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ABSTRACT

Household Cooking Fuel Choice in India, 2004-2012: A Panel Multinomial Analysis

We use two waves of nationally representative India Human Development Survey to examine factors driving the cooking fuel choice in urban and rural India, separately. We utilize a random effects multinomial logit model that controls for unobserved household heterogeneity. We find that a clean-break with the use of traditional fuels is less likely in rural areas, but more probable in urban areas. The household characteristics (e.g. income, education) that are positively correlated with use of clean fuel also increases the probability of fuel stacking for rural households. We also find that access to paved road is an important determinant for rural household adopting clean fuel, and there exists evidence of social spillover effects in rural areas. Moreover, the bargaining power of women that is associated with economic status (e.g. education or economic freedom) is positively associated with the use of clean fuel. Finally, we find considerable impact of liquefied petroleum gas prices on the probability of use of clean fuel for urban households, but no significant impact for rural households.

JEL Classification: Q42, Q35, O12, O13, C25

Keywords: fuel choice, fuel stacking, random eects multinomial logit, India

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1 Introduction

Around 3 billion people cook using polluting open fires or simple stoves fuelled by kerosene, biomass (wood, animal dung and crop waste) and coal (WHO, 2018).[1] Using traditional fuels, such as firewood, charcoal, or agricultural waste, produces both indoor and outdoor air pollution and threats public health (Bruce et al., 2000; Smith, 2000; Alem et al., 2016). Collecting traditional fuels is time-consuming, and women and children are often responsible for this job. Thus use of traditional fuels reduces their time for studying or doing other productive activities (Burke and Dundas, 2015). For economic growth, it is crucial to replace traditional fuels with modern fuels, like electricity, kerosene, or liquefied petroleum gas (LPG) (Kaygusuz, 2011). Not surprisingly, the issue of household transition from traditional fuel to clean fuel has received considerable attention from both researchers and policymakers.[2] A number of studies published over the past three decades investigate the factors driving the transition. Muller and Yan (2018) provide a recent survey of the literature. As argued by Muller and Yan (2018), even though some studies are merely based on simple descriptive statistics, one can see the emergence of econometric methods to quantify the patterns and factors of household fuel use. Majority of the existing literature on fuel-transition is based on cross-section data, and only recently, researchers have used panel data to have more credible estimation strategy (Alem et al., 2016; Choumert-Nkolo et al., 2019).

In the literature on fuel transition from traditional to clean fuel, “energy ladder model” is quite popular (Hosier and Dowd, 1987; Leach, 1992; Leach and Mearns, 2013; Van der Kroon et al., 2013). “Energy ladder model” states that the households would move along the energy ladder when they receive higher income or social status. However, households are usually unable to get rid of traditional fuels completely because of cost consideration, culture preference, or supply side considerations (Masera et al., 2000; Alem et al., 2016). It has been noted that multiple fuel use constitutes the rule rather than the exception in many

[1] https://www.who.int/en/news-room/fact-sheets/detail/household-air-pollution-and-health

[2] Cooking fuels also have attracted increasing interest over the years because fuel wood harvesting has caused extensive deforestation.

urban and rural areas of developing countries, and the use of multiple fuels is described as "fuel stacking" (Heltberg, 2004; Masera et al., 2000; Ruiz-Mercado and Masera, 2015).

In this paper, we use a nationally representative panel data from India, India Human Development Survey (IHDS), to examine determinants of cooking fuel choice in urban and rural India, separately. We use multi-period multinomial logit model of fuel choice that account for unobserved time and choice invariant household heterogeneity. In addition to the usual household characteristics and prices of different fuels, the richness of the IHDS data allows us to control village level infrastructure, and women's bargaining power.

Given the population size and development stage of India, interest in households' transition from traditional to clean fuels is not new, and there exists significant literature on this topic. However, the existing literature on India use either a single or multiple cross-section data. Gangopadhyay et al. (2003) estimate a multinomial logit to model household main fuel (both cooking and lighting fuels together) choice separately for rural and urban Indian households using one round of Consumer Expenditure Survey collected by National Sample Survey (NSS) in 1999-00. Farsi et al. (2007) also use one round of NSS cross-section data collected in 1999-00 to examine household cooking fuel choice in urban India. Compared to Gangopadhyay et al. (2003), they use an ordered discrete choice framework and focus only on cooking fuels for urban households. In comparison to above mentioned two studies that use single round of cross-section data, Viswanathan and Kumar (2005) and Cheng and Urpelainen (2014) use multiple rounds of NSS cross-section data. Viswanathan and Kumar (2005) use three rounds of NSS data collected in 1983, 1993-94, and 1999-00 to descriptively document expenditure on different types of fuel and share of clean fuel in total fuel expenditure in rural and urban India and Indian states. Cheng and Urpelainen (2014) use two rounds of NSS data collected in 1987-88 and 2009-10, and discuss fuel-stacking behavior for lighting and cooking in India. They use a two-stage model: in the first stage they estimate a probit model for use of any modern fuel, while in the second stage they examine whether households engage in fuel stacking behavior conditional on using any modern fuel. They find the stacking of LPG and traditional biomass has grown rapidly in India over 1987 and 2010. They also find that although the household income has a robust negative effect on cooking fuel stacking in 1987, it has a positive effect in 2010. They speculate that with the dramatic rise in the use of LPG in 2010, fuel stacking has become so common that even relatively wealthy households now engage in it.

It is worth noting that the dynamic fuel stacking behavior cannot be observed in cross-section data (Alem et al., 2016). Moreover, the covariates available in the NSS data, that most of Indian literature on fuel choices is based on, are limited. For example, the NSS data do not contain any information that can be used to measure the bargaining power of the women in the household except education of individuals. Similarly information on village infrastructure is not available in the NSS data.[3]

We contribute to existing literature in the following ways. First, unlike the existing literature on India (Cheng and Urpelainen, 2014; Farsi et al., 2007; Viswanathan and Kumar, 2005; and Gangopadhyay et al., 2003) that is based on cross-section NSS data, we use a panel data and take account of household heterogeneity using a multinomial random effects model.[4] The advantage of panel data is that it relaxes the assumption—multiple observations within a choice are independent (Alem et al., 2016). Second, distinct from existing literature on India, we also look at the bargaining power of women using multiple indicators available in our data. Third, for rural households, we examine the impact of village level infrastructure

[3]Moreover, the NSS data report expenditure on consumption of energy (fuel, light and household appliances) during the last 30 days. Thus it does not distinguish between cooking and lighting. Cheng and Urpelainen (2014) reduce the dimensionality of the lighting fuel choice to that of kerosene and electricity, while focusing on liquefied petroleum gas (LPG) and biomass on the cooking part. While for most fuels the primary use for cooking or lighting is distinct, fuels such as kerosene could be used for both. According to 68th round of NSS data collected in 2011-12, about 2.7 percent of households reported kerosene as the main source of cooking while only 0.17 percent of households report electricity as main source of cooking. The 2011 Census data suggest that 2.9 percent of the households use kerosene as main source of cooking, while only 0.1 percent of households use electricity as main source. Nonetheless, even if kerosene might not be the main source of cooking, it could be a supplementary source of cooking. For example, 2011 IHDS that asks whether households use kerosene, and for what purpose, about 27 percent households responded using kerosene for either cooking or cooking and lighting both.

[4]Recently, Mekonnen and Köhlin (2009) and Alem, et al. (2016) use multinomial logit model with random effects to study fuel choices in Ethiopia, Choumert-Nkolo et al. (2019) use multinomial logit model with random effects to study fuel choice in Tanzania.

on fuel choice.

