Sustainable development and fuel choice: A case study of India

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Abstract: In India, households use more than one fuel for the fulfillment of energy requirements. So, they have to decide not only how much of a particular fuel to use, but also which fuel to choose. Energy is a necessity for a household. The demand for energy for cooking and lighting is increasing rapidly in India. Presently, India faces a dual challenge of providing clean fuel for the vast majority of households and also taking measures to reduce greenhouse gas emissions. If India adopts a carbon tax to reduce the carbon emissions so as to affect the price of fossil fuels, then this carbon tax may create considerable effect on fuel choice of households. This study examines the effect of adopting a carbon tax on fuel choice of rural households in India. It uses 2009- 10 National Sample Survey data covering over 59,119 households of rural areas. The study uses regression analysis and multinomial logit model to examine the effect of carbon tax on fuel choice of rural households. We find that with increase in income of households, the expenditure on modern fuels is increased. On the other hand with increase in price of modern fuels due to imposing a carbon tax, households are less likely to choose modern fuels than traditional fuels.

Keywords : Fuel choice, Carbon tax, Household demand

Introduction

Presently, India faces the challenge of providing access to sufficient, affordable and clean fuel sources of energy to a large population. In particular provision for rural population presents a gigantic task. This is reflected in the National Sample Survey (NSSO)[1] 66th round report, which reveals that since 1993-94 until 2009-10 there is only 2% drop in the percentage of households using firewood, while the percentage of households using LPG has increased from 2% to 15%. In 2009-10 around 76.3% of households still depended on firewood. From the comparison of three NSSO rounds (55th, 61st, 66th) data it has been found that the consumption of traditional fuel in terms of absolute quantities has been rising in the rural sector (Energy Statistic 2013).

In India, households use multiple fuels for their energy consumption. These fuels differ in terms of generating carbon emissions. The relative proportion in which these fuels are used has changed over time. While 62% of the households in rural areas were using kerosene as a primary source of energy for lighting in 1992-93, in 2009-10, 66% households used electricity for lighting. This observation shows that in rural areas electricity replaced kerosene as a fuel used for lighting. On the other hand, this scenario is different in urban areas. Since 1993-94, dependence of households on firewood has reduced from 30% to 17.5%, and dependence on kerosene has declined from 23.2% to 6.5% in 2009-10. The percentage of households using LPG have increased from 30% to 64.5% during the same period.

Although the consumption of modern fuels has increased among Indian households, a substantial number of households use firewood for their cooking requirements. For example, according to census 2011, around 62% of households depended on traditional fuel.[2] This consumption is higher in rural areas as compared to the urban areas.

[1] NSSO is an organization under the Ministry of Statistics of the Government of India. It conducts nationwide household consumer expenditure surveys at regular intervals as part of its "rounds". Each round is normally of a year's duration.
[2] Firewood, charcoal and dung cake are mainly included in traditional fuels. In our study we have concentrated only on firewood.

This behavior of consumption of traditional fuels in rural regions is a matter of concern, because the use of traditional fuels not only generate carbon emissions, but also cause indoor pollution that has adverse health impacts, especially on women and girl children.

