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FUEL CHOICES IN URBAN INDIAN HOUSEHOLDS*

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Abstract

This paper applies an ordered logit model to fuel choices and patterns of cooking fuels in urban Indian households. A large microeconomic dataset is employed to carry out the analysis. The results show that in addition to income, there are several socio-demographic factors such as education and sex of the head of the household, which are important in determining household fuel choice. In addition, the model performs better when information on the shares of different fuels in total useful cooking energy are included, and this suggests that it is important to incorporate multiple fuel use patterns in modeling fuel choice in the Indian context.

I. Introduction

For a number of developing countries, including India, issues relating to energy choice and household energy transitions are important from a policy standpoint. Efforts at encouraging households to make substitutions that will result in more efficient energy use and less adverse environmental, social and health impacts are advocated in many of these countries. But this requires, as a first step, research and analysis of the factors that affect or determine energy choices and consumption patterns in rural and urban areas. Information on this is limited and studies that have tried to quantify the effects empirically are even less forthcoming. A few recent examples of those that use econometric methods include Reddy (1995), Hosier & Dowd (1987) and Gangopadhyay et al. (2003).

In rural areas, choices are constrained by lack of access to more commercial fuels and markets for energy using equipments and appliances. Often, the choice of fuel is determined more by local availability and transaction and opportunity costs involved in gathering the fuel (mostly wood, dung and other biofuels) rather than by household budget constraints, prices and costs. Modeling choices in such circumstances is complicated and often there is little data available on proximity to supply of biofuels, opportunity costs or time needed for collection.

In contrast to rural households, urban ones have a wider choice and greater accessibility to modern commercial fuels, electricity, and energy using end-use equipment and appliances and therefore greater potential for fuel switching. The rapid growth of urban areas in developing countries has been accompanied by a huge surge in the demand for household fuels and electricity. In India, the share of urban population increased from 17.3 percent in 1951 to about 28 percent in 2001. Changing urban lifestyles have important implications for the quantum and pattern of energy use in households residing in these areas and suggest various avenues for policy relevant research. In India, household energy is required to meet the needs for cooking and water heating and for lighting and powering electrical equipment and appliances. However, the bulk of energy used in households even today is for cooking[1] and therefore a focus on cooking energy consumption patterns assumes further importance.

Despite a major shift away from the use of biomass fuels towards commercial fossil fuels and electricity over the last couple of decades, in urban areas, there are still many poor Indian households who rely on firewood as their primary source of cooking energy. However, there appears to be a clear order of preference and progression in terms of the switching and substitution behavior of households in their choice of cooking fuel. While all households do not necessarily switch completely or, in other words, terminate the use of one fuel when taking up the use of another, the general observation is that LPG (liquid petroleum gas) is the preferred option for those who can afford it and have access to it, particularly for those living in urban areas, as it is the most convenient, least polluting and most efficient fuel for cooking. Kerosene is normally used as a transitional or back-up fuel and firewood is still the choice of fuel among poorer households.

LPG, if compared to kerosene or firewood, has clear health, environmental and productivity benefits. Of course, choice is constrained by cost as well and not only fuel costs matter, but also the start-up costs of connections, equipment and stoves. Some recent studies that have compared total costs of different cooking fuels in India (WB, 2003; Reddy, 2003) find that in some cases the option of purchased

[1] It accounts for about 90% of the total residential energy consumption in India as reported by Natarajan, (1985).

firewood can be even more expensive than LPG particularly, when the efficiency of use is taken into account. A number of factors other than the cost affect the choice of fuel used by the household. The energy ladder hypothesis prescribes income to be the sole factor, however, as will be shown later in the paper, there are several other household characteristics that affect choice.[2] In addition, choice is often not confined to a single fuel, but rather multiple fuel use is the norm for most households and this will be taken into account too.

In this paper, we are interested in an analysis of the cooking fuel consumption patterns in urban households of India. For this purpose we use a microeconomic data set, which is derived from the Indian Household Consumer Expenditure Survey conducted by the National Sample Survey Organisation (NSSO, 2002). Fuel choice is modeled empirically using a discrete choice framework and the substitution relationships between fuels examined. The analysis also helps to identify several socio-demographic variables that are important in determining fuel choice.

The rest of the paper is structured as follows. Section II includes a brief review of the literature. Section III describes the data. Section IV presents the model, and section V contains the results. Finally section VI concludes with a brief discussion of some of the main policy implications.