The main findings of the paper are following. First, there exist substantial differences across urban and rural areas. The household characteristics that are positively associated with the use of clean fuel (e.g. income, education) also increases the use of fuel stacking in rural areas but have no significant effects in urban areas. This suggests that a clean-break with the use of traditional fuels is unlikely to be in occurring rural areas, while more probable in urban areas. Rural households are more likely to go through stages where they shift to mixed fuel and later on to clean fuel. Second, we find that access to paved road is an important determinant for rural households adopting clean fuel and distance to the nearest town is not important. Third, we also find evidence of social spillover effects in rural areas: households residing in villages that reported clean (dirty) fuel as their main source are more likely to use clean (dirty) fuel and less likely to use dirty (clean) fuel. Fourth, the bargaining power of women that is associated with economic status (e.g. education or economic freedom) leads to increase in probability of household using clean fuel. Fifth, we find considerable impact of LPG prices on the probability of use of clean fuel in urban areas, but no significant impact for rural households.

The rest of the paper is organized as follows. Section 2 details the data, Section 3 provides the empirical strategy, Section 4 presents the results, and Section 5 concludes.

2 Overview of Data

2.1 Data Description

We use two waves of large scale India Human Development Survey (IHDS) collected in 2004-05, and 2011-12 (henceforth, 2004 and 2011, respectively). The IHDS are nationally representative and were collected jointly by National Council of Applied Economic Research at Delhi and the University of Maryland (Desai et al. 2005; and Desai and Vanneman, 2015).[5] The 2011 IHDS collected information on 42,153 households (27,580 rural and 14,573 urban). Out of these 42,153 households, 40,018 households were also surveyed in the 2005 IHDS. We use only those households that were surveyed in both rounds. We further drop 653 households who do not report using any cooking fuel. Thus our final data contains a balanced panel of 39,365 households (26,927 rural and 12,438 urban).

The IHDS data contain several socioeconomic information at the household and individual level. The data have information on both household consumption and income, and information on each type of fuel used in the households. Unlike NSS survey that asks for main cooking fuel, IHDS contain detailed energy module where respondents were asked detailed questions about their use of all energy sources. A separate village and women module were also implemented as part of IHDS. The village module contains information of village infrastructure and prices of different fuels. We use prices of different fuels at the village level collected in village module. Since the prices were not available for urban areas, we import district level fuel prices in urban areas from NSS 61st and 68th rounds of consumption expenditure. The NSS 61st and 68th rounds were collected in 2004-05 and 2011-12, and overlap with sample period of IHDS. NSS data do not collect prices at town/village or district levels, hence median prices of different types of fuels reported by households in urban areas in a district are taken as prevailing prices in district.[6]

The women module of the IHDS was implemented to only those households that have a residing adult women in age 18-49. The women module contains questions that we use to assess women autonomy inside the household. We generate five variables to measure women bargaining power. The first one is the education gap which equals to the highest education level of female adults minus the highest education level of male adults in household. We create four additional indices that capture violence against women, involvement in deci-

[5]IHDS data is publicly available from Inter-university Consortium for Political and Social Research (ICPSR). See http://ihds.info/ for more details.

[6]For rural sample, the IHDS data do not report price of coal, we impute price of coal for rural households using district level coal prices from NSS rural sample. District is the lowest level of geographical unit that can be identified in both datasets for matching purposes.

sion making, freedom of movement, and financial independence of women. The indices are constructed by combining multiple questions available in the survey utilizing the principal components analysis (PCA). The PCA takes into account which measures are proxying the same concept as opposed to different concepts.

The first index, violence index, captures the magnitude of violence in the community. It is based on following questions: *In your community is it usual for husbands to beat their wives in each of the following situations?* 1) if she goes out without telling him; 2) if her natal family does not give expected money, jewelry or other items; 3) if she neglects the house or the children; 4) if she doesn't cook food properly; 5) if he suspects her of having relations with other men. The second index, *most say in decision-making*, captures the women's extent of say in various decision making. The index is based on *whether women have say in following decisions*: 1) what to cook on a daily basis; 2) whether to buy an expensive item such as a TV or fridge; 3) How many children to have; 4) what to do if a child falls sick; 5) to whom children should marry.[7] The third index, financial independence index, captures the magnitude of financial freedom enjoyed by women based on the following three questions asked to the respondent woman: 1) Do you yourself have any cash in hand to spend on household expenditures; 2) is your name on any bank account, 3) is your name on the ownership or rental papers for your home.[8] The fourth index, permission index, captures whether female in a household have less freedom to go out. It is constructed using the question: *Do you have to ask permission of your husband or a senior family member to go to . . .* 1) the local health center; 2) the home of relatives or friends in the village/neighborhood; 3) the Kirana shop.

In our data, there are total six fuels used for cooking—firewood, dung, crop residuals, coal/charcoal, kerosene, and LPG. IHDS questionnaire lists each fuel type and asks from the respondent whether the household has used the fuel for cooking purposes. The use

[7]Nordman and Sharma (2016) create similar index by adding the binary responses.

[8]Nordman and Sharma (2016) also create a similar index by adding the binary responses in the three questions.

of electricity as fuel type is not listed, however, according to 2011 Census data, only 0.10 percent of households in India listed electricity as their main cooking fuel (0.07 percent of rural households and 0.15 percent of urban households). Figure 1 and Figure 2 present the types of fuel used by rural and urban households, respectively. As evident from the figures, majority of the households in rural India use firewood, while majority of urban households use LPG. Following the literature, we treat firewood, dung, crop residuals, and coal/charcoal as dirty fuels, while kerosene and LPG are treated as clean fuels. Figure 2 presents the fuel stacking behavior in urban and rural households. As evident, fuel stacking is prevalent in both urban and rural areas, and importantly, the incidence of fuel stacking has increased between 2004 and 2011 in both urban and rural India.

Although, IHDS data also contain information on total expenditure on each type of fuel in the last 30 days, the expenditure information is available if the household bought the fuel from the market. For households who collected their own fuel, there is no available imputed value. This is problematic for traditional fuels as a large fraction of rural households use traditional fuels that are either collected from own land or other places. Moreover, since there is no quantity information on each type of fuel, it is not possible to impute expenditure for households who do not buy traditional fuels. Hence, we do not use information on fuel expenditure in our analysis.[9]

Table 1 provides the descriptive statistics of the variables used in our analysis. The explanatory variables used in the analysis include household head characteristics, household demographic characteristics including the social groups, household consumption expenditure as a proxy for income, fuel prices of alternative fuels at the village level (for rural households) or at the district level (for urban households), and different variables that capture the bargaining power of women as discussed earlier. For rural households, we also control for village infrastructure.

Indian society has historically been characterized by a high degree of social stratification

[9]Choumert-Nkolo et al. (2019) construct continuous indices using the share of expenditure of each type of fuel in total fuel expenditure.

governed by the caste system, which results in exclusion of certain groups from certain economic and social spheres. At the time of independence, the Indian Constitution identified the disadvantaged caste and tribes in a separate schedule of the constitution as Scheduled Castes and Scheduled Tribes (SC/STs), and extended affirmative action protection to these groups in the form of reserved seats in higher educational institutions, in public sector jobs, and in state legislatures as well as the Indian parliament. Other Backward Castes (OBCs) are a group of other backward castes grouped together, and the Government of India provided reserved positions for OBCs in public sector jobs in 1993. Muslims are the largest minority religious group in India, and according to the Government of India (2006), their performance on many economic and education indicators is comparable with that for SC/STs. We control for the social group by including indicators for belonging to Scheduled Castes (SC), Scheduled Tribes (ST), Other Backward Castes (OBC), or Muslim excluding non-Muslim others.