Per capita consumption of energy in India has been rising, but it is significantly below that of developed countries and the world average. Expert group on an integrated energy policy projects that the level of per capita energy consumption of India in 2032 would be less than 74% of the world average. India's 21.9% [3] population lives below the poverty line. Thus India faces a dual challenge of providing clean and less polluting fuel to its vast majority of households and taking measures to reduce green house gas emissions. With a growing global concern about the threat of climate change, India faces pressure from developed countries to adopt policies that mitigate green house gas emissions. One such policy instrument is a carbon tax. Following some developed countries, if India adopts a carbon tax[4] or any equivalent policy measure, which affects the price of fossil fuels, it may create considerable effect on fuel choice of households. The fuel choice decision affects the environment at a local and global level along with household budget and health. Thus, it is important to study the effect of an energy policy on fuel choice decision. It is especially relevant for rural households who have low paying capacity and are dominant users of traditional fuels.
To achieve the goal of clean energy specified in SDGs if India adopts a carbon tax or any equivalent policy measure, which affects the price of fossil fuels, it may create considerable effect on fuel choice of households.The objective of this study is to examine if adoption of a carbon tax policy creates perverse effect in terms of incentivizing rural households to move towards traditional fuels. It may happen because these fuels are available to the households free of cost or at a very low price. If that happens then total emissions may increase instead of falling down and also it would have adverse effect on the health of household members. More specifically we want to examine the effect of an increase in the price of modern fuels on the probability that the household moves to traditional fuel. The study focuses on rural households, as they have easier access to firewood. Further we consider choice of fuel for the purpose of cooking and lighting. Data for this study is obtained from NSSO's 66th round survey covering the period July 2009 to June 2010. In this study first we use regression analysis to examine the effects of fuel price on fuel demand. Secondly, assuming household's fuel consumption decision a choice problem, multinomial logit model has been developed. To strengthen our results, we also calculate marginal effects. We found that with increase in price of modern fuels, the demand for traditional fuel also increases. Our findings also suggest that in rural areas lower income households have a higher probability to choose traditional fuel.
The next section describes the energy ladder hypothesis. Third section provides the review of related literature. Fourth section provides the econometric analysis for fuel choice and data used. Fifth section contains the empirical analysis of fuel choice using regression equation. Sixth section contains the multinomial logit and marginal effects. Finally, conclusions are given in seventh section.

Fuel choice

In general, there are a number of fuels that can serve the same purpose of cooking and lighting. These are mainly firewood, dung cake, chips, kerosene, LPG, electricity, etc. These fuels may differ in terms of emissions, ease of use, prices, etc. Thus, it is important to understand household fuel choice behavior and adopt policies to shift households toward cleaner fuels. There are two theories describing the shift in household fuel choice—energy ladder hypothesis and energy stack model. *Energy ladder hypothesis* examines the household fuel choice behavior. This model depicts a three-step fuel switching procedure. In the first stage, households mainly use traditional fuels. With an increase in income, households shift towards transition fuels; kerosene, coal and charcoal. In the third step, households shift towards more energy efficient fuels like electricity, LPG or natural gas. This theory proposes that as income increases further, households reject the consumption of traditional fuels and shift towards modern and energy efficient fuels. The shift is primarily caused by an increase in income.

Contrary to the energy ladder theory, according to the *energy stack model,* fuel choice behavior of households takes a portfolio choice form. Instead of traditional theory, it assumes that as a response to increase in income, households do not completely shift towards a new efficient fuel but continue using more than one fuel. (Figure1.1)

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[3] Planning commission of India (2009).
[4] A Carbon Tax is a specific tax, placed on fossil fuels in proportion to their carbon content or CO_2 emission

