Cooking Fuel Choices
—Analysis of Socio-economic and Demographic Factors in Rural India—

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Abstract

Indoor air pollution from the combustion of traditional cooking fuels causes millions of annual premature deaths in the developing world. This study examines the socio-economic and demographic factors that affect household choices of cooking fuels used in India. Survey data collected from 68 households in the rural areas of West Bengal were analyzed. The results of the regression analyses show that the location of the kitchen and the availability of free fuel affect the choice of clean cooking fuels. Furthermore, household income, age and education level of the household head are positively associated with clean fuel choices, while household size and distance to the nearest market are negatively associated with clean fuel choices.

Key Words: Cooking fuel, econometrics, field survey, India, indoor air pollution

1. Introduction

Approximately 90% of the energy consumed by households in developing countries is used for cooking, making it the most energy intensive household activity41, and India is no exception. Cooking fuel choices are a matter of great concern for households and policy makers in India21. From the perspective of economists, cooking fuel is considered an important index of the standard of living and is used to compile the multi-dimensional poverty index in India31. India, which is a developing country, reflects a duality in the context of domestic fuel usage because of the co-existence of users of modern (clean) fuels (e.g., kerosene, liquefied petroleum gas and electricity) and traditional (dirty) fuels (e.g., firewood, agricultural crop residue, cow dung cakes, and coal). Urban India has witnessed a rapid transition from traditional to modern cooking fuels41. On the other hand, according to recent national survey report51, a majority of the rural population (78%) continues to rely on traditional fuels for cooking. However, this scenario is
gradually changing in rural India because individuals have recently begun to switch to modern cooking fuels. Therefore, rural India is an ideal location to analyze domestic fuel choices and possible determinants due to a greater variation of domestic fuel usage.

At the individual level, cooking fuel is a necessity for everyone; prior studies have reported that the poorest populations of a society, whose consumption decisions are often overlooked, increase domestic fuel consumption with an increase in economic well-being. Often, poor households, particularly in rural India, decrease their consumption of other goods to fulfill their fuel demand and because of affordability and accessibility constraints, must use dirty fuels that adversely affect their health. Indoor air pollution from the incomplete combustion of traditional cooking fuel causes approximately 1.04 million annual premature deaths in India and is also responsible for various short term and long term pulmonary and ophthalmic diseases in developing countries with women and kids as worst sufferers.

Several studies have suggested various policies to decrease the health hazards related to indoor air pollution for individuals who live in rural areas; one plausible policy is to substitute dirty fuels with cleaner fuels. However, there are various factors that affect fuel choices for households in rural India; therefore, it is necessary to analyze and understand these factors.

Over the past two decades, several observational studies were conducted to analyze and understand the possible determinants of cooking fuel in India. Vishwanathan and Kumar observed that income was the primary determinant of cooking fuel in India. However, contradictory findings have been observed in literature as well. Ekholm et al. and Gundimeda and Köhlin provided clear evidence that fuel choices in India were influenced by fuel prices. Proximity to markets and access to modern amenities such as electricity significantly influenced the choice of clean fuel. Demographic factors such as household size; age of household members; gender of the first new-born child of the household; and the level of education of household members, particularly that of the females have been associated with cooking fuel choices. Other demographic factors including religion and caste also impact the fuel choice in India.

We examined possible determinants of the choice of cooking fuel in rural India by analyzing data that were collected from a field survey of rural areas of West Bengal, one of the most populous Indian states.

This study contributes to the existing literature in the following way. We found that the location of the kitchen in the dwelling unit and the availability of free fuel affected the choice of cooking fuel in rural Indian households, which to our knowledge has not been observed in prior studies.

The remainder of the paper is organized in the following manner: Section 2 provides a brief description of the cooking fuel market and institutions in rural India. Section 3 presents a very basic estimation model to analyze the fuel decision. A brief description of the survey site and sampling design is presented in Section 4. The data from the survey and descriptive statistics are discussed in Section 5. In Section 6, the results of the estimation are provided. Finally, Section 7 presents the concluding remarks.