3 Empirical framework

Our analysis is based on an multinomial logit model with unobserved heterogeneity. Each household i faces j choices of cooking fuel at time t. Each fuel choice corresponds to certain level of utility. Household chooses the one for which the utility is the highest. In our setting, there are three choices at each time t: only dirty fuel ($j = 1$), a mix of clean and dirty fuels ($j = 2$), and only clean fuel ($j = 3$).[10]

Household i's indirect utility of a choice j at the time t in a random effects context can be specified as follows:

$$V_{ijt} = X_{it}'\beta_j + \gamma_{ij} + \varepsilon_{ijt},\ t = 1, 2;\ j = 1, 2, 3 \tag{1}$$

where X_{it} is a matrix of observed explanatory variables that are expected to affect fuel choice and β_j is the choice specific parameter vector. γ_{ij} and ε_{ijt} are unobserved random compo-

[10]In a study in Guatemala, Heltberg (2005) captures the stacking behavior of households by using three categories: only wood, only LPG, or LPG and charcoal for cooking.

nents, where γ_{ij} is household and choice specific. At time t, household chooses the alternative with highest utility, V_{ijt}. Assuming that the ε_{ijt}'s are all independently distributed according to a type I extreme-value distribution, it can be shown that the conditional probability of household i choosing the category j at time t is given by:

$$P(Y_{it} = jX_{it}, \gamma_{i2}, \gamma_{i3}) = \frac{exp(X'_{it}\beta_j + \gamma_{ij})}{\sum_{c=1}^{3} exp(X'_{it}\beta_c + \gamma_{ic})} \tag{2}$$

where only dirty fuel is chosen as base outcome, so γ_{i1} and β_{i1} are normalized to zero.

If there is no unobserved heterogeneity across households: $\forall j : \gamma_{ij} = \gamma_j$, Eqn (2) will be a pooled multinomial logistic regression. As discussed in Alem et al. (2016), the standard multinomial logit model using the pooled sample (ignoring household heterogeneity) assumes that households' choices are independent, both within a choice (that is, for multiple observations across time of the same choice) and across all alternative choices made by the household over time. However, facing same set of choices in different time-periods, households are more likely to make similar choices over time. The random effects specification relaxes the assumption that multiple observations within a choice are independent. With this model, the choice probabilities for repeated choices made by household i share the same time-invariant unobserved heterogeneity γ_{ij}, where the household-specific effects act as a random variable that produces a correlation among the residuals for the same household within choices, but leaves the residuals independent across households. The multinomial random effects models are estimated using STATA gsem command.

4 Results

4.1 Household fuel choices

Table 2 presents the estimates of the panel multinomial logit models with random effects for rural and urban areas. The rural model includes additional village level characteristics compared to the urban model. Table 2 does not include variables capturing women bargaining power.[11] As evident from Table 2, the variances of the heterogeneity terms for both clean fuel and stacking are large and highly significant. Moreover, addition of random effects leads to a large increase in the log likelihood value over that for a standard pooled multinomial logit without random effects, and a likelihood ratio test rejects the pooled multinomial in favor of random effects.[12]

In Table 3, we present the average marginal effects from the random effects models reported in Table 2. Households belonging to the disadvantaged groups SCs, STs, and OBCs are more likely to use only dirty fuel in rural areas compared to households belonging to non-Muslim others group. Moreover, the disadvantaged category households are less likely to use only clean fuel or stack in rural areas compared to non-Muslim other households. In contrast to rural areas, SC/ST households in urban area are more likely to stack compared to non-Muslim other households. Importantly, similar to rural areas households belonging to disadvantaged categories (SC/STs and OBCs) are more likely to use only dirty fuel and less likely to rely on only clean fuel compared to households belonging to non-Muslim others group.

An increase in monthly per capita consumption increases the probability of use of both mixed and clean fuel in rural areas. Importantly, increase in consumption expenditure leads to a larger increase in the probability of mixed fuel use than increase in probability of only clean fuel in rural areas. As expected, increase in consumption expenditure reduces the probability of relying only on dirty fuel in rural areas. We find slightly different results for urban households. While increase in consumption expenditure is associated with a significant decrease (increase) in the probably of use of only dirty (clean) fuel, increase in consumption expenditure reduces the use of mixed fuel marginally. It is noteworthy that there exists

[11] In all of our estimations, we control for the six region. Ideally, we would like to control a finer geographical unit such as state (for urban sample) and districts (for rural sample). However, because of large sample size and presence of large number of indicators lead to convergence issues in the estimation.

[12] Pooled multinomial estimates are reported in appendix Table A2, however, we do not discuss the results here.

substantially large difference in the use of sole fuel between rural and urban areas. In 2011, only 69 (7) percent of rural households reported use of only dirty (clean) fuel, while 31 (23) percent urban households reported using only dirty (clean) fuel. Given the large differential in the use, the differences in rural-urban results regarding use of mixed fuel support the idea that households move from dirty fuel to mixed fuel and then to clean fuel. Many studies have studied the impact of income/consumption on fuel choice, and findings have been mixed. Our findings in rural India are similar to Heltberg (2004, 2005) who use multiple country data and finds that with increase in income, households tend to add modern fuels to their mix as partial rather than perfect substitutes for traditional ones. Alem et al. (2016) suggest that households tend to switch to a multiple fuel–use strategy as their incomes rise, for reasons that include the reliability of supply and convenience of use of different stoves and fuel types. Hence, supply side considerations with differential initial use levels might be driving reasons behind differential impact of income on mixed fuel in rural areas compared to urban areas.

Increase in household size increases the probability of fuel stacking in both urban and rural areas, and reduces the probability of relying on only one type of fuel. Heltberg (2004) and Alem et al. (2016) also find that larger households are more likely to be involved in fuel stacking. A higher dependency ratio increases the probability of relying on only dirty fuel while reducing the probability of use of any clean fuel (either clean only or mixed). This is true both in urban and rural areas. Importantly, children are normally involved in collecting traditional fuel. More children reduce the cost of collecting traditional fuel; hence, increase the use of traditional dirty fuel. Households who derived their main income through salary or trade are less (more) likely to use dirty (clean) fuel in both urban and rural area compared to households whose main income source in cultivation/agriculture. Moreover, households whose main income source is salary or trade are more likely to use mixed fuel in rural areas, while less likely to use mixed fuel in urban areas.

Female-headed households in rural areas are less likely to use only dirty fuel and more likely to be involved in fuel stacking behavior. In urban areas, female headed households are more likely to rely only on clean fuel. It is important to note that the female-headed rural households are only marginally more likely to use clean fuel, while for the urban households the impact on the use of mixed fuel is insignificant. This suggests that females prefer to use clean fuel, however, because of supply constraints, they move to mixed fuel in rural areas, while they moves to clean fuel in urban areas. The existing literature also supports the idea that the female-headed households prefer modern fuels to traditional fuels (Farsi et al., 2007; Rao and Reddy, 2007; Rahut et al., 2014). This is generally attributed to the fact that women are often responsible for household cooking and thus are directly affected by the air pollution emitted from the burning of the dirty fuels. Age of head also reduces the use of only dirty fuel and increases the probability of household adopting clean fuel in both rural and urban areas. Muller and Yan (2018) suggest that this result implies clean fuels is more affordable for the elderly than the young people because the later facing liquidity constraints. The education of household head plays a role in fuel choices. More education is associated with a decline in the probability of relying on only dirty fuel, while increases the probability of relying only on clean fuel in both rural and urban areas. Consistent with other results, although more education increases the probability of fuel stacking in rural areas, it decreases the probability of fuel stacking in urban areas.