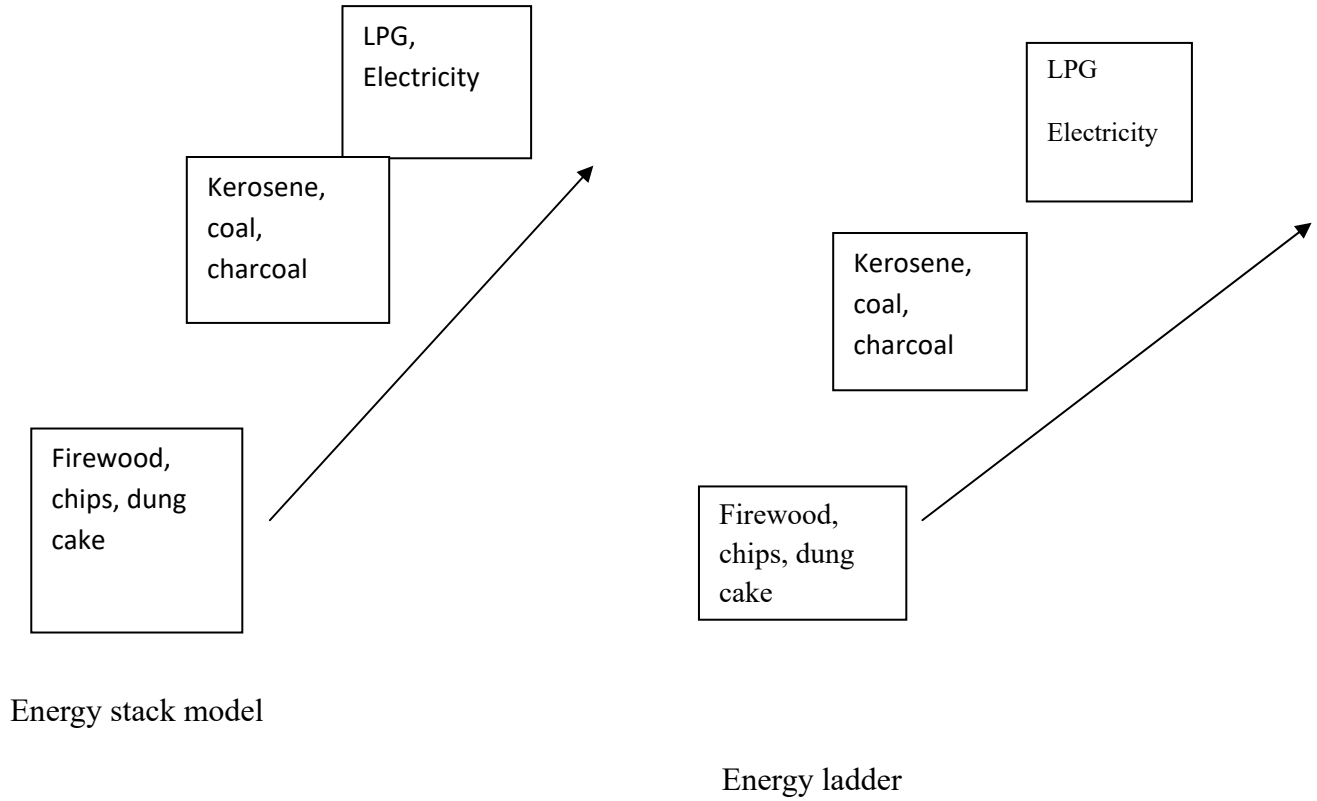

figure1.1

Source-Sclag and Zuzarte(2008)

In the literature, it has been seen that fuel switching is common in urban areas when there is an increase in income while fuel stacking [5] is dominant in rural areas. From empirical studies, it is found that household fuel choice decision is affected by various factors - economic and non-economic. Economic factors include household income, and household expenditure. The non-economic factors include social and demographic factors such as household size, social group (caste), education of head of the household, location etc.

Apart from these factors, prices of alternative fuels can also play an important role in decision of fuel choice in a country like India. As was noted earlier, in India around 62% households (census of India) rely on traditional fuels, which are available generally free of cost. So, if there is a carbon tax on fossil fuels or any other policy instrument which increase the price of fuels, then there might be a possibility that rural households shift towards traditional fuels. Therefore, it will be interesting to examine that how far price affects the household decision to choose a particular fuel type.

Literature review

From a policy point of view, issues related to fuel choice are important for many developing countries including India. Literature analysis includes both economic and non-economic factors that affect fuel choice. Household fuel

[5] Fuel switching can be defined as the choice to completely shift and use a new fuel. On the other hand, in fuel stacking households do not completely shift towards a new fuel but consume different fuels in different proportions.

choice behavior is explained by energy ladder hypothesis, which depicts that household income is the sole factor determining the fuel choice of a household. This hypothesis assumes that as income increases, households reject the consumption of traditional fuels and shift towards the modern and more energy efficient fuels. Current literature on household fuel choice depicts that, contrary to Energy ladder theory, there are many other factors other than income which affect fuel choice behavior (Davis, 1998; Masera et al., 2000).