2. Cooking Fuel Market in Rural India

In India, the public sector, as a seller of energy, is a major factor that affects the domestic fuel market. Instances of fuel stacking are often observable in rural India where households continue to use multiple fuels; primary fuels are those that are used predominantly and alternative fuels are used occasionally. In fuel stacking practice, unlike the energy ladder hypothesis where individuals substitute one (dirtier) fuel with the other (cleaner) with an increase in income, individuals continue to stack fuels and use one fuel occasionally while continuing to use another fuel predominantly. To simplify this analysis, we focused on the choice of primary cooking fuel in our study.

The most commonly used fuels in India’s rural areas are firewood and solid bio-mass fuels (cow dung cakes and agricultural crop residue) because of their ready availability at no cost or at a very low monetary cost. Liquefied Petroleum Gas (LPG) and kerosene are two cooking fuels that are subject to regulated pricing; these fuels are marketed and distributed by government-controlled petroleum companies at a price fixed by the Government of India. The price and availability of coal and electricity is controlled by the Ministry of Coal and Mines and the Ministry of Power, respectively. However, there are
Cooking Fuel Choices in Rural India

133

3. Fuel Choice Decision Model

The theoretical basis for the analysis of fuel choice decision is the random utility model. According to the random utility model, a rational individual or household will choose a particular cooking fuel if and only if, that choice maximizes the expected utility. The econometric analysis of cooking fuel choices is a typical example of the analysis of a discrete variable, because households must choose among a set of alternative cooking fuels; therefore, the analysis requires the use of a qualitative choice model. We utilized a simple binary choice model with N number of households, where the representative household-i, could choose from two categories of cooking fuels and a K-dimensional vector, consisting of different characteristics of that household, influenced the choice. To simplify this study, we restricted the analysis to the choice between clean and dirty cooking fuels in alignment with prior studies. For this study, kerosene, LPG and electricity are defined as clean fuels and fuelwood, cow dung cakes, coal and charcoal are defined as dirty fuels.

Let $y^*_i$ be a latent variable that is unobservable and determined by the following model:

$$ y^*_i = \beta_1 + \sum_{k=2}^{K} \beta_k x_{ik} + \epsilon_i = X_i^\prime \beta + \epsilon_i \quad (1) $$

where $x_{ik}$ represents the characteristic $k$ of household-i and $\epsilon_i$ represents an error term. We assumed that the independent variables were exogenous. The fuel choice was selected as:

$$ y_i = 1 \text{ (Clean fuel) if } y^*_i > 0; \quad y_i = 0 \text{ (Dirty fuel) if } y^*_i \leq 0. \quad (2) $$

The probability that household-i chose clean fuel was calculated as: $\text{Prob}(y_i=1|X_i)=G(X_i^\prime \beta)$, where $G(.)$ represents the cumulative distribution function of the error. We assumed that the error term followed logistic distribution. Therefore, the probability that household-i chose clean fuel was calculated as:

$$ \text{Prob}(y_i=1|X_i) = \frac{\exp(X_i^\prime \beta)}{1+\exp(X_i^\prime \beta)} \quad (3) $$

We estimated the response probabilities using the Maximum Likelihood Estimation method.

4. Survey Site and Sampling Design

To analyze the determinants of cooking fuel choices in rural India, we conducted a field survey in a rural region under the Dhapdhapi-II gram panchayat in West Bengal during August, 2016. Gram Panchayat is the keystone of a local, rural self-government in India. Dhapdhapi-II includes 17 villages and is one of the 312 gram panchayats in the South 24 Pargana district. The total adult population was 13,024 in January, 2016. The survey region is located ap-
proximately 35–40 km south-east of the state capital city, Kolkata and is well connected to the city by roads and railways.

This rural area has a wide variation of households in terms of socio-economic factors and possesses properties of a third world rural region such as duality, income inequality, lack of infrastructural development, pollution and lack of awareness. However, because of its close proximity to the city of Kolkata, the residents have greater accessibility to modern amenities and, therefore, their fuel choice options are not constrained. The households in this survey site is representative of the rural population of West Bengal and also bears some features which is common to other areas of rural India as well. The villages under Dhapdhapi-II gram panchayat were considered an ideal survey area to analyze cooking fuel choice decisions in rural India.