The prices of fuels have drawn considerable attention in fuel choice literature. We find that an increase in firewood prices reduces (increases) the probability of use of only dirty (clean) fuel in rural areas, and has no impact on the fuel stacking behavior. In urban areas, increase in firewood prices reduces probability of use of either only dirty fuel or mixed fuel, while increases the probability of use of only clean fuel. Thus, households tend to shift to clean fuel sources as price of firewood increases. Importantly, the magnitude of impacts of increase in firewood prices are much larger in urban areas compared to rural areas. This is possibly because, while the households in urban areas mostly rely on market for firewood, households in rural areas can self-collect firewood potentially reducing the impact of an increase in firewood prices. Increase in price of coal reduces the probability of using either clean or dirty fuel and increases the probability of use of mixed fuel in both urban and rural areas. It is noteworthy that less than 2 percent of rural households and close to 5 percent of urban households reported use coal for cooking. Increase in dung prices increases the probability of using only dirty fuel, while reduces the use of mixed fuel in rural areas. The estimates suggest that increasing dung prices also increases the probability of use of clean fuel; however, the magnitude of impact is marginal. Increase in use of dirty fuel with dung prices is counter-intuitive; however, as our indicator for dirty fuel contains four types of fuel, there is a possibility of cross-substitution. Some scholars suggest that cross-price effects can be an important driver of fuel substitution (Muller and Yan, 2018). For example, Peng et al. (2010) show that high coal prices increase the probability of choosing biomass in China, suggesting that coal and biomass may be substitutes.

Increase in kerosene prices decreases the use of only dirty fuel for rural households while increasing the probability of relying on only clean fuel or mixed fuels. For urban households increase in kerosene prices increases the use of only clean fuel but reduces the probability of use of dirty or mixed fuel. It is noteworthy that our clean fuel category includes both LPG and kerosene, and cross-substitution within clean fuel group may increase the use of clean fuel. Akpalu et al. (2011) find kerosene and LPG are substitutes. Gupta and Kohlin (2006) using data in India suggest a high cross-price elasticity of LPG with respect to Kerosene as well. Nonetheless, the decreased use of only dirty fuel as a result of increase in kerosene price is puzzling. However, similar results are reported in some other contexts. For example, Lay et al. (2013) report a statistically significant negative effect of the kerosene price on the choice of wood in Kenya. In fact, kerosene prices are not considered as an effective policy instrument to trigger fuel switching (Pitt, 1985; Lee, 2013; Akpalu et al., 2011). Interestingly, kerosene in India is one of the subsidized commodities for household use, and been distributed by the Public Distribution System (PDS) for decades. In other words, the actual kerosene prices faced by the households may be different than the market prices based on the households' eligibility for PDS and amount of PDS kerosene consumed. This introduces another uncertainty regarding the impact of market price for kerosene on clean fuel.

Increase in the price of LPG reduces use of mixed fuel and increases the use of dirty fuel for rural households, although the impact on dirty fuel is not statistically significant. Nonetheless, the impact of LPG price is much stronger in urban areas compared to rural areas, which is not surprising given a much higher incidence of LPG use in urban areas. For urban households, one percent increase in prices leads to 13.6 percentage points decline in use on clean fuel, and leads to a 14.3 percentage points increase in use of only dirty fuel. This is consistent with the evidence in the fuel choice literature that suggest a strong own-price effects for the demand of LPG (Farsi et al., 2007; Zhang and Kotani, 2012), and a substitution relationship between LPG and firewood (Heltberg, 2004; Sehjpal et al., 2014).

The availability of modern fuel like LPG should not be a big issue for urban households, however, it can be a key issue for rural households. Seventy eight percent of the urban households reported using LPG in 2012; however, only 30 percent of the rural households reported using LPG. Access to the LPG may be a contributing factor in the observed difference in the use of LPG across urban and rural areas besides other demand side factors. Increase in the distance to nearest town increases the use of dirty fuel and reduces the use of mixed fuel. There is no impact on the use of only clean fuel. Whether the village has paved road or not seems to an important determinant of fuel choice. Not having paved road lead to 4 percentage points increase in use of dirty fuel while it reduces the use of clean or mixed fuel. We also find evidence of social spillovers. Households residing in villages that reported clean fuel as their main source are more likely to use clean or mixed fuel and less likely to use dirty fuel. Households residing in villages that reported dirty fuel as their main cooking energy source are more likely to use dirty fuel and less likely to use clean fuel.

4.2 Women's bargaining power

Appendix Table A1 presents the results of multinomial random effects models that also include women bargaining power, while Table 4 presents the average marginal impacts. Note that Table 4 is similar to Table 3 except that Table 4 models also include variables that capture the bargaining power of women. Since the bargaining information is constructed from the women module that was implemented only if the household has a residing adult women in age 18-49, inclusion of bargaining variables leads to loss of significant number of observations. However, the estimates of the rest of the variables remain qualitatively similar to what is presented in Table 3, and discussed earlier. Hence, we focus only on bargaining variables from the Table 4.

A greater education gap between female and male—namely greater women bargaining power— in the rural households results in a lower probability to use only dirty fuel but a higher probability to use only clean fuel and mixed fuel. The education gap makes urban households more likely to use only clean fuel, and less likely to use either dirty or mixed fuel. Similar findings are also reported in the Ahmad and Oliveira (2015) for urban India and Choumert-Nkolo et al. (2019) for Tanzania. Increase in women's financial independence increases the probability of use of clean fuel for urban households while reducing the probability of dirty or mixed fuels. For rural households also more financial independence lead to increase in probability of use of mixed fuel and reduction in probability of use of dirty fuel. The impact of financial independence on the use of clean fuel for rural households is marginal, however, positive. Our result suggests that empowering women by education and individual finance could be effective policy instruments to accelerate the process of fuel switching.

Women greater bargaining power as captured by more say in household decisions has no significant impact on fuel choice for rural households. For urban households, however, more say in household decision marginally increases the probability of use of dirty fuel. A one standard deviation increase in say increases probability of use of dirty fuel by 0.6 percentage points for urban households. Violence index, that captures the perception of women about the amount of violence prevalent, increases the probability of using only dirty fuel or only clean fuel, while reduces the probability of using mixed fuel for rural households. For urban households, an increase in violence index increases the probability of use of only clean fuel while reducing use of mixed fuel. Recall that a larger violence index implies less bargaining power for women. Given the index is standardized, the impact of violence index remain marginal.[13] The permission index that captures the permission needed has no significant impact on the choice of fuel. Overall, the bargaining power of women that is associated with economic status (e.g. education or economic freedom) leads to increase in probability of household using clean fuel.

5 Conclusion

In this paper, we use two waves of India Human Development survey panel data to examine factors determining household fuel choice in rural and urban areas, separately. Majority of literature on fuel choice in India is based on cross-sectional data and thus does not allow for household heterogeneity. We contribute to the existing literature on India by using a panel data, and utilizing multinomial logit with random effects. Moreover, we also examine the impact of village infrastructure and women bargaining power on fuel choice.

We find considerable incidence of fuel stacking where households use both clean and dirty fuel together in both urban and rural areas. The use of only clean fuel remains low in rural areas, and between 2004 and 2011, there is an increase in fuel stacking not only in rural areas but also in urban areas. We find that the household characteristics that are positively associated with use on only clean fuel, such as education, per capita expenditure, are also positively associated with use of fuel stacking for rural households. For urban households, these characteristics have mostly no significant impact on fuel stacking. For rural households,

[13]Moreover, the violence index captures respondent woman's perception about the status of women in the community, and may not be capturing the intra-household bargaining power of respondent women.

we find access to paved road increases the probability of use of clean fuel suggesting supply side considerations play a role in adoption of clean fuel. We also find that female-headed households are more likely to adopt clean fuel, and increasing economic freedom of women is positively association with use of clean fuel.

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Figure 1: Types of fuel used by rural households by survey year.

