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Determinants of Household Fuel Choice Behavior in Rural Maharashtra, India

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Abstract. This paper applies multinomial logit model to household fuel use for cooking and heating to analyse the factors that determine the fuel choice in rural part of Buldhana district, Maharashtra, India. The model discusses the socio-economical variables of household energy preferences such as size of household, age of household head, education status of family members, dwelling status and income level. The model examines choice between a set of mutually exclusive and highly differtiated fuels for cooking and heating such as firewood, LPG, kerosene and other fuel. The study reveals that the firewood would be an important fuel in future for majority of households in surveyed villages. Lack of income generating opportunities is the main factors in switching to cleaner fuels. For households who cannot afford LPG or kerosene but purchase or collect firewood, improved biomass stove may be a good option. Raising public awareness would facilitate switching to cleaner fuels.

Keywords: Behavior analysis, cooking and heating energy fuel, multinomial logit model

1. Introduction

The rural energy planning in developing countries like India needs the issue relating to energy choice and household energy transition. Energy for cooking remains a major concern of consumers and policy makers in India. There have been few systematic studies of available options. But regional approach is necessary due to diversity of diet and cooking practices [1]. Many developing countries have initiated efforts to advocate more efficient energy use and to reduce adverse environmental and health impacts by encouraging fuel substitution. More research and analysis of factors are required to determine household fuel choice and energy consumption pattern, specifically in rural. There is little data of local availability and transition and opportunity costs involved in gathering the biomass and other fuels in rural by which fuel choice is often determined. Rural households require fuel mainly for cooking and heating and therefore its pattern and choices are important to study. Data from Census, 2001 indicates that more than 139 million households in India (72% of all households) rely on traditional energies for cooking needs. Out of this, more than 124 million households reside in rural areas. Firewood remains the major source of cooking fuel in India, with more than 100 million households using this fuel, of which more than 88 million are rural households. Out of modern energies, LPG is most widely used for cooking purposes: around 26 million urban households and 7.5 million rural households are using this fuel. Kerosene is used in 12.5 million households, out of which around 10 million are urban households. Electricity is practically not used for cooking purposes. Sixty-four per cent of the rural households rely on firewood for cooking and another 26% rely on crop residue or animal wastes. This implies that 90% of the rural households depend on traditional energies for their cooking needs. On the other hand, less than 30% of urban households rely on traditional energies for cooking [2]. Fuel choices are constrained by lack of access to commercial fuel at reasonable prices and costs of equipment and appliances. Many poor households in rural India solely rely on firewood as their primary source of cooking and heating, despite of shift away from biomass to commercial fuels [3].

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As LPG (liquid petroleum gas) is convenient, less polluting and efficient fuel, it is preferred by those who can afford it and have access to it. But the shift from biomass or kerosene to LPG is constrained by fuel cost and cost of connection. The choice of fuel by household appears to be dependent on not only cost but other factors also. In this study, Multimonial Logit (MNL) model has been used for determining significance of various factors on fuel choice in rural households. The most widely used choice model is MNL model due to simple mathematical structure and ease of estimation where the distribution of the random error term is independent and identical over alternatives [4,5].

2. Energy Consumption Pattern

Four villages named Muradpur, yewta, Sawargaon Dukare (S. Dukre) and Malshemba from Buldhana district located in Vidarbha region of Maharashtra state, India were selected for data collection. The main energy resources in Buldhana district are traditional fuels, mainly fuel wood, agricultural residue and dung. Investigation was conducted in four villages to find rural energy needs and it's potential. Table 1 presents demographic information of four villages. S.Dukre has highest population and muradpur has lowest among four selected villages. The data was collected from 193 stratified samples in four villages of Buldhana district. Fuel wood is used in an average 96.28% of households. Fuel woods are mostly collected by women and children, so it will remain predominant as long as women's labor is not valued. Consumption of fuel wood is still increasing in absolute terms, even when their share in net energy consumption is decreasing. 12.99%, 4.17% and 23.45% of households use dung cake, biogas and LPG respectively. Fuel wood consumption is highest in Muradpur (94.11%). The LPG share is more in Yewta as compared to other three villages due to higher numbers of large family category. Five different fuel mixes were identified. The early argument of dependency on fuel wood by households is supported by higher percentage of this energy source consumption. The energy source LPG comes second and mainly used by high economy group. On average, household using mixed fuel wood-LPG tend to rely more on crop residues and on market to some extent for fuelwood. Potential saving in fuel wood is unlikely to occur as rural households lagging economic power to switch to LPG and relying more on locally available fuel wood. Traditional chulhas used by rural households are very wasteful. They use only 10% of the total heating potential of the fuel burnt in them. A major disadvantage of the traditional chulhas is that they produce a lot of smoke, soot and un-burnt volatile organic matter, which not only blacken the pots and the walls of the kitchen, but also lead to Indoor Air Pollution.