For the survey, sample households were randomly selected from a household list that was prepared based on the electoral rolls that are publicly available on the website of the Chief Electoral Officer of West Bengal that functions under the Election Commission of India. The sampling method was stratified random sampling with the parts consisting of the stratification unit. Part is basically a more detailed stratification unit within each electoral constituency that denotes the area that a voter belongs to. The 17 villages under Dhapdhapi-II gram panchayat are categorized into 16 parts with non-uniform population sizes. As the size of the population under each part was not uniform, the sample size collected from each part was proportional to its population size.

The respondent unit refers to the individual, or chef, who was responsible for cooking for the household. In case of multiple chefs in one household, we noted the response of the person who was responsible for cooking most the time. Our sample size was 68.

5. Variables Used and Descriptive Study

We classified the individual sampling units into two categories of fuel users based on the binary choice model and explored the efficacy of the model by conducting simple diagnostic tests. At a cursory glance, we observed that approximately 35% of the respondents were primarily clean fuel users. We used the dummy variables for various socio-economic and demographic factors such as household size, age, gender, marital status, level of education, occupation of the respondent, religion, belonging to a reserved category (the basis of which in Indian society is the perceived existence of historical and contemporary social discrimination of the ancient caste system and individuals who belong to a reserved category enjoy certain societal privileges), ownership of the dwelling unit, electrification in the house, location of kitchen, possession of a refrigerator, income, participation in a micro-financial scheme, whether the respondent was the decision-maker for fuel and whether cooking fuel was available for free or not. Since, transportation is a significant issue for our survey area, we employed two dummy variables to denote the remoteness of the dwelling unit: whether the time required to reach the nearest motorable road by walking was at most 15 minutes and whether the time required to reach the nearest market by walking was at most 15 minutes. The variables along with their summary statistics are discussed in detail in Table 1.

We observed that all our respondents are female, which was due to the societal pattern that women (particularly married women) are responsible for cooking. Among the respondents, 41% were 40 years or older and approximately 93% were married. Forty-four percent of our respondents belonged to large households with more than 5 members. Sixty-nine percent of the respondents were Hindu and 44% belong to a reserved category, which was surprisingly similar to the proportion of Hindu and reserved category population in the state of West Bengal reflecting the fact that our sample is quite representative of the rural areas of West Bengal in terms of demography. Another 69% of our sample units had obtained an education up to the primary level or more and approximately 91% were homemakers. Although only 37% of our respondents belonged to a high-income household, only 13% had recently participated in a micro financial scheme. This low participation in microfinance can be due to a recent financial scam associated with the collapse of a Ponzi scheme in West Bengal, whose operation was similar to that of microfinance organizations. Ninety-four percent of the respondents owned their dwelling units and 99% had access to electricity in their home. Fifty-four percent had their kitchen outside the dwelling unit and 25% owned a refrigerator. It took fifteen minutes or
less for 78% of the sample to reach the nearest motorable roads from their dwelling units and 78% of the respondents required at least 15 minutes to reach the nearest market from their dwelling unit by walking. Thirty-two percent of the respondents reported that their cooking fuel was available for free; specifically, they or other family members (particularly children) collected the cooking fuel. However, this in no way involves the exploitation of child labor and fuel collection is conducted during their leisure time.

As per traditions and societal patterns in rural India, women are not the overall decision makers in households; however, we noted that approximately 50% of our respondents were the decision makers for the primary cooking fuel that was used in the household.

To assess about the respondents’ awareness regarding the PMUY scheme, we asked if they were aware of the scheme. Around 59% percent of the dirty fuel users reported that they were aware and 73.07% of the aware ones responded that they were not eligible for this scheme due to lack of ownership of BPL card. The remaining dirty fuel users who were aware of the scheme stated that they either had already participated or expected to participate soon. Surprisingly, 25% of the clean fuel users reported that they were unaware of this scheme. Details of these results are discussed in Table 2.

To assess respondents’ awareness about the polluting nature of the fuels, we surveyed their perceptions about how clean they thought their fuel was. Seventy-five percent of the dirty fuel users responded that their fuel caused pollution while around 16% of the dirty fuel users reported that their fuel cause no or low pollution. Ninety-six percent of the clean fuel users reported that their fuel cause no or little pollution. Nine percent of dirty fuel users and 4% of clean fuel users responded that they were not aware of the polluting nature of their fuel. This observation indicates that the respondents in our survey area have some awareness about the polluting nature of the cooking fuel they used. We have discussed these results in details in Table 3.