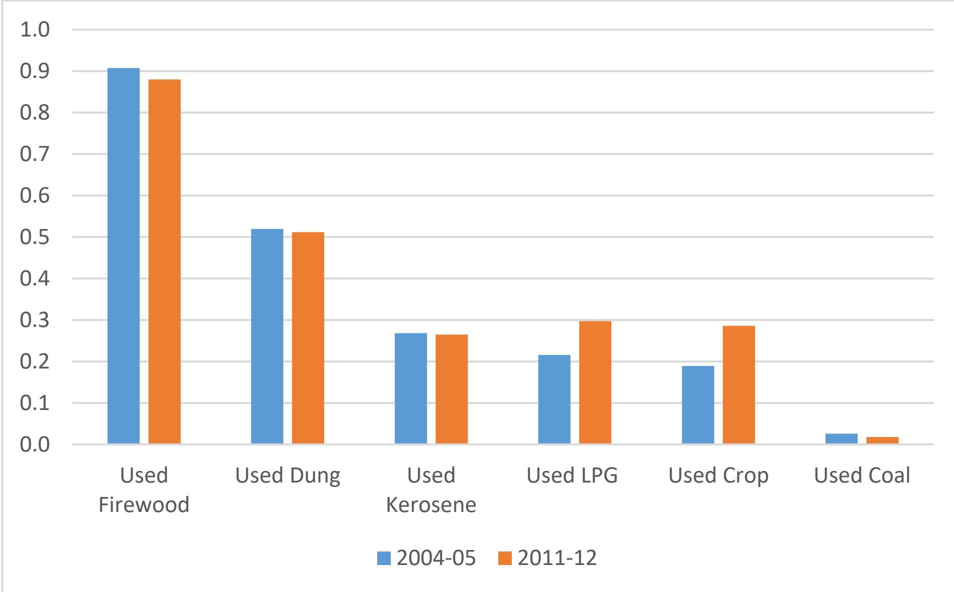

Figure 2: Types of fuel used by urban households by survey year.

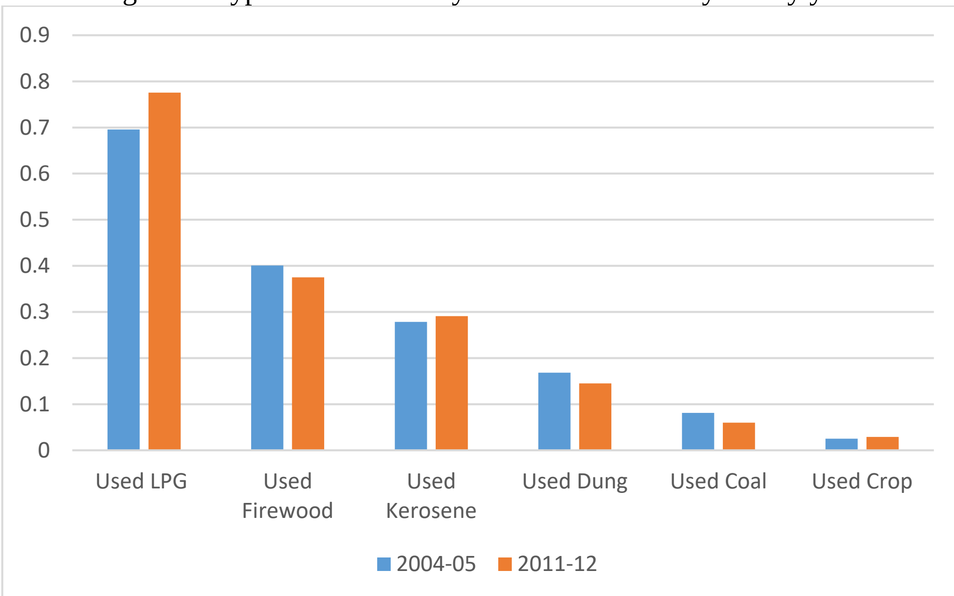

Figure 3: Fuel stacking by region and survey year.

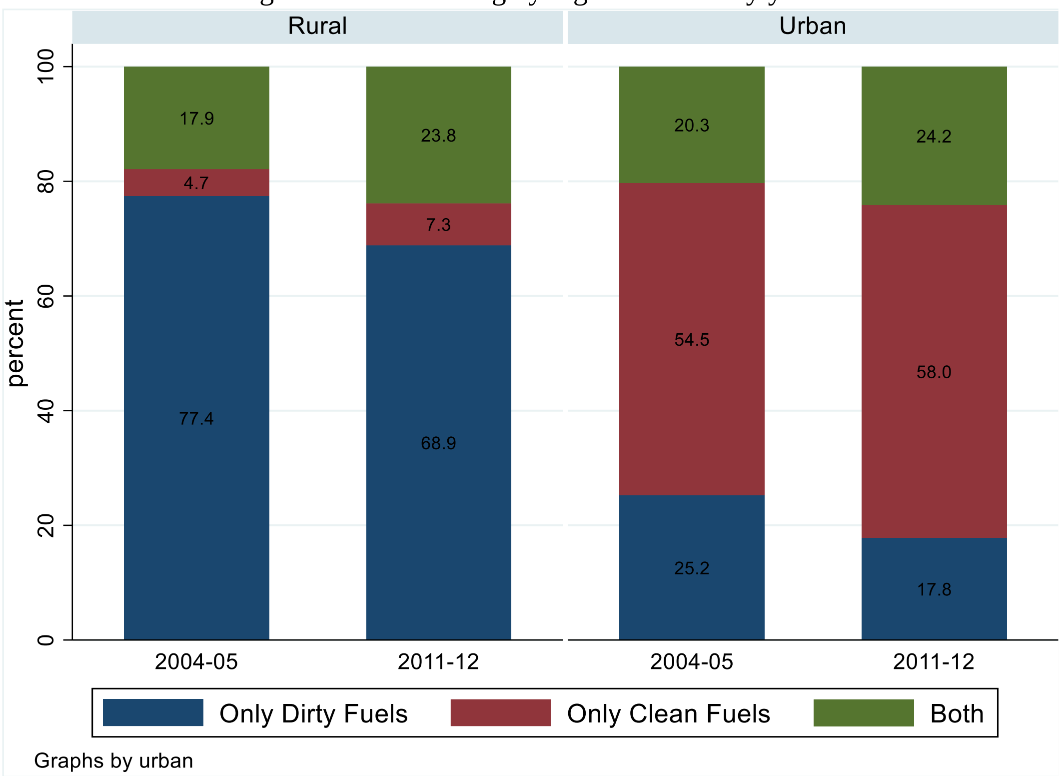

Table1: Summary Statistics

	2004		2011	
Rural	**Mean**	**SD**	**Mean**	**SD**
Fuel use				
Firewood	0.906	0.292	0.884	0.320
Dung	0.509	0.500	0.536	0.499
Crop	0.184	0.387	0.293	0.455
Kerosene	0.255	0.436	0.267	0.442
LPG	0.210	0.408	0.298	0.458
Coal	0.026	0.160	0.017	0.130
Fuel choices				
Only Dirty Fuel	0.766	0.423	0.688	0.463
Only Clean Fuel	0.046	0.209	0.069	0.253
Mixed	0.188	0.391	0.243	0.429
Household characteristics				
Scheduled Caste/Tribes (SC/ST)	0.332	0.471	0.343	0.475
Muslim	0.092	0.290	0.091	0.288
Other Backward Class (OBC)	0.360	0.480	0.358	0.480
Household size	6.524	3.163	5.470	2.296
Dependency ratio	0.788	0.625	0.758	0.586
Main income source: salary	0.121	0.326	0.125	0.331
Main income source: non-agriculture wage	0.164	0.370	0.234	0.424
Main income source: trade	0.103	0.303	0.088	0.284
Log real per capita expenditure	6.345	0.628	6.613	0.621
Female head	0.040	0.195	0.057	0.232
Age of head	46.906	12.936	47.725	12.873
Head's years of education	4.358	4.375	4.944	4.562
Fuel prices				
Log firewood price	0.311	0.742	1.194	0.676
Log coal price	0.011	1.160	0.999	0.971
Log dung price	0.206	0.927	0.513	0.836
Log kerosene price	2.635	0.350	3.460	0.240
Log LPG price	5.755	0.209	6.086	0.133
Village level variables				
Nearest town distance (km)	14.007	10.639	13.927	11.194
Village has no paved road	0.327	0.469	0.136	0.343
Percentage of households electrified	68.569	32.910	79.057	26.637
Village main fuel is clean	0.060	0.238	0.154	0.361
Village main fuel is biomass	0.169	0.375	0.846	0.361
Women bargaining power				
Education gap	-2.814	4.392	-2.465	4.755
Violence index	0.099	1.022	0.055	0.995
Most say in decision making	-0.111	0.886	-0.108	0.896
Financial independence	-0.078	0.947	-0.084	0.964
Permission needed index	0.089	0.936	0.079	0.924
Sample size	**27,679**		**26,779**	
Urban	**Mean**	**SD**	**Mean**	**SD**
Fuel use				
Firewood	0.398	0.489	0.381	0.486
Dung	0.168	0.374	0.147	0.354
Crop	0.026	0.158	0.030	0.170
Kerosene	0.283	0.450	0.299	0.458
LPG	0.684	0.465	0.781	0.414
Coal	0.081	0.274	0.061	0.238
Fuel choices				