According to Masera et al. (2000) household fuel choice can also be considered as a portfolio choice. According to this model with an increase in income, a household does not directly shift towards a new fuel, but it can continue using more than one fuel. In some studies, it is found that in urban areas, fuel switching [6] is the primary reaction to increase in income while fuel stacking or multiple fuel use is prevalent in rural areas.
Most empirical studies on fuel choice have found contradicting results. Kebede et al. (2002) found that in Ethiopia as there is an increase in income household uses more energy goods. Barnes and Oian (2002) found that in developing countries, as there is an increase in income traditional fuels do not completely disappear but, households increase consumption of these fuels.

A Large number of studies also found that fuel prices have a negative effect on fuel substitution. (Barnes and Oian1992; Kebede et al. 2002; Schlag and Zuzarte 2008; and Mekonmen and Kohlin 2008) for example Mekonmen and Kohlin 2008, have shown that when there is an increase in kerosene price, households using non solid fuels (modern fuels), shift to use of either only solid fuels (firewood) or a mix of solid and non-solid fuels. Israel 2002, found that market barriers (prices) also play an important role to determine fuel choice in addition to location, education of households etc.

In our knowledge, there are mainly three studies (Reddy, 2005; Gangopadhyay et al., 2003; Pachuari et al. 2005) which examine the factors affecting the fuel choice of households in India.
Reddy et al. (2005) made an attempt to determine the factors which affect household's decision to choose a particular fuel: -Firewood, LPG, Kerosene and electricity. They used a multinomial logit model for estimate fuel choice in India. In their results they found that economic as well as non economic factors affect household fuel choice, namely, per capita income, household size, educational status of head of the household and occupation of the household members etc. affect their decision.

Another study is done by Gangopadhyay et al., (2003) for the World Bank, used NSSO data for 1993-94 and 1999-2000 to examine the determinants of fuel choice for Indian households. They developed a multinomial logit model to examine the effectiveness of different subsidies (on LPG and Kerosene) given by government to households for a shift towards more efficient and clean fuels (e.g. – LPG and Kerosene). They found that subsidies are badly targeted and provide little help in meeting social policy objectives.
There is another study by Pachauri et al., (2005) that looks at the fuel choice in urban households taking into account fossil fuels only, with assumption of multiple fuel use for 1999-2000. They have applied an ordered logit framework to determine fuel choice. On the basis of calculation they found that their results are coherent with the energy ladder hypothesis.

Econometric analysis

We examine the effect of modern fuel prices on fuel choice. In this analysis we consider LPG, Kerosene (market kerosene & kerosene PDS)[7], electricity and firewood because these fuels are used most commonly in India. An important point to note, after examining the NSSO data, is that in India households use more than one fuel for cooking and lighting purpose (figure1.2).

For the purpose of our analysis we use two different models. Firstly, we use regression analysis to examine the effects of fuel price on fuel demand along with the existence of the energy ladder hypothesis in Indian rural areas. Secondly, assuming household's fuel consumption decision a choice problem, multinomial logit model has been developed. To examine the energy ladder hypothesis in India we used a regression model. Following Kebede et al. (2002) we regressed budget share[8] of firewood on household income, price of alternative fuels, household size and other social and economic variables. Our regression equation is given by following form-

[6] Fuel switching can be defined as the choice to completely shift and use a new fuel.

[7] Market kerosene - kerosene available at market price, kerosene PDS - kerosene provided by government by public distribution system.

[8] Budget share of modern fuels, can be calculated as monthly per capita expenditure on modern fuels divided by total monthly per capita expenditure of household.

$$D_i = \alpha_0 + \alpha_1 \ln X_i + \alpha_2 \ln P_j + \alpha_3 h_i + \alpha_4 y_k$$

Where

D_i is budget share of firewood in total monthly per capita expenditure of household i.

X_i is a monthly per capita expenditure by household *i.*

P_j is the price of alternative fuels.

h_i is household size and

y_k represents other social and economic factors.

Second, assuming household's fuel consumption decision as a discrete choice problem we use multinomial logit model[9] to examine the effect of price on fuel substitution. Multinomial logit model describes the behavior of consumers when they are faced with a variety of goods with a common consumption objective (Pundo & Fraser 2006).

