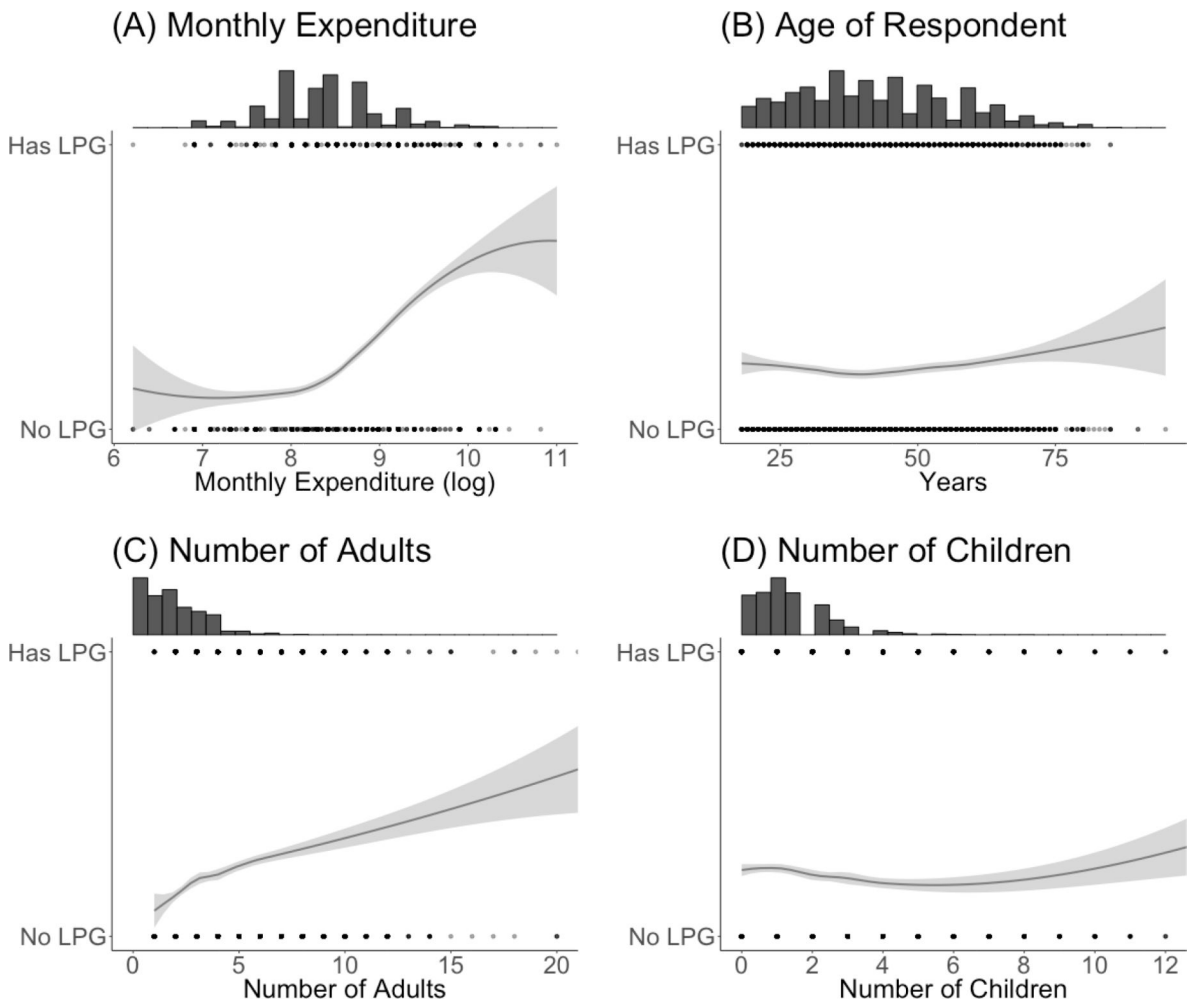

Figure 2:

We show scatter plots with continuous covariates on the x-axis and LPG ownership status on the y-axis. Marginal histograms show the distribution of the x-axis continuous variable. A locally estimated scatterplot smoothing function (LOESS) provides an estimation of the fraction of households across the distribution of the continuous covariate owning LPG. Standard errors are shown with shaded areas and estimates use the ACCESS data.

Table 1:

Summary statistics of dependent, explanatory, and control variables. When exponentiated, 8.35 is 4,230 Rupees, which is equivalent to 66.02 USD at 64.07 INR to 1 USD. Data are estimated from ACCESS using survey weights to account for village-clustered sampling scheme.