Only Dirty Fuel	0.247	0.432	0.173	0.379
Only Clean Fuel	0.543	0.498	0.573	0.495
Mixed	0.210	0.407	0.254	0.435
Household characteristics				
Scheduled Caste/Tribes (SC/ST)	0.211	0.408	0.218	0.413
Muslim	0.149	0.356	0.162	0.368
Other Backward Class (OBC)	0.314	0.464	0.306	0.461
Household size	5.787	2.637	5.226	2.195
Dependency ratio	0.656	0.579	0.596	0.518
Main income source: salary	0.400	0.490	0.404	0.491
Main income source: non-agriculture wage	0.214	0.410	0.240	0.427
Main income source: trade	0.298	0.458	0.278	0.448
Log real per capita expenditure	6.774	0.636	7.091	0.658
Female head	0.056	0.230	0.080	0.272
Age of head	45.867	12.282	49.051	11.967
Head's years of education	7.492	4.867	7.891	4.860
Fuel prices				
Log firewood price	0.394	0.348	1.187	0.379
Log coal price	0.717	1.354	1.693	1.173
Log kerosene price	2.823	0.216	3.379	0.266
Log LPG price	5.696	0.038	6.030	0.059
Women bargaining power				
Education gap	-2.025	4.329	-1.505	4.476
Violence index	-0.166	0.948	-0.126	0.997
Most say in decision making	0.092	0.997	-0.010	0.976
Financial independence	0.227	1.070	0.136	1.007
Permission needed index	-0.121	1.057	0.006	1.021
Sample size	**10,961**		**11,861**	

Table 2: Multinomial logit with random effects for fuel choice, rural and urban households

	Rural		Urban	
	(1)	(2)	(3)	(4)
	Clean only	***Mixed***	***Clean only***	***Mixed***
SC/ST	-1.714***	-1.482***	-2.332***	-1.217***
	(0.096)	(0.061)	(0.139)	(0.121)
Muslim	-0.485***	-0.372***	-1.863***	-0.949***
	(0.126)	(0.078)	(0.146)	(0.127)
Other Backward Class (OBC)	-0.903***	-0.829***	-1.447***	-0.888***
	(0.081)	(0.054)	(0.125)	(0.113)
Household size	0.057***	0.156***	0.072***	0.187***
	(0.013)	(0.007)	(0.017)	(0.015)
Dependency ratio	-0.194***	-0.285***	-0.231***	-0.174***
	(0.057)	(0.034)	(0.065)	(0.056)
Main income source: salary	2.101***	1.225***	2.072***	0.886***
	(0.083)	(0.055)	(0.130)	(0.111)
Main income source: non-agriculture wage	0.431***	-0.017	0.282**	-0.047
	(0.099)	(0.054)	(0.126)	(0.102)
Main income source: trade	2.077***	0.944***	1.667***	0.372***
	(0.093)	(0.063)	(0.130)	(0.111)
Log real per capita consumption expenditure	1.645***	1.271***	2.125***	1.240***
	(0.055)	(0.036)	(0.079)	(0.072)
Female head	0.457***	0.504***	0.542***	0.250**
	(0.100)	(0.062)	(0.116)	(0.101)
Age of head	0.029***	0.020***	0.024***	0.011***
	(0.002)	(0.002)	(0.003)	(0.003)
Head's years of education	0.244***	0.176***	0.309***	0.161***
	(0.008)	(0.005)	(0.011)	(0.010)
Log firewood price	0.191***	0.056**	1.073***	-0.150
	(0.041)	(0.025)	(0.117)	(0.102)
Log coal price	-0.070**	0.107***	-0.075**	0.269***
	(0.028)	(0.017)	(0.029)	(0.027)
Log dung price	-0.126***	-0.305***		
	(0.030)	(0.020)		
Log kerosene price	0.585***	0.518***	1.546***	0.411***
	(0.100)	(0.065)	(0.175)	(0.151)
Log LPG price	0.206	-0.262**	-2.359***	-1.537**
	(0.261)	(0.111)	(0.767)	(0.686)
Nearest town distance (km)	-0.007**	-0.010***		
	(0.003)	(0.002)		
Village has no paved road	-0.727***	-0.423***		
	(0.092)	(0.050)		
Percentage of households electrified	0.019***	0.017***		
	(0.002)	(0.001)		
Village main fuel is clean	1.317***	0.864***		
	(0.100)	(0.069)		
Village main fuel is biomass	-0.425***	-0.134**		
	(0.093)	(0.058)		
Constant	-22.040***	-12.881***	-6.935	-2.101
	(1.583)	(0.719)	(4.432)	(3.963)
Heterogeneity covariance				
var(a1)	5.077		6.812	
	(0.333)		(0.474)	
var(a2)	3.066		3.276	

	(0.155)	(0.277)
Covariance(a1,a2)	3.227***	3.309***
	(0.196)	(0.317)
Region controls	Yes	Yes
Year controls	Yes	Yes
Log likelihood	-25639.121	-15117.697
Observations	52,409	21,911

Note: Only dirty fuel is base category, Standard errors in parentheses.
*p<0.1, **P<0.05, ***p<0.01.