II. Literature Review

In the literature there are few studies that have tried to investigate factors affecting fuel choice using disaggregate household data. Amongst the studies for developing countries, we can distinguish between two types of analysis, those that use

[2] For a discussion of the energy ladder hypothesis see Leach, 1992, Sathaye & Tyler, 1991, Smith et al., 1994, Reddy & Reddy 1994

simple descriptive statistics and others that have employed econometric methods to analyze fuel choice.[3]

So what can one say from the literature about factors that determine the choice of fuels used by a particular household? The traditional view on fuel switching in the household sector of developing countries has been that households gradually ascend an "energy ladder" and that there is a simple linear progression from relatively inefficient fuels and energy end-use equipment to more efficient fuels, electricity and equipment, with increasing income levels and urbanization [Leach, 1992, Sathaye & Tyler, 1991, Smith et al., 1994, Reddy & Reddy 1994]. However, recent literature on household energy use in developing countries shows that the energy ladder theory is too simplistic and that there are many other factors other than income that determine fuel choice [Davis 1998, Masera et al. 2000 and Barnett 2000]. The study by Hosier and Dowd (1987) that tests the energy ladder hypothesis empirically for household fuel choice in Zimbabwe using a multinomial logit model also shows that although economic factors do affect fuel choice, a large number of other factors are also important in determining household fuel choice. In addition, much of the literature bears out that fuel switching is often not complete and is a gradual process with many households often using multiple fuels. The reasons for multiple fuel use are varied and not dependent on economic factors alone, although the affordability or cost of the energy service also has an important bearing on the household's choice. In some cases, households choose to use more than one fuel because they want to increase the

[3] The studies that make use of simple descriptive statistics employ data from relatively small surveys. See for instance WB, 1999; WB, 2002; Alam et al., 1998.

security of supply. In other cases, the choice might be dependent on cultural, social or taste preferences.

Prior research for India includes only two studies that have empirically analyzed fuel choice for households in India using a discrete choice framework. The first of the two studies is by Reddy, 1995 and looks at household energy carrier choices for a sample of households residing in the city of Bangalore. He employs a series of binomial logit models to determine the choice between each pair of energy carriers, to explain the shifts in and the pattern of consumption of different fuels used for cooking and water heating. Results of the study confirm the hypothesis that households ascend an energy ladder and the choice is largely determined by income. However, factors such as family size and occupation of the head of the household are also seen to play a role in fuel selection amongst households in Bangalore.

More recently, the study by Gangopadhyay et al., (2003) done for the World Bank, employs a multinomial logit framework to represent household fuel choice separately for rural and urban Indian households. They also employ data from the NSSO household expenditure survey, which we use in this paper. However, they model household decisions concerning the choice of both cooking and lighting fuels together and therefore look at a choice set that consists of all the key alternatives of different energy carrier combinations used by households. They too take into account the possibility of multiple fuel use. The objective of the study was to study the effectiveness of the existing price subsidies in facilitating a shift to the cleaner and more efficient fuels – kerosene and LPG. Their results indicate that the subsidies are fiscally unsustainable and also of little help in meeting social policy objectives as they are seriously mistargeted and favor the rich disproportionately.

Recently, the availability of household level consumer expenditure survey data for India from the NSSO has made it possible to conduct an empirical analysis of factors that might influence household energy choices for a large representative sample covering the entire country.

Our paper focuses attention on several issues that have not been addressed in most previous analyses and differs from the previous studies described above in three important regards.

i. We analyze choices only in urban households, as we believe an analysis of choice of household fuels within rural areas, without incorporating information on nearness of source of biofuels or time required for collection, would be incomplete.

ii. The analysis looks at the choice of cooking fuels alone, as cooking energy needs comprise the majority of household energy needs in India and the energy services required for cooking are quite separate and disparate from those for either lighting or powering appliances.

iii. We assume that there is a natural order of progression in terms of the choice of fuels based on their efficiency, ease of use, and cleanliness and therefore employ an ordered logit framework to model fuel choice. In addition, so as to take into account multiple fuel use, we also estimate the model by incorporating the share of different fuels used in total useful cooking energy consumed by the household.