We conducted the Chi-square test for independence between the dependent variable and each of the mentioned independent variables. The results are reported in details in Table 1. We observed that there...
was an association between the fuel choice decision and education, religion, distance to the nearest motorable road, location of the kitchen, ownership of a refrigerator and the ability to obtain free fuel. However, because the Chi-square test is unable to address the issue of confounding, we estimated the regression model and analyzed possible determinants of the cooking fuel in our survey area.

6. Results

6.1 Estimation results

First, we examined the odds ratio to determine whether any of our independent variables were associated with each other and the result is presented in Table 4. The farther is the value of the odds ratio from 1.0 in a given direction, the stronger the association between two variables. We observed that the dummy variable for income and the dummy variable for ownership of a refrigerator were associated with an odds ratio equal to 16.97 and the dummy variable for distance to the nearest motorable road and that to the nearest market were also associated with an odds ratio equal to 11.75. We concluded that the dummy variables for the distance to nearest motorable road and to the nearest market were associated with each other as were the dummy variables for income and ownership of a refrigerator. We also observed that the dummy variables for income and participation in a microfinance scheme were not associated.

From the estimation results of the equation using logit regression (Model 1 in Table 5), we found that household size, age, education, distance to nearest market, location of the kitchen, income and free availability of cooking fuel significantly determined the choice of cooking fuel in rural Indian households. In alignment with prior studies, it was also revealed that large households chose dirty fuels; this may occur because the opportunity cost of time to collect dirty fuel is lowered for larger households. This study found that older individuals chose cleaner fuels; this may have occurred because older individuals with expected higher savings can afford clean fuels, as suggested in prior studies.
Cooking Fuel Choices in Rural India

ness of the ill-effects of dirty fuel, which conforms to the previous studies\(^{17, 28}\). Our results align with prior studies\(^ {14}\) in that when the location of the household was closer to a market, accessibility was improved and it was more likely that cleaner cooking fuels were used. Furthermore, we observed that households with higher incomes chose cleaner fuel due to greater affordability, which conforms to the energy ladder hypothesis and prior studies\(^ {10}\). Interestingly, we noted that households with a kitchen located inside the dwelling area chose cleaner fuel, which may have occurred because smoke from fuels makes the interior of the dwelling area dirty and impacts their health. However, how well they perceived that smoke was harmful to their health was beyond the scope of our current analysis and may be considered a scope of future work.

Finally, we found that households with a greater ability to obtain free cooking fuels chose dirty fuels that were often collected or produced by the household, which was another notable observation. Because most our respondents had not participated in micro-finance, we removed that variable and estimated the alternative model (Model 2). For the second model, we noted that the results from the previous model did not change much. However, the second model had a lower log likelihood value, Akaike Information Criterion (AIC) value and Bayesian Information Criterion (BIC) value and therefore, was a better fit for the data\(^ {26}\).

We tried to observe the marginal effects of the explanatory variables on the choice of cooking fuel. We observe that the marginal effects of household size, age, distance to the nearest market, location of the market, income (in model-2 only) and availability of free fuel are significant on the choice of cooking fuel. However, the marginal effect of education was not found to be significant in any of the models which may be due to confounding\(^ {26}\).

6.2 Simple diagnostic test

We utilized the best model (Model 2) to conduct a simple diagnostic test to check the accuracy of our classification of clean fuel and dirty fuel in alignment with the method used by Friedman \textit{et al.}\(^ {24}\).

We observed that the probability of correct classification was 0.8529. The sensitivity and specificity of the classification rule were 75\% and 90.91\%, respectively. We concluded that, based on the sample studied among the clean fuel users, 75\% were identified correctly and among the dirty fuel users, 90.91\%
were been identified correctly. The positive predictive value and negative predictive value were 81.82% and 86.96%, respectively. Therefore, we concluded that among the classified clean fuel users in our sample, 81.82% were actual clean fuel users and among the classified dirty fuel users, 86.96% were actual dirty fuel users. To clarify, the false discovery rate and false omission rates were, respectively, 18.18% and 13.04%.