Table 3: Average marginal effects of multinomial logit with random effects

	Rural			Urban		
	(1)	(2)	(3)	(4)	(5)	(6)
	Dirty Only	***Clean Only***	***Mixed***	***Dirty Only***	***Clean Only***	***Mixed***
SC/ST	0.132***	-0.029***	-0.104***	0.129***	-0.156***	0.027***
	(0.005)	(0.003)	(0.005)	(0.008)	(0.009)	(0.009)
Muslim	0.034***	-0.009**	-0.025***	0.102***	-0.126***	0.025**
	(0.007)	(0.004)	(0.006)	(0.009)	(0.010)	(0.010)
Other Backward Class (OBC)	0.073***	-0.014***	-0.059***	0.086***	-0.087***	0.002
	(0.005)	(0.002)	(0.004)	(0.008)	(0.008)	(0.008)
Household size	-0.012***	-0.001***	0.013***	-0.010***	-0.006***	0.016***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Dependency ratio	0.024***	-0.001	-0.023***	0.015***	-0.012**	-0.003
	(0.003)	(0.002)	(0.003)	(0.004)	(0.005)	(0.005)
Main income source: salary	-0.119***	0.048***	0.071***	-0.106***	0.153***	-0.047***
	(0.005)	(0.002)	(0.004)	(0.008)	(0.010)	(0.010)
Main income source: non-agriculture wage	-0.005	0.015***	-0.011**	-0.007	0.033***	-0.026**
	(0.005)	(0.003)	(0.005)	(0.008)	(0.011)	(0.010)
Main income source: trade	-0.098***	0.053***	0.045***	-0.070***	0.147***	-0.077***
	(0.005)	(0.003)	(0.005)	(0.008)	(0.011)	(0.010)
Log real per capita consumption expenditure	-0.116***	0.031***	0.085***	-0.123***	0.133***	-0.010*
	(0.003)	(0.002)	(0.003)	(0.005)	(0.005)	(0.005)
Female head	-0.043***	0.005*	0.038***	-0.028***	0.039***	-0.010
	(0.005)	(0.003)	(0.005)	(0.007)	(0.009)	(0.009)
Age of head	-0.002***	0.001***	0.001***	-0.001***	0.002***	-0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Head's years of education	-0.016***	0.005***	0.011***	-0.017***	0.021***	-0.004***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Log firewood price	-0.007***	0.005***	0.001	-0.028***	0.123***	-0.094***
	(0.002)	(0.001)	(0.002)	(0.007)	(0.009)	(0.008)
Log coal price	-0.007***	-0.005***	0.011***	-0.009***	-0.027***	0.036***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Log dung price	0.024***	0.002**	-0.026***			
	(0.002)	(0.001)	(0.002)			
Log kerosene price	-0.046***	0.010***	0.037***	-0.068***	0.132***	-0.064***
	(0.005)	(0.003)	(0.005)	(0.011)	(0.013)	(0.013)
Log LPG price	0.016*	0.013	-0.029***	0.143***	-0.136**	-0.007
	(0.010)	(0.009)	(0.010)	(0.050)	(0.058)	(0.057)
Nearest town distance (km)	0.001***	-0.000	-0.001***			
	(0.000)	(0.000)	(0.000)			
Village has no paved road	0.041***	-0.017***	-0.025***			
	(0.004)	(0.003)	(0.004)			
Percentage of households electrified	-0.002***	0.000***	0.001***			
	(0.000)	(0.000)	(0.000)			
Village main fuel is clean	-0.082***	0.028***	0.054***			
	(0.006)	(0.003)	(0.006)			
Village main fuel is biomass	0.016***	-0.012***	-0.004			
	(0.005)	(0.003)	(0.005)			
Region controls		Yes			Yes	
Year controls		Yes			Yes	
Observations		52,409			21,911	

Note: *p<0.1, **P<0.05, ***p<0.01. Standard errors in parentheses.

Table 4: Average marginal effects of the multinomial random effects with women bargaining power

	Rural			Urban		
	(1)	(2)	(3)	(4)	(5)	(6)
	Dirty Only	***Clean Only***	***Mixed***	***Dirty Only***	***Clean Only***	***Mixed***
SC/ST	0.114***	-0.021***	-0.093***	0.103***	-0.136***	0.033***
	(0.006)	(0.003)	(0.006)	(0.010)	(0.010)	(0.010)
Muslim	0.005	0.001	-0.007	0.080***	-0.107***	0.027**
	(0.008)	(0.004)	(0.008)	(0.010)	(0.012)	(0.012)
Other Backward Class (OBC)	0.054***	-0.011***	-0.043***	0.070***	-0.074***	0.004
	(0.005)	(0.003)	(0.005)	(0.009)	(0.010)	(0.010)
Household size	-0.009***	-0.001**	0.010***	-0.006***	-0.009***	0.015***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Dependency ratio	0.027***	0.000	-0.027***	0.015***	-0.006	-0.009
	(0.004)	(0.002)	(0.004)	(0.005)	(0.007)	(0.007)
Main income source: salary	-0.117***	0.047***	0.070***	-0.115***	0.164***	-0.049***
	(0.006)	(0.003)	(0.005)	(0.010)	(0.013)	(0.012)
Main income source: non-agriculture wage	-0.006	0.011***	-0.005	-0.008	0.049***	-0.041***
	(0.005)	(0.004)	(0.006)	(0.009)	(0.013)	(0.012)
Main income source: trade	-0.092***	0.052***	0.039***	-0.073***	0.150***	-0.077***
	(0.006)	(0.003)	(0.006)	(0.010)	(0.013)	(0.012)
Log real per capita consumption expenditure	-0.118***	0.031***	0.086***	-0.117***	0.130***	-0.013**
	(0.004)	(0.002)	(0.004)	(0.006)	(0.006)	(0.007)
Female head	-0.053***	0.010**	0.043***	-0.054***	0.065***	-0.011
	(0.009)	(0.005)	(0.009)	(0.011)	(0.013)	(0.013)
Age of head	-0.003***	0.001***	0.002***	-0.002***	0.002***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Head's years of education	-0.018***	0.005***	0.012***	-0.017***	0.021***	-0.004***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Log firewood price	-0.006**	0.005***	0.001	-0.032***	0.129***	-0.096***
	(0.003)	(0.002)	(0.003)	(0.009)	(0.010)	(0.010)
Log coal price	-0.008***	-0.004***	0.011***	-0.011***	-0.028***	0.039***
	(0.002)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)
Log dung price	0.028***	0.002**	-0.030***			
	(0.002)	(0.001)	(0.002)			
Log kerosene price	-0.051***	0.011***	0.040***	-0.064***	0.144***	-0.081***
	(0.007)	(0.004)	(0.007)	(0.013)	(0.015)	(0.015)
Log LPG price	0.020*	0.003	-0.023*	0.243***	-0.238***	-0.005
	(0.011)	(0.009)	(0.012)	(0.058)	(0.067)	(0.068)
Nearest town distance (km)	0.001***	-0.000	-0.001***			
	(0.000)	(0.000)	(0.000)			
Village has no paved road	0.037***	-0.018***	-0.020***			
	(0.005)	(0.004)	(0.005)			
Percentage of households electrified	-0.002***	0.000***	0.001***			
	(0.000)	(0.000)	(0.000)			
Village main fuel is clean	-0.072***	0.027***	0.045***			
	(0.007)	(0.004)	(0.007)			
Village main fuel is biomass	0.031***	-0.012***	-0.019***			
	(0.006)	(0.004)	(0.006)			
Education gap	-0.007***	0.002***	0.005***	-0.006***	0.008***	-0.002**
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Financial independence	-0.018***	0.004***	0.014***	-0.024***	0.034***	-0.011***
	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)
Most say in decision making	-0.002	0.001	0.001	0.006**	0.001	-0.008**
	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)

Violence	0.009***	0.004***	-0.013***	-0.001	0.010***	-0.010***
	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)
Permission index	-0.001	0.001	-0.000	-0.004	0.006*	-0.002
	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)
Region controls		Yes			Yes	
Year controls		Yes			Yes	
Observations		36,074			15,455	

Note: *p<0.1, **P<0.05, ***p<0.01. Standard errors in parentheses.