III. Data

The household micro budget data used in this study is from the household expenditure survey Round 55 covering the period July, 1999 to June, 2000 conducted by the National Sample Survey Organization (NSSO), a part of the department of statistics of the Indian government (NSSO, 2002). We selected the 1999-00 cross-section data to analyze fuel choices because it is the most recent quinquennial round of the survey that we had access to. The survey collects information on quantity and value of household consumption for a wide variety of consumer goods and services. In addition, data on a host of other socio-economic and infrastructural variables is collected via the survey. The data is collected from a large nation-wide sample[4] of households living in both rural and urban areas using the interview method. For the analysis presented in this paper, we make use of data only from the urban sample[5] and the quantity and expenditure data for fuels/ energy on a 30-day recall basis.

For the urban sector, the complete sample from Round 55 consists of 48,924 households representing 51.4 million households and a total urban population of approximately 314 million people. The information on cooking energy consumption is available for 46,918 households. Data pertaining to a few observations where there were missing or extreme values were excluded. We also excluded all observations where the household has no cooking arrangement or "other fuels", that is, fuels other than LPG, kerosene or firewood were used as a cooking fuel. This comprised about

[4] For details regarding the sampling methodology refer to NSSO (2002).
[5] The official definition of urban areas is based on number of criteria including "(a) the population of the place should be greater than 5000; (b) a density of not less than 400 persons per square km.; (c) three-fourths of the male workers are engaged in non-agricultural pursuits" (GoI, 2001).

11% of the total urban sample.[6] The final analysis was conducted using a sample of 41,593 household level observations.

The data for urban India also indicates that households in India tend to use multiple fuels, which correspond to a vector of energy services. Complete switching, where one fuel totally substitutes for another, is less common. Amongst urban households in India, the main cooking fuels in use are firewood (often bought), kerosene and LPG (liquid petroleum gas). The data indicate that in 1999-00, 30% of urban households still used firewood as a cooking fuel, while the percentage using kerosene was about 70% and about 50% used LPG. Most households use two fuels, however, about half of LPG users (25% of the population) used LPG exclusively as their source of cooking fuel. Both the choice of household cooking fuel and the amount consumed are related to the income (per capita expenditure level) and also to the household size. This relationship between the choice of primary cooking fuel and income level can be seen from Figure 1. As different fuels vary in their efficiency, the main cooking fuel is defined as the fuel that provides the highest share of total useful cooking energy[7] used by the household. This does not necessarily correspond with the reported primary cooking fuel in the data. The rate of useful energy for LPG, kerosene and wood are respectively taken as 276 kJ/liter, 148.5 kJ/liter and 21 kJ/kg. The choice of wood as cooking fuel diminishes as income increases and that of LPG rises. Whereas in the case of kerosene, the number of people using this fuel for cooking peaks for those in the third decile group and then declines.

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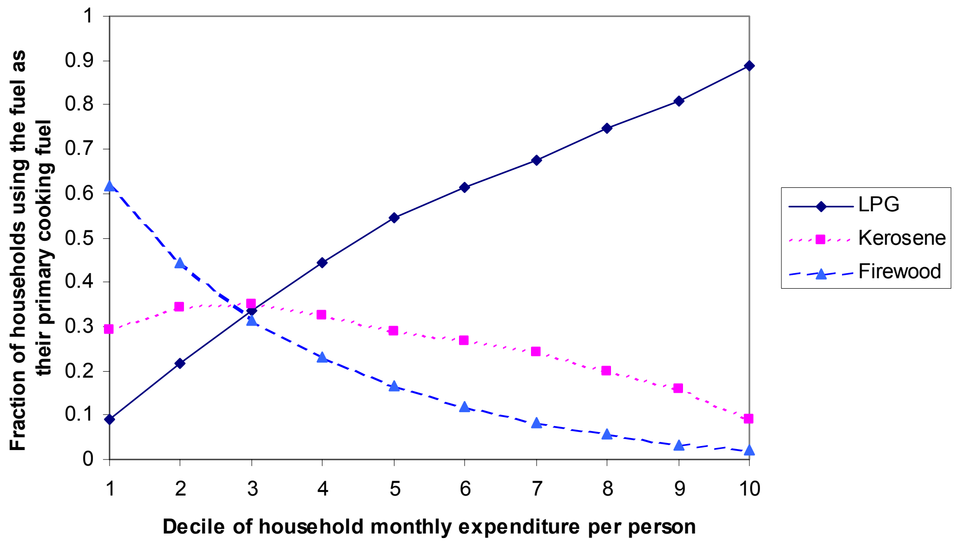
[6] These observations mainly consist of 1,768 households with no cooking arrangement, 2,087 using coal and 877 using dung cake as their main cooking fuel and 542 households that use LPG, kerosene or wood as their main fuel but use other fuels as well.