Table 1: Demographic and population Information of surveyed Villages

Name of Village	Population	Number of Households	Total Land (ha)	Population density (Persons/ha)	Cultivated land (ha)	Irrigated land (ha)
Malshemba	1270	256	639	1.99	560	30
Muradpur	913	196	520	1.76	494	4
S Dukre	2292	459	485	4.73	433	10
Yewta	1555	316	1377	1.13	1215	50

The average consumption of fuel wood for cooking is 1.7 kg/person/day in summer, 1.74 kg/person/day in winter and 1.81 kg/person/day in monsoon. Consumption rate is 2.35% more in winter and 6.32% more in mansoon. The average dung cake consumption in summer is 0.39 kg/person/day, 0.40 kg/person/day in winter and 0.42 kg/person/day in mansoon. Average consumption of biogas and kerosene is 0.13 m3/person/day and 0.42 l/person/day respectively. LPG consumption of rate is more in Yewta due to more numbers of large family categories. An average fuel wood consumption for heating in summer is 1.23 kg/person/ day, 1.38 kg/person/day in winter and 1.47 kg/person/day in monsoon. Fuel wood consumption rate is 12.63% more in winter and 19.96% more in monsoon than summer. Dung cake consumption is also main supporting fuel for heating in rural. It has an average consumption rate of 0.14 kg/person/day in summer, 0.16 kg/person/day in winter which is 14.04% more than in summer and 0.18 kg/person/day in monsoon which is 28.07% more than in summer.

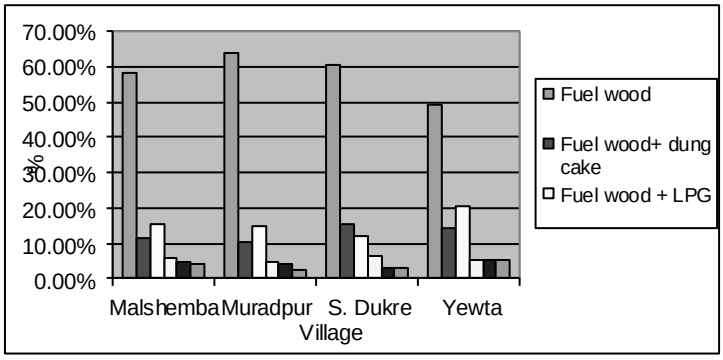

Fig. 2: Percentage distributions of households by fuel-mix

3. The Model

This study presents MNL model to determine the significance of variable appeared to impact a household's choice of cooking and heating fuel in rural India. The model examines choice between a set of mutually exclusive and highly differentiated fuels for cooking and heating such as firewood, LPG, kerosene and other fuels (eg. Dung cake, dung/crop residues). The MNL reduces to a logit model if two discrete choices are to be made. The probability of choosing type of cooking and heating fuel lies between zero and one without any reallocation in alternatives set and without considering change in fuel prices or fuel attributes. The main assumption of the model is that household makes such a fuel choice that maximizes utility. The multinomial logit model is an extension of binary logit model. The multinomial logit model estimates the effects of explanatory variables on dependent variables with unordered response categories. One important issue on the use of multinomial logit model is the assumption of independence from irrelevant alternatives, or IIA. Simply stated, IIA property holds the ratio of the choice probabilistic of any two alternatives (in response categories) for a particular observation if not influenced by any other alternatives [20]. Individual is assumed to select the fuel choice that maximizes the expected utility. The i th individual's expected utility of the form

$$V_{ij} = X_i \beta_j + \varepsilon_{ij} \quad (1)$$

where, $j = 1,2,3,4$

The utility is maximized by the particular fuel choice preferred by individual. The vector of individual characteristic X_{ij} includes all the variables such as household, economical, demographic and geographical which may affect the fuel choice for cooking and heating.