	Percent or Mean	SD	Min	Max
LPG adoption (=1)	22%			
Decision Maker:				
Woman Household Head	6%			
Man Household Head	78%			
Both	14%			
Monthly Expenditure (Logarithmized)	8.38	0.59	2	11
Number of Adults	4.29	2.31	1	35
Number of Children	2.48	2.03	0	22
Age of Respondent	42.58	14.19	18	95
Religion:				
Hindu	87%			
Muslim	13%			
Caste:				
Scheduled Caste	19%			
Scheduled Tribe	9%			
Other Backward Class	47%			
General	25%			
Household Head Education:				
No Formal Schooling	32%			
Up To 5th Standard	31%			
More Than 5th Standard	36%			

Table 2:

Summary statistics presented by household decision-makers using the ACCESS data using survey weights to account for village-clustered sampling scheme.

	Woman Household Head (n=486)	Man Household Head (n=6678)	Both (n=1251)
LPG adoption (=1)	26%	21%	22%
Monthly Expenditure (Logarithmized)	8.35	8.39	8.36
Number of Adults	3.64	4.37	3.98
Number of Children	2.12	2.5	2.47
Age of Respondent	41.79	42.76	41.51
Religion:			
Hindu	82%	87%	84%
Muslim	17%	12%	15%
Caste:			
Scheduled Caste	20%	19%	19%
Scheduled Tribe	9%	9%	11%
Other Backward Class	43%	47%	48%
General	29%	25%	22%
Household Head Education:			
No Formal Schooling	53%	30%	36%
Up To 5th Standard	26%	32%	33%
More Than 5th Standard	21%	39%	31%

Table 3:

Quasi-binomial survey-weighted logistic regressions (logit link) of LPG adoption by households in the sample reporting average marginal effects using the ACCESS data. Standard errors reported in parenthesis are adjusted for the village-clustered sampling strategy.

	Dependent variable:					
	LPG Adoption					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Decision-Maker:						
Ref: Man Household Head						
Woman Household Head (=1)	0.035	0.034			0.091***	0.080***
	(0.019)	(0.019)			(0.018)	(0.018)
Both (=1)	−0.002	0.027			0.031*	0.054***
	(0.014)	(0.014)			(0.013)	(0.013)
Monthly Expenditure (logarithmized)			0.121***	0.127***	0.120***	0.125***
			(0.086)	(0.008)	(0.001)	(0.008)
Number of Adults			0.006**	0.005*	0.001**	0.006**
			(0.002)	(0.002)	(0.002)	(0.002)
Number of Children			−0.012***	−0.014***	−0.011***	−0.014***
			(0.002)	(0.002)	(0.002)	(0.002)
Age of Respondent			0.001***	0.001***	0.001***	0.001***
			(<0.001)	(<0.001)	(<0.001)	(<0.001)
Religion						
Ref: Other						
Hindu (=1)			0.005	0.009	0.006	0.010
			(0.014)	(0.014)	(0.013)	(0.014)
Caste:						
Ref: General Caste						
Scheduled Caste (=1)			−0.140***	−0.145***	−0.139***	−0.145***
			(0.014)	(0.014)	(0.014)	(0.014)
Scheduled Tribe (=1)			−0.185***	−0.111***	−0.183***	−0.109***
			(0.020)	(0.020)	(0.020)	(0.020)
Other Backward Class (=1)			−0.063***	−0.059***	−0.062***	−0.059***
			(0.010)	(0.010)	(0.010)	(0.010)
Household Head Education:						
Ref: No Formal Education						
Up To 5th Standard (=1)			0.102***	0.102***	0.108***	0.108***
			(0.014)	(0.012)	(0.014)	(0.012)
More Than 5th Standard (=1)			0.218***	0.213***	0.226***	0.221***

	Dependent variable:					
	LPG Adoption					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
			(0.012)	(0.012)	(0.013)	(0.013)
State Variables:						
Ref: Jharkhand						
Bihar (=1)		0.104***		0.079***		0.084***
		(0.013)		(0.013)		(0.012)
Madhya Pradesh (=1)		0.108***		0.111***		0.113***
		(0.013)		(0.013)		(0.012)
Odisha (=1)		0.023		0.049**		0.05**
		(0.015)		(0.017)		(0.017)
Uttar Pradesh (=1)		0.268***		0.254***		0.258***
		(0.012)		(0.012)		(0.0112)
West Bengal (=1)		0.151***		0.166***		0.163***
		(0.014)		(0.015)		(0.014)
Observations	8563	8563	8563	8563	8563	8563
R^2	0.000	0.048	0.142	0.190	0.146	0.194

Note:

*p<0.05

**p<0.01

***p<0.001

Average Marginal Effects are reported.

Table 4:

Summary statistics of reasons for LPG non-adoption presented by household decision-makers. No respondents in the described sample have LPG. Data used come from ACCESS.

	Woman Household Head	**Man Household Head**	**Both**	**All Non-Adopters**
	(n=356)	**(n=5281)**	**(n=989)**	**(n=6712)**
Unavailable	64%	73%	71%	72%
Installation Cost	91%	95%	96%	95%
Monthly Cost	85%	88%	90%	88%
Lack of Information	40%	42%	39%	41%

Table 5:

Mean and standard error are shown for overall satisfaction with the primary household cooking arrangement by gender of the respondent, as well as the distribution of households falling in to each sub-category. For example, 70% of households where the respondent was a woman and the household had LPG reported to be satisfied with their primary cooking arrangement. P-Values reported are derived from two-sided t-tests of mean satisfaction score where Dissatisfied = 1, Neutral = 2, and Satisfied = 3. Data used come from ACCESS.