[7] Refer to Pachauri & Spreng, 2004 and Pachauri et al. 2004 for a description of how useful energy is calculated for households using the survey data.

Figure 1. Main cooking fuel by income



The pie chart depicted in Figure 2 also shows the percentage of households using single versus multiple fuels among the sample. Among LPG and kerosene users, there are many who use only a single primary fuel for cooking. This is not the case for firewood users, most of who use kerosene as well. Finally, there are very few households that use a combination of LPG and firewood or who use all three fuels.

Figure 2. Distribution of cooking fuel choice

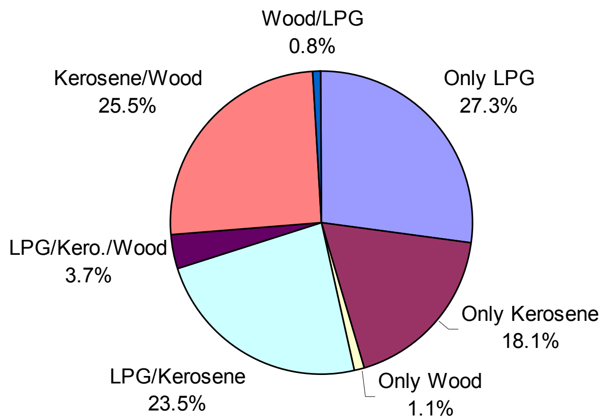
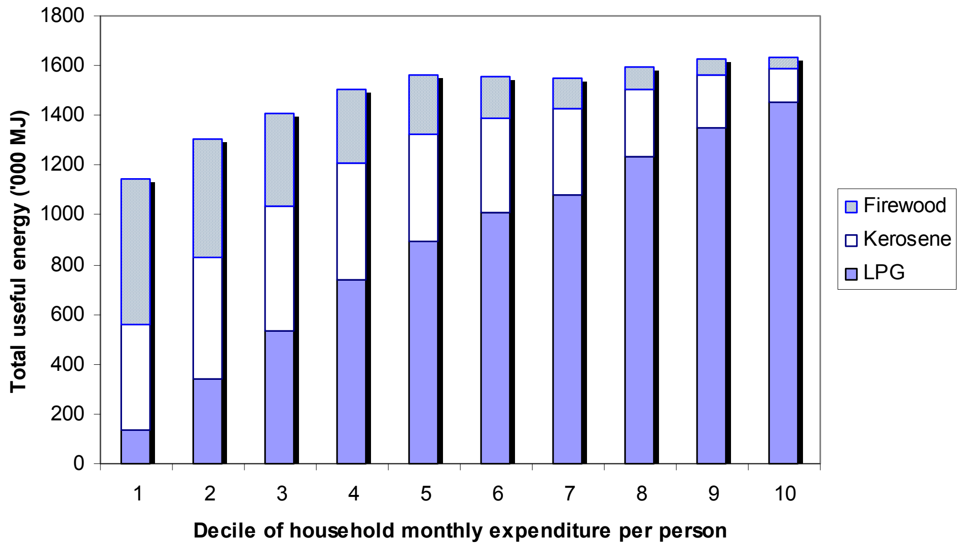


Figure 3 plots total useful energy use for cooking across income decile groups. One observes an increase in the amount of energy use with income, however there is a leveling off among the higher income deciles. It is important, however, to observe that the share of different fuels in the total varies significantly across deciles with those among the lower deciles having a larger share of firewood and kerosene, whereas LPG has the largest share amongst higher income decile households.

Figure 3. Total cooking energy by Income (41,593 households)



The distribution of households by their main fuel choice is given in Table 1. This table shows that LPG is the main cooking energy source for a majority (53.6%) of the households in the sample. Although on average, LPG accounts for slightly less than half of cooking energy, the median share of LPG is about 69 percent. This implies that for the majority of the urban households, more than two third of cooking energy is provided from LPG. Nevertheless, kerosene and firewood are used as the main energy source in a considerable number of urban households (26 and 21 percent of the sample respectively). Even in the households that mainly use LPG, the share of kerosene is on average, about 7 percent of total cooking energy. For individual households, the data reveals that the majority share is that of the primary cooking fuel in total useful energy when means are considered and in the case where the median value is taken, then for the case of LPG and kerosene users, the share of secondary fuel drops to zero (see Table 1). This suggests that it is only among firewood users that the secondary/additional fuel share is significant. Among LPG and kerosene users, it seems likely that the additional fuel is probably used only as a back up. Table 1 also shows the average share of kerosene purchased from the private market as opposed to the subsidized public distribution system. These numbers show that households that use kerosene as their primary fuel purchase more than half of their fuel from the market, whereas the majority of those who use kerosene as a secondary fuel use the subsidized kerosene. This implies that both market and subsidized prices may affect the choice probabilities.