Let Y be the dependent variable. The dependent variable is the fuel choice for cooking and heating (firewood, LPG, kerosene and other fuel) with firewood as a reference choice. Let $\Pr(Y_i = j)$ be the probability of choosing fuel for cooking and heating. j is the number of fuels in the choice set (in our case, number of fuels are four and $j = 1$ for reference fuel, firewood)). Let x_i be the vector of predictor (exogenous) social factors (variables) and β_j is a vector of the estimated parameters.

$$\Pr(Y_i = j) = \frac{\exp(x_i \beta_j)}{\sum_{j=2}^{4} \exp(x_i \beta_j)} \quad (2)$$

Random distribution terms are independently and identically distributed [21] and odds of choosing an alternative fuel remain unaffected [22]. The probability of choosing fuel does not change respective to one alternative or more. Vector x_i consists of variables that measure economic, household characteristics, and individual characteristics, and other variables of importance in the region.

4. Results and Discussions

Table 3 gives the standard deviation of variable values. Table 4 presents the estimation of β coefficient of the multinomial logit model and test results. The household size has non-linear relationship with fuel choices. Negative and significant coefficient for the family size variable suggests that likelihood of a household using LPG as the main fuel increased, but at decreasing rate. The households with higher size are

more likely to use kerosene and other fuel like firewood. This confirms the assumption that firewood is mostly preferred fuel in larger household as it is freely available or cheaper than other fuels if to be purchased. One percent increase in size of household would increase the probability of choosing other fuels like dung-cake, dung/crop residue and straws by 0.009% and would reduce the probability of choosing the LPG and kerosene by 0.03 and 0.007 percent respectively.

Table 3: Descriptive statistics

Variables	Minimum	Maximum	Mean	Std. deviation
Size of household (HH)	2.000	9.000	4.953	1.712
Age of HH head	23.000	73.000	48.399	9.253
Primary	0.000	1.000	0.446	0.498
Secondary	0.000	1.000	0.409	0.493
Higher	0.000	1.000	0.145	0.353
Landless	0.000	1.000	0.192	0.395
1-3 ha of land	0.000	1.000	0.368	0.483
3-10 ha of land	0.000	1.000	0.316	0.466
Over 10 ha of land	0.000	1.000	0.124	0.331
Livestock	0.000	1.000	0.710	0.455
Women in HH	1.000	5.000	2.295	1.076
Dwelling status of HH	0.000	1.000	0.855	0.353
Total income of HH (Rs./ month)	1500.000	8200.000	6253	1127

Age of household head has significant effect on the fuel choice. The result shows that the age of household head has negative statistically significant coefficient. Older head of household may incline to traditional fuel more as a matter of habit as compared to younger household head. Female headship of household seems to reduce likelihood of using modern fuels, but would increase the likelihood of choosing other fuels like straws and dung/crop residues. This may be due to poverty associated to the household headed by female. The rise in ratio of adult female in household would increase the probability of using other fuels and decrease the probability of choosing modern fuel. The probability of choosing LPG as a fuel reduces by 0.023% and probability of using other fuels would increase by 0.012%.

Table 4: Estimation of multinomial logit model for rural households' cooking and heating fuel preferences