The multinomial logit model is given by the following expression-

$$P\,[Yi = j] = \frac{\exp(\beta_j X_i}{\Sigma_{j=0}^{j}(\beta_j X_i)}$$

Where P [Yi = j] is the probability of choosing fuel type either LPG, kerosene, electricity with reference to firewood. J is the number of fuels in the choice set. Xi is a vector of explanatory variables. β_i is a vector of estimated parameters. A positive β coefficient implies an increase in the likelihood that household use that particular fuel with respect to reference fuel.

In our model dependent variable is fuel type and can take four values: firewood, kerosene (kerosene available at market price and public system), electricity and LPG. Firewood is base fuel in our model. The estimated coefficient evaluates the estimated change in the logit for one unit change in independent variable. A positive estimated coefficient entails an increase in the likelihood that households will choose particular modern fuel in comparison to firewood. On the other hand negative coefficient implies that there is less likelihood that a household will shift towards modern fuel from firewood.

We now describe the explanatory variables used in our study. Descriptive statistic of explanatory variables is presented in Table 1. Basically, the aim of this paper is to examine the effect of price on household fuel choice. Fuel prices are calculated by dividing the expenditure on each fuel type by the corresponding quantities of each fuel consumed by per household. However, to get a clearer picture we also include some other socio - economic factors which play an important role in determining household fuel choice.

I. Household income is the main factor, which affects the fuel choice. However, there is a lack of income data for Indian households so we use the monthly total consumer expenditure as a proxy for income. NSSO provides the monthly per capita expenditure of households. From the energy ladder theory it is assumed that total expenditure has a positive effect on household's fuel choice.

II. *Household size* has been used as an explanatory variable. Theoretically, household (HH) size is expected to influence negatively to firewood alternatives. The reason behind it is that larger household generally means larger labor input is required for the firewood collection. It has also been found that for many people it is less expensive to cook with firewood than with its alternatives (Pundo & Fraser, 2006).

III. *Household type,* a dummy variable used to show the mode of earning of household. NSSO divides the households on the basis of their income during one year. In rural areas, households are divided as: -

- Self employed in non agriculture
- Agricultural labour
- Other labour
- Self employed in agriculture
- Others

On the other hand in urban areas households are divided as –

[9] Reddy (2005) states that energy choice for cooking is a typical example of a discrete variable since household have to choose among a set of alternatives. We understand that households may be consuming more than 1 fuel, but for the purpose of our analysis, we are considering the primary fuel.

- Self employed
- Regular wage/ salary earning
- Casual labour
- Other

To measure the impact of social factors, *Social group* dummy is used as an explanatory variable. NSSO has divided household into four groups. ST, SC, OBC and others. In this analysis, we use three dummy variables for social status-SC/ST, OBC and General category.

Data sources

The household data used in the paper is obtained from the household expenditure survey Round 66th covering the period July 2009 to June 2010 conducted by the National Sample Survey Organization of Government of India. The 66th round is the most recent quinquennial round of the survey, which collected the data for the entire country. The main advantage of NSSO survey is that it provides information on quantity and value of household consumption for wide variety of goods and services. It also provides the detailed information about the social and economic characteristics of households. In the present analysis, sample data on 100855 households at all India level has been used. Rural sample consists of 59,119 households and urban sample consists of 41736 households. In present analysis, we focus only on rural sector.

Regression Analysis

Table 1: Descriptive statistic

Variable	Mean	Std. Dev.
Price LPG (Rs. / Kg)	24.06363	0.00373
Price Kerosene (PDS) (Rs. / Litter)	10.79978	0.002755
Price Kerosene (Rs. / Litter)	24.47435	0.006643
Price electricity (RS. /std.unit)	2428.301	1.96122
Household Size	4.856966	0.004841
MPCE (Rs.)	1195.215	5.43775
Electricity MPCE (Rs.)	112.7557	0.281156
Kerosene(pds) MPCE (Rs.)	23.70889	0.04319
Kerosene (MPCE) (Rs.)	10.62699	0.06193
LPG MPCE (Rs.)	64.10139	0.25325
Firewood MPCE (Rs.)	45.79556	0.10503

*MPCE – monthly per capita expenditure
*PDS - public distribution system

The results of regression analysis are given in table 2. We regressed the budget share of firewood on per capita expenditure, household size, social group and household type.