Table 1. Average and median share of household's useful cooking energy by primary cooking fuel

		Average share of cooking energy			Fraction of households	Average share of kerosene purchased in the market
		Firewood	Kerosene	LPG		
Primary fuel used for cooking	Firewood	76.2% (78%)	23.0% (22%)	0.8% (0)	20.9%	31.2% (0)
	Kerosene	7.1% (0)	91.4% (100%)	1.5% (0)	25.5%	55.2% (56%)
	LPG	1.5% (0)	7.2% (0)	91.3% (100%)	53.6%	28.6% (0)
	Total	18.5% (0)	32.0% (16%)	49.5% (69%)	100%	38.9% (0)

- Median shares are given in parantheses.

The above descriptive analysis suggests that the observed patterns in the data are consistent with the “energy ladder” theory. In other words, there is a clear order in the distribution of energy shares by the primary fuel (see Table1). Firewood and LPG at the two extremes are more likely to be used with kerosene in the middle, than with each other. Moreover, at the bottom of the ladder, households are more likely to use two fuels. In contrast, the closer one gets to the top of the ladder (LPG), the more does a single fuel choice become likely. The econometric model used in this paper is in line with the ordered preferences observed in the data.

Table 2 presents the descriptive statistics of the household characteristics variables included in the model specification. As seen in the previous discussion, household income has a considerable effect on the fuel choice. This variable is proxied by the household's per capita monthly expenditure. Dummy variables for the level of education of the head of the household, occupation, female headed households, season, geographic location (state dummies and a dummy for households in metropolitan areas), are included in the model in addition to variables relating to household size and income, fuel prices, and age of the head of the household.[8] Fuel prices are calculated as the median value of individual prices for each one of the 78 regions (sub-states) in the sample. The individual prices are calculated by dividing the cost of each fuel type by the corresponding quantities for each household.

[8] See the appendix for sample means of state dummies.

Table 2. Descriptive statistics (41,593 urban households)

	Mean	Std. Dev.	Minimum	Maximum
LPG price* (Rps/liter)	11.808	0.610	10.56	13.33
Kerosene market price* (Rps/liter)	9.145	2.139	4.80	13.00
Kero. price in public system* (Rps/liter)	3.218	0.383	2.70	5.00
Firewood market price* (Rps/kg)	1.448	0.465	0.67	3.50
Household monthly income (Rps)	4232.1	3136.2	108	68805
HH monthly expenditure per person (Rps)	1020.4	796.6	18	35612
Age of the HH head	44.83	13.32	5	98
Number of persons in the HH	4.711	2.387	1	30
HHs with a single member	0.063	0.243	0	1
HHs with a female head	0.104	0.305	0	1
Main HH income from casual labor	0.122	0.327	0	1
HH head illiterate	0.178	0.382	0	1
HH head's education primary school or less	0.218	0.413	0	1
HH head has a university education	0.190	0.392	0	1
HH's residence in a metropolitan area**	0.214	0.410	0	1
Interview was held in Monsoon	0.249	0.433	0	1
Interview was held in Winter	0.248	0.432	0	1

* All prices are calculated as regional median prices over 78 regions.
** Metropolitan areas are considered as cities with more than a million habitants.

IV. Model and Estimation Methods

As discussed in the previous sections, the observed patterns in the data suggest that the fuel choice in urban households is consistent with an ordered discrete choice framework. These models such as ordered logit and probit are often used for ordered categorical response variables that represent groups of continuous variables, such as income groups. However, the application of these models can be extended to categorical variables that have an “assessed” order, such as “the extent of pain relief after treatment” (cf. Anderson, 1984). These variables are referred to as assessed, ordered variables. In many of these response variables, the ordering is not obvious at the first sight. We contend that the cooking fuel type in an Indian household can be considered as an ordered variable, in that the three fuel types can be clearly ordered in terms of comfort and ease of use.