Source	LPG		Kerosene		Other fuel	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Intercept	-11.11	47.41	-4.39	2.55	-2.17	2.20
Size of household (HH)	-0.54	0.30	-0.62	0.24	-0.12	0.19
Age of HH head	-0.98	0.04	-0.27	0.04	-0.11	0.03
Primary	-0.64	0.00	-0.31	0.00	0.17	0.00
Secondary	-0.35	0.90	-0.96	0.71	-0.53	0.50
Higher	2.03	1.07	1.27	1.06	0.98	0.97
Landless	-0.92	0.00	-0.21	0.00	-0.12	0.00
1-3 ha of land	-0.87	1.80	-0.42	0.81	-0.28	0.73
3-10 ha of land	-0.54	1.79	-0.78	0.86	-0.42	0.75
Over 10 ha of land	3.72	2.05	-2.48	1.17	-2.14	1.16
Livestock	-1.43	0.88	0.05	0.76	1.74	0.61
Women in HH	-0.17	0.54	0.76	0.29	0.19	0.22
Dwelling status of HH	-0.64	1.32	-1.40	0.86	0.29	0.69
Income of HH (Rs./ month)	2.14	0.00	0.96	0.00	-0.65	0.00

The size of household (number of members) is minimum two and maximum nine people in surveyed villages with an average of five people per household. The household size has non-linear relationship with fuel choices. Negative and significant coefficient for the family size variable suggests that, likelihood of a household using LPG as the main fuel increases, but at decreasing rate. The households with higher size are more likely to use kerosene and other fuel. This confirms the assumption that, firewood is mostly preferred fuel in larger household as it is freely available or cheaper than other fuels if to be purchased. One percent

increase in size of household would increase the probability of choosing other fuels like dung-cake, dung/crop residue and straws by 0.87% and would reduce the probability of choosing the LPG and kerosene by 0.058% and 0.53% respectively. The odd ratio implies that LPG is 0.71 times likely to be preferred than firewood if the size of household increases. The odd ratios for kerosene and other fuels are 1.25 and 1.20 respectively, indicating that, if the household size is increased, kerosene and other fuels are likely to be preferred as the additional fuel sources along with firewood being a main. This implies that, if the proper mechanism is developed to disseminate the modern fuel in rural region, kerosene and other fuels would be preferred than LPG. About 32% household heads are aged more than 50 years, 24.5% are aged of 40-50 years and remaining aged less than 40 years indicating mixed aged household heads. In fact, an increase in the age of the household member was expected to be less likely to make a household switch from firewood. The result shows that, the age of head of household has negative statistically significant coefficient. Older head of household may incline to traditional fuel more as a matter of habit as compared to younger household head. Female headship of household seems to reduce likelihood of using modern fuels, but would increase the likelihood of choosing other fuels like straws and dung/crop residues. This may be due to poverty associated to the household headed by female. The rise in ratio of adult female in household would increase the probability of using other fuels and decrease the probability of choosing modern fuel. The probability of choosing LPG as a fuel increases by 0.40% and probability of using other fuels would increase by 0.81%. The level of education is expected to increase the income level and hence, increase the probability of choosing comparatively cleaner fuels. The dwelling status has significant impact on the adoption of fuel. In the surveyed villages, around 86% of household has own dwelling indicating no constraints on fuel use pattern and storage of fuel. It has positive significance for LPG and other fuel and negative for kerosene. The middle and higher income households residing in own dwelling have sufficient space to store fuel and hence have mixed fuel choice. They generally prefer LPG and firewood for cooking and firewood for heating purpose. The poor households generally do not have their own dwelling and likely to adopt other fuel. This is because such households are rented and must follow the owner occupancy rules. The probability of shifting from traditional fuel to modern fuel has less relative significance for poor and middle category households. The probability of choosing LPG increases by 0.67% if dwelling status is improved. The probability of using kerosene increases by 0.045% and other fuel by 0.62%. Odd ratio indicate that the improvement in dwelling status likely to increase the choice for LPG by 1.39 times and other fuel by 1.6 times.