Table 2: Regression results

	Budget share of firewood			
Independent Variable	Coefficient	SE	t-value	p>|t|
ln(mpce)	-0.0349982	0.0001707	-204.98	0.000
HH size	-0.0039013	0.000038	-102.69	0.000
ln(Price LPG)	0.0302845	0.0013552	22.40	0.000
ln(Price kerosene PDS)	0.0103383	0.0007801	13.25	0.000
ln(price kerosene)	-0.0025762	0.0005665	-14.55	0.000
ln(price electricity)	0.0029574	0.0002086	14.18	0.000
Profession 1	0.0037106	0.0002627	14.12	0.000
Profession 2	0.0093163	0.000333	27.98	0.702
Profession 3	0.0081667	0.0002897	28.19	0.000
Profession 4	0.0096457	0.0002559	17.69	0.000
SC/ST	0.0102136	0.0001807	45.89	0.000
OBC	0.0017628	0.0002145	8.22	0.000
Constant	0.165136	0.0052732	31.32	0.000
R- squared	0.21			

*profession1 –self employed (non agriculture)
*profession 2 – agriculture labour
*profession 3 –other labour
*profession 4 – self employed (agriculture)

We found that the coefficient on log of monthly per capita expenditure of household used as a proxy of household income is negative. This implies that if household's income increases then budget share of firewood will reduce in total expenditure. This shows that with increase in income firewood becomes inferior good for households. We also found that Coefficients of log of price are positive except price of kerosene (market price). This implies that with an increase in the price of LPG, kerosene (PDS) and electricity budget share of firewood or in other words, expenditure on firewood will increase. On the other hand, with an increase in the price of kerosene (market price) the expenditure on firewood will reduce. Coefficients of SC/ST and OBC dummy are significant and positive, suggesting that controlling for income, in rural the backward castes are more inclined to use modern fuels as compared to forward castes. Occupational dummy also has a significant effect on demand for firewood. Our results show that coefficient of agriculture labor and other labor are positively related to demand for traditional fuels. As expected the coefficient of household size is negatively related with the share of firewood in total consumption expenditure.

Multinomial logit Analysis

Assuming household consumption decision as a discrete choice problem, we use multinomial logit model to examine the fuel substitution pattern. Ideally multiple discrete-continuous extreme value model (MDCEV) should be used for this analysis. However, we used a simplified model in this study. For our purpose of analysis, we look only at the primary fuel choice of households.[10]

The results for multinomial logit are presented in table 3

Table 3: Multinomial logit model result with base firewood

Alternatives	Kerosene	Electricity	LPG
Intercepts	-8.477444	-5.330049	-12.28918
ln (price LPG)	-0.3674353*	-1.303616	-0.7874072
ln (price kerosene)	2.037531	-0.883998*	0.7263564
ln (price kerosene PDS)	1.013565	-1.677474	- 0.1121643*
ln(price electricity)	0.3334001	0.7444457	-0.5238257
ln(MPCE)	-0.5899835	1.1087545	2.236152
Household size	0.4099547	0.4182049	0.4801022
Profession1	0.1658773	-0.0844961*	-0.5299325
Profession 2	0.0196922*	-0.270322	-1.760813
Profession 3	-.0305669*	-0.326608	-1.258733
Profession 4	-0.446643	-0.2572414	-1.130054
SC/ST	-0.4685643	-0.5619132	-0.7519635

[10] In our analysis we have assumed the fuel with maximum expenditure as primary fuel of a household.