In this paper we use an ordered logit model (cf. Green, 2003 and Wooldridge, 2002 for more details). In this model it is assumed that the individual choices are based on a latent variable, which can be considered as a measure of random utility. This latent variable is defined as a linear function of explanatory variables:

$$y_i^* = X_i\beta + Z_i\gamma + \varepsilon_i\,, \qquad (1)$$

where X_i is the vector of alternative fuel prices faced by the household i; Z_i is the vector of household characteristics; β and γ are the parameter vectors to be estimated; and ε_i is an *iid* stochastic error term that represents the unobserved heterogeneity. The probability of choosing alternative j is defined as:

$$\Pr(y_i = j) = \Pr(k_{j-1} < y_i^* \le k_j) \;\; ; \quad -\infty = k_0 < k_1 < \ldots < k_J = +\infty \;, j \in \{1, 2, \ldots, J\}\,, \qquad (2)$$

where k_j's are the threshold parameters.

Assuming a logistic probability distribution for the error term ε_i, the above probability can be written as:

$$\Pr(y_i = j) = \frac{1}{1+\exp(-k_j + X_i\beta + Z_i\gamma)} - \frac{1}{1+\exp(-k_{j-1} + X_i\beta + Z_i\gamma)}\,. \qquad (3)$$

The model in equation (3) can be estimated using maximum likelihood estimation method. To account for the fact that there are some households that use two or more fuels, we estimate two versions of the model, the first one (Model *I*) looks only at the choice of primary cooking fuel. The second model (Model *II*) allows for the possibility of multiple fuel use by including the share of different fuels in total cooking energy consumption. In this model, the shares in terms of useful energy are considered as the probability weights. Thus, for each household rather than one single main fuel, all the fuels with non-zero share are taken into account. The likelihood function is weighted differently for each fuel, weights being equal to the corresponding shares. This approach, commonly used for grouped or aggregate data, assumes that the fuel choice of a household in a given period (in our case a month) consists of a series of repeated decisions made over the period. The share of each fuel is interpreted as the probability of that fuel being chosen for one of these decision problems.

As seen in equation (2), the choice probabilities are assumed to be a function of a continuous latent variable (y^*) that can be considered as the household's "energy status" or the position of the household on the energy ladder. Ordered logit model is a proportional odds model in the sense that the odds ratio of switching from an alternative to the next one is invariant to the alternative. Namely, the probability ratio $\frac{\Pr(y_i^* > k_j)}{\Pr(y_i^* \leq k_j)}$ is shown to be equal to $\exp(X_i\beta + Z_i\gamma)$, thus not a function of *j*.[9] This assumption is valid to the extent that the energy status changes linearly, that is the effort (costs) required to move up from a wood-using kitchen to a kerosene one, is more or less similar to that of changing from kerosene to LPG. At this stage, we assume that this is the case. This assumption can be relaxed by using a generalized ordered logit model, which is being considered for an upcoming version of the paper.

[9] Anderson (1984) proposes a generalized ordered logit model that relaxes the proportional odds assumption. This author argues that the generalized ("stereotype") model is more flexible, thus preferable in cases where ordering is not "*a priori* obvious".

V. Results

The maximum likelihood results from the two versions of the model that are described in section IV above, are presented in Table 3. Most of the parameter estimates on the explanatory variables included in the model are significant and have the expected signs. The coefficients on the price of LPG and the price of market kerosene are significant and negative so that an increase in the price results in a shift away from that particular fuel towards other fuels. Household income has a significant positive effect on the probability of choosing LPG as a cooking fuel over either firewood or kerosene. The size of the household and the age of the head of the household also have a positive effect on the probability of choosing LPG, as does the household being headed by a female. The household head being illiterate or only having primary education increases the probability of choosing firewood or kerosene as a cooking fuel, whereas those households where the head has a higher level of education are more likely to use LPG. Living in larger cities or metros also increases the probability of choosing LPG as cooking fuel. A number of state dummies are also included in the model and the coefficients on these are mostly significant, suggesting that there are differences in the choice behavior of households living in different regions of the country (look at the appendix for a more detailed list of results including the state dummy variables).

Table 3. Ordered logit regression results

Model I: Main fuel choice, Model II: All choices with energy shares as probability.