The value of probability of using LPG as a cooking fuel is taken as base and the number of household who will use LPG as the family size is calculated by using logit model. It is found that if the family size is increased from present value of 3.5 who are using LPG as a main fuel for cooking to 4, the number of households will decrease from 39 to 34 similarly if the family size is increased to 4.5, the number of households using LPG will decrease from present 39 to 32. If the size of household is increased to 5, the number of households using LPG will be decreased from 39 to 29. If the size of household is decreased from present 3.5 to 3, the number of households using LPG will be increased from 39 to 42. Hence in the coming 10 years, size of household will be an important parameter in the adopting the LPG as a main fuel for cooking. The number of households using fuel wood is presently 141 and that will be increased to 147, if the size of household is increased from 3.5 to 4 and will be increased to 159, if the size of household is increased from 3.5 to 4.5. The households using fuel wood would be decreased from 141 to 132, if the size of household decreased from 3.5 to 3. The number of household using fuel wood as main fuel would be decreased from 141 to 127, if the households with secondary educated head are increased from present 89 to 122. The number of households using LPG as a main fuel would be increased from 39 to 47, if the household with college educated head of household is increased from 4 to 11. The result hence highlighted a number of factors that determine the household fuel choice and are relevant for policy making. The study shows that the level of education, dwelling status and size of household are the significant factors in determining the probability of switching from fuel wood to cleaner fuel. Hence, many factors help trigger fuel switching. As many households continue to use firewood in rural areas, this will negatively impact on the economies of the region and the implications of this on environment are obvious. A solution to these environmental consequences need the modern fuels for cooking and heating end-use can be made more accessible and affordable. From an energy policy point of view, the results show that in order to encourage households to

make fuel switch that will result in more efficient energy use and less adverse environmental, social and health impacts, dissemination of biogas digester and solar water heating system, a promotion of higher levels of education and a promotion of general economic development could be effective instruments.

5. Policy Implications

The lack of progress in the penetration of biomass technology in rural was due to deficiencies in past policies. Firstly, policies mainly relied on supply side push rather than demand side management which played little role in biomass policy. Secondly, biomass was considered to be a traditional fuel for meeting energy demands in rural India. The depletion and degradation of forests mainly affects women of poor rural households, who gather firewood from forests. The rural women mainly rely on the energy sources which are not the part of market economy to fulfill household activities for cooking and heating. They are more vulnerable to environmental degradation which has direct impact on their work. The development of renewable energy sources for cooking and heating will ease the pressure on forests. The solar energy for cooking and heating can be a possible alternative to the use of firewood, kerosene and other fuels. Solar cooking can be a useful mitigation tool with regards to deforestation and economic debasement of rural poor. The use of solar cookers in rural is for below its theoretical potential. The most important parameter in this progress is high cost of investments. Dissemination program of renewable energy devices such as solar cooker needs to be addressed to improve its social-economical and technological aspects thereby reaping potential. This will make solar cooker more accessible to rural households. Solar water heating is cost effective even today and can replace biomass if pursued. Designing effective subsidy scheme for LPG and kerosene for rural households appeared to be difficult, by analyzing household fuel choice and alternative policies to current subsidy pattern. In rural areas, promoting a shift towards cleaner fuel by giving cash subsidy does not seem to be working properly as an alternative policy to phase down subsidy. Rural people may continue using firewood as fuel even if modest amount of cash given to them, as subsidy to cleaner fuel is not budget priority for them. The LPG subsidy scheme failed to encourage the substantial and sustainable use of LPG. The intervention strategy for using cleaner fuel would be possible by accelerating awareness about health benefits of using modern fuels. Biomass will remain the primary fuel in rural India in the foreseeable future. The promotion of cleaner biomass based technology (such as improved stoves, biogas, and briquettes) is found to be viable alternative in rural. It would be beneficial to determine what type of other energy options are likely to work at local level and in different economic circumstances. It is also important to indentify target areas where the probable switch to cleaner fuel is possible- that is those households who purchase biomass at small scale and areas where there are income opportunities that ensure households to adopt modern fuel for cooking and heating.

6. Conclusions

The study presents the set of important factors that determine the fuel choices in rural households for cooking and heating. The MNL analysis shows that the size of household, age of head of household, education status of family members, dwelling status and income level determine the type of fuel for cooking and heating. The study also reveals that the firewood would be the important fuel in foreseeable future for the majority of households in surveyed villages. The behaviour analysis presents that the energy fuel choice in rural region depends on many parameters and its study is needed to frame the policies for the probable fuel shift for cooking and heating end-uses. But the behaviour analysis is not sufficient for effective implementation of energy resource planning. It is to be supported with policies related to economic provision and effect of fuel prices on fuel choice for the effective dissemination programme

7. References

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