OBC	-0.3521741	-0.2255433	-0.3351699
Log Likelihood	-64217.778		
Wald chi2(36)	15663.11		

*not significant

Table 3 presents the multinomial logit results for kerosene, electricity and LPG as compared to firewood. We found that coefficients for household monthly per capita expenditure for kerosene, electricity and LPG are statistically significant. We also found that with increase in monthly per capita expenditure, the likelihood of using electricity and LPG increases by 1.08 and 2.23 percent respectively, and likelihood of choosing kerosene reduces by 0.56 percent as compared to firewood. This shows that when monthly per capita expenditure increases household may increase the expenditure on electricity and LPG relative to firewood. This implies that firewood becomes inferior fuel for households when their expenditure increases.

Results for alternative fuel prices are significant and important for our analysis. We found that the coefficient of log of price of LPG is significant and negative for kerosene, electricity and LPG. This implies that a rise in the price of LPG makes it less likely for the households to choose modern fuels than firewood. The coefficient for log of price of kerosene (market price) is negative for electricity and positive for kerosene and LPG. This shows that with increase in price of kerosene there is less likelihood of using electricity over firewood. This implies that with increase in price of kerosene the expenditure on electricity will reduce relative to firewood. Similarly the coefficient of log of price kerosene (PDS) is found negative for LPG and electricity and positive for kerosene. This shows that with one unit increase in the price of kerosene households are less inclined to choose electricity and LPG over firewood. The estimates for price of electricity show that with increase in price of electricity households are more likely to use kerosene and electricity and less likely to use LPG as compared to firewood.

The coefficients for dummy variable of social status are statically significant and are found negative. This implies that if households are from ST/ SC and OBC category then there is less likelihood to use modern fuels as compare to forward castes. Coefficients for occupational dummies which indicate expected life style are also statistically significant and are found negative. Our results show that self employed (non agriculture & agriculture) and agriculture labor is less inclined to choose LPG and electricity as compared to firewood.
The coefficient for household size is positive for modern fuels and is statically significant. This shows that if household size increased there is a higher probability to consume modern fuels relative to firewood.

Conclusion

Energy is a necessity for a household. In India households use more than one fuel for the fulfillment of their energy requirements, because of this they have to decide not only how much to use a particular fuel but also which fuel to choose. The fuel choice decision affects the environment at a local and global level along with household budget and health. Thus, it is important to study the effect of an sustainable development policy on fuel choice decision. To analyze the effect of price and income is important for domestic energy policy as well as for effective environmental policy.

Our study provides an econometric analysis of determinants of fuel choice of rural households of India. However, our basic motive is to examine the effect of alternative fuel prices on fuel choice of households. Our study confirms the assertion that prices of alternative fuels are a major determinant of energy demand, however substitution between fuels due to change in prices of alternative fuels is not so easy in the short run. Our regression analysis results suggest that with increase in price of modern fuels, the demand for traditional fuel (firewood) in rural areas also increases. Similarly, in multinomial logit results we found that with increase in the price of LPG and price of kerosene (PDS) households are more inclined to choose firewood. Our results also suggest that in rural areas lower income households have higher probability to choose traditional fuel.

So this suggests, if there is a carbon tax on modern fuels to restrict the consumption of these fuels for environmental concerns, then there is a possibility that rural households will increase the demand for firewood which is available to them free of cost or at a low price. However, it is interesting to note from the results that other than economic factors, social- demographic factors also affect the fuel choice decision. This was found that SC, ST and OBC are less inclined to choose modern fuels as compared to firewood. Similarly, if households earn their income from agriculture activities then they are less likely to choose modern fuels. Other than these factors distance from forests,

location of household, education level of household head, availability of modern fuel, etc. are also important determinants of fuel choice of households. Our study supports the other studies for India that fuel choice is not determined entirely by economic factors.

Our study suggests that if there is a carbon tax on modern fuels, then there is a possibility that demand for firewood will increase in rural areas. This study suggests, from a policy point of view, that if the government wants to balance the environmental and developmental issues, then the government should give some kind of relief or subsidy to lower income households as well as educate and encourage the rural households for efficient use of modern fuels.

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