	Model I			Model II		
Alternatives in ascending order: Firewood, Kerosene, LPG	**Coeff.**		**Std. Error**	**Coeff.**		**Std. Error**
ln (LPG price)	-2.418	**	0.362	-2.226	**	0.346
ln (Kerosene market price)	-0.349	**	0.087	-0.253	**	0.083
ln (Kero. price in public system)	0.056		0.155	-0.117		0.149
ln (Firewood market price)	0.036		0.069	-0.021		0.066
ln (HH monthlyexpenditure per person)	2.109	**	0.031	1.787	**	0.029
ln (Age of the HH head)	0.899	**	0.039	0.797	**	0.037
ln (Number of persons in the HH)	0.785	**	0.032	0.605	**	0.030
HHs with a single member	-0.619	**	0.059	-0.631	**	0.057
HHs with a female head	0.527	**	0.038	0.436	**	0.037
Main HH income from casual labor	-0.712	**	0.033	-0.598	**	0.032
HH head illiterate	-1.503	**	0.033	-1.317	**	0.032
HH head's education primary school or less	-0.907	**	0.028	-0.833	**	0.027
HH head has a university education	1.111	**	0.045	0.936	**	0.039
HH's residence in a metropolitan area	0.284	**	0.031	0.300	**	0.030
Interview was held in Monsoon	-0.011		0.027	-0.035		0.026
Interview was held in Winter	-0.040		0.027	-0.057	*	0.026
Log Likelihood	-29717.5			-31884.1		
Pseudo R-squared	0.292			0.252		
Percentage of correct prediction of the household's main fuel in the sample:						
Observed main fuel: Wood	55.4%			42.6%		
Kerosene	34.7%			52.5%		
LPG	87.1%			81.4%		
Total	67.1%			65.9%		

* significant at .05; ** significant at .01; State dummies are included in the model but not listed.

The results for Model *II*, which is identical to Model *I* except that the dependent variable in this case is not the primary cooking fuel but is the share of fuels in total useful cooking energy consumption. The results from Model *II* are very akin to that of the first model, with all the variables having the same signs and similar levels of significance. However, the order of magnitude of the coefficients is slightly lower in the case of most variables in Model *II* as compared to Model *I*. Both models clearly show though that there are a number of factors, other than income, influencing the choice of household cooking fuel in urban India.

The rates of correct prediction of the household's main fuel are given at the bottom of Table 3. Both models provide correct predictions in about two thirds of the entire sample. However, there are differences within groups of households by their main fuel type. Model *I* performs slightly better than Model *II* for households that use wood or LPG as their main fuels, while Model *II* has a better rate in kerosene users. In general, the models are better in predicting the probability of LPG use in comparison to that of either kerosene or firewood use.

In order to better understand the nature of the substitution patterns between the three main cooking fuels amongst different households, the elasticities or marginal effects of the variables at the sample means are also calculated and presented in Table 4. Moreover, the marginal effects for the variables household income and price of LPG calculated for different income tiles of the population are listed in Table 5. As expected, being in a lower income category increases the probability of choosing wood over kerosene when LPG price increases. A rise in the income level of a household increases the probability of choosing LPG as a cooking fuel, however the probability of the shift being from either wood or kerosene differs depending on which income group the household belongs.

Table 4. Marginal effects at the sample mean (only significant effects are listed)
(dP/dX for continuous variables and discrete change in probability for dummy variables)

	Model I			***Model II***		
	Wood	**Kero.**	**LPG**	**Wood**	**Kero.**	**LPG**
ln (LPG price)	0.21	0.38	-0.59	0.19	0.37	-0.56
ln (Kerosene market price)	0.03	0.06	-0.09	0.02	0.04	-0.06
ln (HH monthly expenditure per person)	-0.18	-0.33	0.52	-0.15	-0.30	0.45
ln (Age of the HH head)	-0.08	-0.14	0.22	-0.07	-0.13	0.20
ln (Number of persons in the HH)	-0.07	-0.12	0.19	-0.05	-0.10	0.15
HHs with a single member	0.07	0.09	-0.15	0.07	0.09	-0.15
HHs with a female head	-0.04	-0.08	0.12	-0.03	-0.08	0.11
Main HH income from casual labor	0.08	0.10	-0.18	0.06	0.09	-0.15
HH head illiterate	0.19	0.16	-0.36	0.16	0.15	-0.31
HH head's education primary school or less	0.10	0.13	-0.22	0.09	0.12	-0.20
HH head has a university education	-0.07	-0.17	0.25	-0.06	-0.16	0.22
HH's residence in a metropolitan area	-0.02	-0.05	0.07	-0.02	-0.05	0.07