Furthermore, the positive likelihood ratio was 8.25, which indicates that a household that used clean fuel was 8.25 times more likely to be categorized in the clean fuel user class when compared to a household that used dirty fuel. The negative likelihood ratio was 0.275, which indicates that a household that used clean fuel was 0.275 times less likely to be categorized in the dirty fuel user class when compared to a household that used dirty fuel. Therefore, the diagnostic odds ratio was 30, which indicated the effectiveness of the classification rule.

The results of this study provide opportunities for our future research; we plan to observe how cooking fuel choices are affected by the fuel choices of peers, given that a fraction of individuals were aware about the polluting nature of cooking fuels which in our knowledge have not been observed before. It is likely that an individual’s choice of cleaner cooking fuel may be influenced by that of his peers indicating the presence of peer effect apart from the effect of other socio-economic and demographic variables. Future research that incorporates a broader framework is needed to estimate how different perceptions related to the diseases caused by indoor air pollution as a consequence of incomplete combustion of dirty fuel affects cooking fuel decisions, apart from common socio-economic and demographic variables as observed in this study.

7. Conclusion

We estimated a simple binomial logit model based on primary data that were collected through a field survey in villages under the Dhapdhapi-II gram panchayat in West Bengal, India to analyze the possible determinants of cooking fuel choices in rural India. We found that household size, age, education, distance to nearest market, location of the kitchen, income and availability of free cooking fuel were the primary determinants of the cooking fuel choice. However, due to a small sample size, numerous other variables were not statistically significant in our estimation and hence it was revealed that approximately 85% of the classifications were correct and the diagnostic odds ratio was 30, which indicates the effectiveness of the classification rule.

The results of this study provide opportunities for our future research; we plan to observe how cooking fuel choices are affected by the fuel choices of peers, given that a fraction of individuals were aware about the polluting nature of cooking fuels which in our knowledge have not been observed before. It is likely that an individual’s choice of cleaner cooking fuel may be influenced by that of his peers indicating the presence of peer effect apart from the effect of other socio-economic and demographic variables. Future research that incorporates a broader framework is needed to estimate how different perceptions related to the diseases caused by indoor air pollution as a consequence of incomplete combustion of dirty fuel affects cooking fuel decisions, apart from common socio-economic and demographic variables as observed in this study.

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Sensitivity 75%
Specificity 90.91%
Positive Predictive Value 81.82%
Negative Predictive Value 86.96%
Positive Likelihood Ratio 8.25
Negative Likelihood Ratio 0.275
Diagnostic Odds Ratio 30
Probability (correct classification) 0.8529
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References

燃料選択
—インド農村部における社会・経済的要因の分析—

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摘 要

途上国の家庭内での調理に起因する室内大気汚染が問題視されている。調理時に発生する煙の健康への悪影響が報告されている。調理時に使用する燃料・エネルギー源を変えることでこの室内大気汚染を減らすことが可能であるが、途上国の多くの家庭が汚染を引き起こす伝統的な燃料の使用を続けていている。家庭の燃料選択を対象とした実証研究が始ままっているが、家計レベルのミクロ・データセットを用いた研究はまだ少ない。本研究はインド・西ベンガル州の68世帯を対象としたフィールド調査と収集したデータを用いた計量経済学的分析によって、インドの家計の燃料選択に影響を与える社会経済的要因を明らかにした。対象地域から無作為に抽出した家計の調理担当者を対象としてインタビュー調査を行い、薪・牛糞・石炭を「汚い燃料」、ケロシン・液化天然ガス・電力を「きれいな燃料」と定義し、データを生成した。家計の燃料選択をランダム効用モデルを用いてモデル化し、収集したデータを用いて、回帰分析を行った。ロジット・モデルを用いた尤度法による回帰分析の結果、調理が家の中で行われる家計ほど、また、燃料を無料で入手することができない家計ほど、「きれいな燃料」を選択することがわかった。加えて、「家計所得」「回答者の年齢」「教育水準の高さ」に関する指標と「きれいな燃料」の選択との間に正の相関が見られ、「家計の構成員数」「最も近い市場への距離」に関する指標と「きれいな燃料」の選択との間に負の相関が見られた。これらの結果を活用し、家計の社会経済的状況に応じた室内大気汚染削減政策を立案することが求められる。

キーワード: 調理用燃料、計量経済学、フィールド調査、インド、室内大気汚染