Appendix

Table A1: Multinomial logit model with random effects including women bargaining power measures

	Rural		Urban	
	(1)	**(2)**	**(3)**	**(4)**
	Clean only	***Mixed***	***Clean only***	***Mixed***
yr2011	-0.116	0.004	-0.156	1.005***
	(0.181)	(0.108)	(0.358)	(0.319)
SC/ST	-1.382***	-1.268***	-2.002***	-0.976***
	(0.115)	(0.071)	(0.162)	(0.142)
Muslim	-0.003	-0.070	-1.570***	-0.755***
	(0.145)	(0.090)	(0.169)	(0.148)
Other Backward Class (OBC)	-0.670***	-0.598***	-1.252***	-0.752***
	(0.097)	(0.062)	(0.146)	(0.132)
Household size	0.030*	0.116***	0.011	0.133***
	(0.017)	(0.009)	(0.021)	(0.018)
Dependency ratio	-0.184**	-0.326***	-0.207**	-0.210***
	(0.077)	(0.045)	(0.085)	(0.073)
Main income source: salary	2.083***	1.178***	2.322***	1.044***
	(0.105)	(0.069)	(0.167)	(0.140)
Main income source: non-agriculture wage	0.327***	0.016	0.402***	-0.093
	(0.121)	(0.063)	(0.156)	(0.125)
Main income source: trade	2.025***	0.848***	1.770***	0.460***
	(0.111)	(0.074)	(0.162)	(0.135)
Log real per capita consumption expenditure	1.661***	1.262***	2.128***	1.226***
	(0.071)	(0.045)	(0.102)	(0.092)
Female head	0.650***	0.585***	1.008***	0.541***
	(0.167)	(0.100)	(0.183)	(0.160)
Age of head	0.036***	0.031***	0.034***	0.020***
	(0.003)	(0.002)	(0.004)	(0.004)
Head's years of education	0.265***	0.187***	0.326***	0.168***
	(0.011)	(0.007)	(0.014)	(0.013)
Log firewood price	0.186***	0.050*	1.187***	-0.072
	(0.051)	(0.030)	(0.143)	(0.122)
Log coal price	-0.041	0.110***	-0.060*	0.290***
	(0.034)	(0.020)	(0.036)	(0.032)
Log dung price	-0.142***	-0.345***		
	(0.037)	(0.024)		
Log kerosene price	0.654***	0.556***	1.632***	0.338*
	(0.123)	(0.078)	(0.210)	(0.180)
Log LPG price	-0.071	-0.258**	-4.200***	-2.682***
	(0.274)	(0.131)	(0.922)	(0.819)
Nearest town distance (km)	-0.009**	-0.011***		
	(0.004)	(0.002)		
Village has no paved road	-0.731***	-0.363***		
	(0.111)	(0.059)		
Percentage of households electrified	0.018***	0.019***		
	(0.002)	(0.001)		
Village main fuel is clean	1.223***	0.733***		
	(0.124)	(0.083)		
Village main fuel is biomass	-0.533***	-0.311***		
	(0.113)	(0.070)		
Education gap	0.099***	0.070***	0.124***	0.063***

	(0.008)	(0.005)	(0.010)	(0.009)
Violence	0.031	-0.124***	0.078*	-0.032
	(0.037)	(0.023)	(0.044)	(0.039)
Most say in decision making	0.032	0.022	-0.060	-0.105***
	(0.039)	(0.024)	(0.044)	(0.039)
Financial independence	0.220***	0.195***	0.482***	0.212***
	(0.036)	(0.023)	(0.046)	(0.042)
Freedom	0.025	0.005	0.081*	0.030
	(0.037)	(0.023)	(0.043)	(0.038)
region = 2, Central	-1.478***	-1.888***	-1.237***	-1.221***
	(0.162)	(0.087)	(0.166)	(0.146)
region = 3, East	-0.531***	-0.487***	-1.041***	0.534***
	(0.167)	(0.087)	(0.175)	(0.149)
region = 4, Northeast	1.507***	-0.255*	-0.581*	-1.001***
	(0.196)	(0.143)	(0.334)	(0.306)
region = 5, West	0.670***	-1.122***	0.244	-0.910***
	(0.129)	(0.084)	(0.192)	(0.180)
region = 6, South	0.365***	-0.763***	-1.296***	-0.659***
	(0.117)	(0.072)	(0.167)	(0.146)
Constant	-20.689***	-13.010***	3.040	4.676
	(1.706)	(0.855)	(5.308)	(4.718)
Heterogeneity covariance				
var(a1)	5.014		6.469	
	(0.452)		(0.607)	
var(a2)	2.837		3.039	
	(0.196)		(0.361)	
Covariance(a1,a2)	2.972***		3.212***	
	(0.258)		(0.415)	
Log likelihood	-17,908.13		-10,600.323	
Observations	36,074		15,455	

Note: Only dirty fuel is base category. *p<0.1, **P<0.05, ***p<0.01. Standard errors in parentheses.

Table A2: Pooled Multinomial logit model for fuel choice, rural and urban

	Rural		Urban	
	(1)	**(2)**	**(3)**	**(4)**
	Clean only	***Mixed***	***Clean only***	***Mixed***
yr2011	-0.116	-0.116	-0.253	0.710
	-0.181	-0.181	(0.718)	(0.866)
SC/ST	-1.103***	-0.967***	-1.300***	-0.664***
	(0.139)	(0.094)	(0.157)	(0.146)
Muslim	-0.275	-0.176	-1.025***	-0.527**
	(0.396)	(0.265)	(0.236)	(0.232)
Other Backward Class (OBC)	-0.548***	-0.528***	-0.792***	-0.505***
	(0.176)	(0.107)	(0.207)	(0.157)
Household size	0.033*	0.117***	0.055***	0.144***
	(0.017)	(0.012)	(0.019)	(0.019)
Dependency ratio	-0.131**	-0.217***	-0.154***	-0.134**
	(0.062)	(0.039)	(0.042)	(0.060)
Main income source: salary	1.544***	0.876***	1.572***	0.666***
	(0.097)	(0.073)	(0.153)	(0.127)
Main income source: non-agriculture wage	0.327*	-0.036	0.295**	-0.026
	(0.188)	(0.144)	(0.131)	(0.088)
Main income source: trade	1.622***	0.673***	1.310***	0.249**
	(0.131)	(0.088)	(0.162)	(0.123)
Log real per capita consumption expenditure	1.269***	1.010***	1.606***	0.907***
	(0.109)	(0.089)	(0.097)	(0.134)
Female head	0.317**	0.366***	0.288**	0.124
	(0.142)	(0.098)	(0.141)	(0.082)
Age of head	0.022***	0.014***	0.015***	0.005
	(0.003)	(0.003)	(0.005)	(0.005)
Head's years of education	0.176***	0.123***	0.187***	0.095***
	(0.009)	(0.010)	(0.017)	(0.014)
Log firewood price	0.159**	0.037	0.607*	-0.301
	(0.063)	(0.063)	(0.338)	(0.344)
Log coal price	-0.088	0.089	-0.076	0.227**
	(0.079)	(0.060)	(0.112)	(0.094)
Log dung price	-0.054	-0.234***		
	(0.067)	(0.077)		
Log kerosene price	0.398*	0.340**	1.052**	0.269
	(0.221)	(0.145)	(0.459)	(0.284)
Log LPG price	0.047	-0.213	-1.907	-1.331
	(0.769)	(0.140)	(1.856)	(2.036)
Nearest town distance (km)	-0.004	-0.007		
	(0.006)	(0.007)		
Village has no paved road	-0.614***	-0.328***		
	(0.183)	(0.094)		

Percentage of households electrified	0.015***	0.015***		
	(0.003)	(0.003)		
Village main fuel is clean	0.953***	0.592***		
	(0.136)	(0.141)		
Village main fuel is biomass	-0.442***	-0.162		
	(0.157)	(0.111)		
region = 2, Central	-0.797***	-1.237***	-0.772**	-0.717**
	(0.284)	(0.222)	(0.382)	(0.317)
region = 3, East	-0.047	-0.159	-0.602	0.603
	(0.369)	(0.561)	(0.468)	(0.536)
region = 4, Northeast	1.354***	0.125	0.188	-0.184
	(0.258)	(0.197)	(0.327)	(0.329)
region = 5, West	0.670	-0.798***	0.107	-0.720*
	(0.420)	(0.304)	(0.322)	(0.404)
region = 6, South	0.482	-0.395	-0.729	-0.277
	(0.353)	(0.354)	(0.462)	(0.460)
Constant	-16.054***	-9.887***	-4.226	-0.462
	(4.565)	(0.863)	(10.346)	(11.972)
Log likelihood	-26,408.45		-15,804.58	
Observations	52,409		21,911	

Note: Only dirty fuel is base category. *p<0.1, **P<0.05, ***p<0.01. Standard errors in parentheses.