Table 5. Marginal price and income effects at the sample median by income category (estimated from Model II)

Alternative:		**Wood**	**Kero.**	**LPG**
ln (HH monthly expenditure per person)				
HH expenditure per person:	10 percentile	-0.30	-0.05	0.35
	25 percentile	-0.21	-0.22	0.43
	Median	-0.12	-0.32	0.44
	75 percentile	-0.06	-0.28	0.34
	90 percentile	-0.03	-0.20	0.23
ln (LPG price)				
HH expenditure per person:	10 percentile	0.38	0.06	-0.44
	25 percentile	0.26	0.27	-0.53
	Median	0.15	0.40	-0.55
	75 percentile	0.08	0.35	-0.43
	90 percentile	0.04	0.25	-0.29

VI. Conclusions

The paper provides results of the estimation of an ordered logit model to fuel choices and patterns of cooking fuels in urban Indian households using a large database consisting of 46,918 observations. The analysis is used to determine the responsiveness of fuel choices to own price, income, price of alternate fuels and variables relating to demographic and geographic characteristics of households.

From the methodological point of view, this paper differs from previous literature in two regards. First, we assume that there is a natural order of progression in terms of the choice of fuels based on their efficiency, ease of use, and cleanliness and therefore, we employ an ordered logit framework to model fuel choice. Second, in order to take into account the typical multiple fuel use pattern of the Indian households, we also estimate a model using the shares of different fuels used in total useful cooking energy consumed by the household. This model seems also to be very appealing in the analysis of energy consumption pattern.

The descriptive analysis and the econometric results reported in the paper suggest that the observed patterns in the data are consistent with the “energy ladder” theory. In other words, there is an order in the distribution of energy shares by the primary fuel that depends on income. Firewood and LPG at the two extremes are more likely to be used with kerosene in the middle, than with each other. However, the results also show that in addition to income, there are several socio-demographic factors such as education and sex of the head of the household, which are important in determining household fuel choice. These results therefore suggest that income is not the only important factor that influences the fuel choice of the Indian households. Our results thus corroborate that of other recent studies that suggest that fuel choice is not determined purely by economic factors and that a more general interpretation of the energy ladder theory is needed.

From an energy policy point of view, the results show that in order to encourage households to make fuel substitutions that will result in more efficient energy use and less adverse environmental, social and health impacts, a subsidization of the LPG gas price, a promotion of higher levels of education and a promotion of general economic development could be effective instruments.

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Appendix. Ordered logit regression coefficients and sample means for state dummies.

State dummy	Sample Mean	*Model I*		*Model II*	
		Coeff.	Std. Error	Coeff.	Std. Error
AP	0.0833	0.230 **	0.064	0.221 **	0.061
ARP,ASM,MPR,MEG, MIZ,NGL, SKM,TRI	0.0838	-0.589 **	0.066	-0.467 **	0.063
BHR	0.0298	-0.340 **	0.079	-0.173 *	0.074
GOA, D&D, A&N Islands, LKS, D&N Hoveli	0.0217	-0.476 **	0.083	-0.458 **	0.079
GUJ	0.0606	0.577 **	0.065	0.435 **	0.062
HAR, PUN	0.0564	0.674 **	0.064	0.675 **	0.061
HP, J&K	0.0203	0.807 **	0.116	0.855 **	0.108
KAR	0.0530	-0.386 **	0.072	-0.416 **	0.068
KER	0.0451	-1.735 **	0.083	-1.567 **	0.079
MP	0.0655	-0.353 **	0.060	-0.159 **	0.057
ORS	0.0188	-0.865 **	0.094	-0.662 **	0.089
RAJ	0.0440	-0.353 **	0.063	-0.129 *	0.060
TN, PON	0.0994	-0.265 **	0.063	-0.296 **	0.060
UP	0.0925	-0.198 **	0.057	-0.084	0.054
WB	0.0505	-0.046	0.079	-0.020	0.075
CHD	0.0173	0.857 **	0.116	0.911 **	0.110
DEL	0.0242	0.513 **	0.097	0.589 **	0.093

The omitted state: MHR; * significant at .05; ** significant at .01.