	Woman Respondent	Man Respondent	P-Value
LPG User	2.61 (0.65)	2.70 (0.56)	0.001
Satisfied	70%	76%	
Neutral	21%	19%	
Disatisfied	9%	5%	
Non-LPG User	2.17 (0.77)	2.24 (0.73)	0.011
Satisfied	40%	42%	
Neutral	38%	40%	
Disatisfied	23%	18%	

Table 6:

In regressions 1–2, we use quasi-binomial logistic regressions (logit link) to examine the association between covariates and households using LPG as their primary cooking fuel. In regressions 3–4, we use generalized linear models (Ordinary Least Squares) with the outcome logarithmized LPG use (kg/month). In regressions 5–6, we use generalized linear models (Ordinary Least Squares) with the outcome firewood use (kg/month). Average marginal effects can be interpreted as a percentage point change in probability of LPG adoption in regressions 1–2 and a percent change in the amount of fuel use when multiplied by 100 in regressions 3–6. Standard errors are adjusted for the village-clustered sampling strategy. Data used come from ACCESS.

	Models Explaining the Use of Cooking Fuels					
	Primary Fuel: LPG		**Log LPG Use (kg/month)**		**Log Firewood Use (kg/month)**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Decision-Maker:						
Ref: Man Household Head						
Woman Household Head (=1)	0.030	0.049	0.074	0.071	−0.114	−0.147
	(0.047)	(0.045)	(0.046)	(0.047)	(0.095)	(0.094)
Both (=1)	−0.025	−0.039	0.010	−0.002	0.002	0.005
	(0.035)	(0.034)	(0.040)	(0.041)	(0.062)	(0.060)
Monthly Expenditure (Logarithmized)	0.005	−0.014	0.051*	0.039	0.085*	0.097*
	(0.020)	(0.019)	(0.023)	(0.023)	(0.042)	(0.041)
Number of Adults	−0.011*	−0.010*	0.019**	0.017**	0.033**	0.034**
	(0.005)	(0.005)	(0.007)	(0.006)	(0.012)	(0.002)
Number of Children	0.003	0.005	0.005	0.006	0.026*	0.029**
	(0.006)	(0.006)	(0.007)	(0.007)	(0.011)	(0.011)
Age of Respondent	<−0.001	<−0.001	< −0.001	< 0.001	0.003	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Religion						
Ref: Other						
Hindu (=1)	−0.129***	−0.120**	−0.133***	−0.102**	0.204*	0.189*
	(0.038)	(0.037)	(0.042)	(0.041)	(0.078)	(0.079)
Caste:						
Ref: General Caste						
Scheduled Caste (=1)	−0.037	−0.036	−0.007	−0.011	0.009	0.024
	(0.041)	(0.061)	(0.043)	(0.041)	(0.070)	(0.069)
Scheduled Tribe (=1)	0.127	0.072	0.077	0.052	0.067	−0.009
	(0.069)	(0.041)	(0.075)	(0.074)	(0.141)	(0.123)
Other Backward Class (=1)	−0.067*	−0.060*	−0.172***	−0.064***	−0.066	−0.048
	(0.026)	(0.025)	(0.029)	(0.029)	(0.051)	(0.050)
Household Head Education:						
Ref: No Formal Education						

	Models Explaining the Use of Cooking Fuels					
	Primary Fuel: LPG		**Log LPG Use (kg/month)**		**Log Firewood Use (kg/month)**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Up To 5th Standard (=1)	0.053	0.019	0.092	0.086	−0.043	−0.027
	(0.040)	(0.038)	(0.049)	(0.050)	(0.073)	(0.072)
More Than 5th Standard (=1)	0.075*	0.050	0.137***	0.142**	−0.098*	−0.092*
	(0.038)	(0.034)	(0.047)	(0.048)	(0.079)	(0.078)
State Variables:						
Ref: Jharkhand						
Bihar (=1)		0.084		0.331**		−0.334***
		(0.063)		(0.100)		(0.104)
Madhya Pradesh (=1)		−0.239***		−0.102		−0.145
		(0.067)		(0.097)		(0.097)
Odisha (=1)		<0.001		−0.022		0.408
		(0.086)		(0.130)		(0.220)
Uttar Pradesh (=1)		−0.250***		0.083		−0.157*
		(0.062)		(0.097)		(0.082)
West Bengal (=1)		−0.132		0.253*		−0.128
		(0.069)		(0.099)		(0.095)
Observations	1851	1851	1793	1793	1317	1317
R^2	0.014	0.072	0.060	0.102	0.062	0.089

Note:

* p<0.05

** p<0.01

*** p<0.001

Average Marginal Effects are reported.