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Modeling fuel choice among households in northern Cameroon

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Abstract: The present study aims to explore economic and socio-demographic factors that influence the household's probability to switch from firewood to clean fuels in northern Cameroon. The paper employs an ordered probit model to construct cooking patterns and fuel choices. Three main cooking sources are considered, such as firewood, kerosene, and liquefied petroleum gas. Utilized data come from the national survey conducted in 2004 by Cameroonian National Institute of Statistics. The study analyzes the data related to the Sudano-Sahelian agro-ecological zone which is one of the most affected by land degradation and desertification. Results indicate that transition from traditional to clean and efficient fuels are still at an initial stage in the studied region. The research shows that income, firewood, and kerosene prices, age of household heads, their educational level and willingness to have a gas cylinder, as well as type of dwelling have a significant impact on fuel switching. The study recommends that government policy should be in the direction of providing targeted social transfer programs rather than supporting fuel subsidies. A necessary attention is also needed in terms of educating people towards adoption of clean fuels in rural areas.

Keywords: Cameroon, firewood, clean fuels, ordered probit model
JEL classification: D1, Q42, Q55, Q58

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1 Introduction

Expansion of agricultural land, road extension, and the heavy use of firewood as a cooking fuel choice have greatly contributed to aggregate carbon emissions and deforestation in developing countries (Geist and Lambin 2001). Duflo et al. (2008) and Akpalu et al. (2011) also highlight a negative impact of usage of traditional solid fuels on atmosphere and peoples' lives. Sagar and Kartha (2007) stress that using biomass as a cooking fuel choice creates a room for higher global warming. These and other studies (e.g., Lewis and Pattanayak 2012; Miah et al. 2011) advocate households to use efficient and clean energy sources to lessen the negative ecological, health, and social impacts.

For the past 50 years, Cameroon also suffered from the adverse effect of climate change which was the result of inappropriate farming and livestock breeding practices. Not less importantly, the rapid population growth was not followed by changes in production techniques and has led to strong human pressure on natural resources and deterioration through overexploitation (MINEP/UNDP/UNOPS 2006). Households in Cameroon heavily rely on firewood for their cooking needs (Mekonnen and Kohlin 2008) and about 70 percent of families use firewood and dung as their main energy source for cooking. Due to the fact that most regions in the country cannot afford a reliable power source, the use of electricity as a fuel option is very small (Mom Njong and Tabi Atemkeng 2011). Investigating factors determining fuel choice (besides income and price) and exploring cooking consumption patterns is very important from a policy perspective. Providing better access to efficient and clean energy sources is a vital part of the fight against poverty. But effective policy-making requires research to be conducted (Farsi et al. 2007) before urging policy makers to develop efficiency enhancing instruments.

There are several ongoing projects in Cameroon which target rehabilitation of soil conditions and deals issues related to desertification. We can distinguish the most relevant ones which are the Green Sahel Operation, the water-soil-tree, and the waza-logone project. The objective of our study is similar to the main aim of the Green Sahel Operation project. In this project households are encouraged to abandon the use of firewood and to substitute it by more efficient energies such as kerosene, liquefied petroleum gas (LPG) and electricity. In general this depends on income; when it becomes higher households prefer using more expensive but cleaner fuels. It could be the case that households do not completely switch but use a combination of fuels (Heltberg 2005) and the worst scenario is households do not switch despite high incomes and continue using firewood.

The present research is one of the first in the context of Cameroon which attempts to determine potential factors that influence households to abandon the use of firewood for the benefit of more efficient fuels. For the analysis a microeconomic data set obtained from National Institute of Statistics (NIS) is used. A discrete choice model is utilized to investigate the fuel choice and inter-fuel substitution relationships. The paper is structured as follows: Sections 2 is devoted to short literature review. Section 3 defines the data and shows some exploratory statistics. Section 4 describes the methodology, and Section 5 shows the results. The final part settles the study with some policy recommendations.

2 Literature review

Households' fuel choice can be broadly described by the energy ladder theory. The energy ladder model shows a household following a simple linear movement from inefficient to efficient fuels

and stoves as household's income increases (Alam et al. 1998; Davis 1998; Leach 1992). The model describes three levels of fuel switching. In the first level, there is strong reliance of households on biomass fuels such as firewood and wastes of animals. These fuels are inefficient because they pollute the air. In the second level because of an increase in income and other factors, households need to abandon the use of firewood and start utilizing coal, charcoal, and kerosene. These fuels are known as transitional fuels in the energy ladder model. In the third level, since households have substantial income, they can afford purchasing improved stoves and move to the cleanest fuels such as electricity and LPG (Barnes et al. 2004; Leach 1992). Instead of having only three stages, there is a possibility of having a more elaborated energy ladder model with more steps in the middle before jumping to GPL or electricity (Barnes and Floor 1999). As seen income plays a heavy role in the explanation of inter-fuel substitution. However, according to empirical evidences from a considerable number of countries, household fuel choices are explained by many other factors as well. It is also interesting to note that the household may use a mix of energy sources rather than one particular source (Barnes and Qian 1992; Davis 1998; Heltberg 2005; Hosier and Kipondya 1993; Pachauri 2004). The reasons could be related to not only economic but also other factors such as affordability and cost of energy service. Households also may prioritize security of supply and hence keep using different types of fuel sources (Farsi et al. 2007). Surrounded culture and taste preferences may also play a vital role in choosing fuel for cooking.

In recent years, renewed focus on energy use patterns has taken attention in the literature due to a negative impact of indoor air pollution on health (Farsi et al. 2007) and climate. In general, two types of studies were conducted in the case of developing countries. The first one is more descriptive in nature (e.g., Akhter et al. 2010; Campbell et al. 2003; Johnson and Bryden 2012; Njiti and Kemcha 2002; Miah et al. 2011). For instance, Miah et al. (2011) carried out an explorative survey on rural and semi-urban households in Bangladesh and concluded that income generating activities should be initiated to move households to efficient and clean fuel options. Njiti and Kemcha (2002) recommended substituting wood energy with ecologically clean fuels in Cameroon. On the other hand, Campbell et al. (2003) recommended the Government of Zimbabwe to question the desirability of encouraging housholds along the energy ladder. In these and other related studies conducted in developing countries, income remained the most vital determinant which defines that energy shift from dirty to clean energy sources (Akther et al. 2010).

The second type is more rigorous analysis using econometric applications. The approaches taken can be divided into ordered and non-ordered descrete models within the context of developing countries (e.g., Davis 1998; Farsi et al. 2007; Heltberg 2005; Jumbe and Angelsen 2011). Farsi et al. (2007, for example, applied an ordered probit model to investigate fuel options and cooking patterns in urban Indian households. In addition to economic factors, their study listed several socio-demographic variables which played a key role in household's fuel choice. Dwelling characteristics also have been mentioned as factors which define the households' energy necessities (Özcan et al. 2013; Narashima Rao and Reddy 2007). The study by Mom Njong and Tabi Atemkeng (2011) is the only empirical study dealing with household cooking fuels choices in Cameroon. The authors estimate a multinomial logit model using the Cameroonian Household Survey Data conducted in 2001. The study looks at exogenous variables that influence household cooking fuel decisions in the country. They found that the level of education attained by the household head, the distance in kilometers separating the household from the town, the fact that the family is owner of his dwelling unit or not, and if the house is modern or traditional are the factors which influence households' decision to choose cooking fuels. All these studies show no consensus (see also for Peng et al. 2010 for discussion) on the consequences of fuel switching for the absolute amount of different types of energy use.

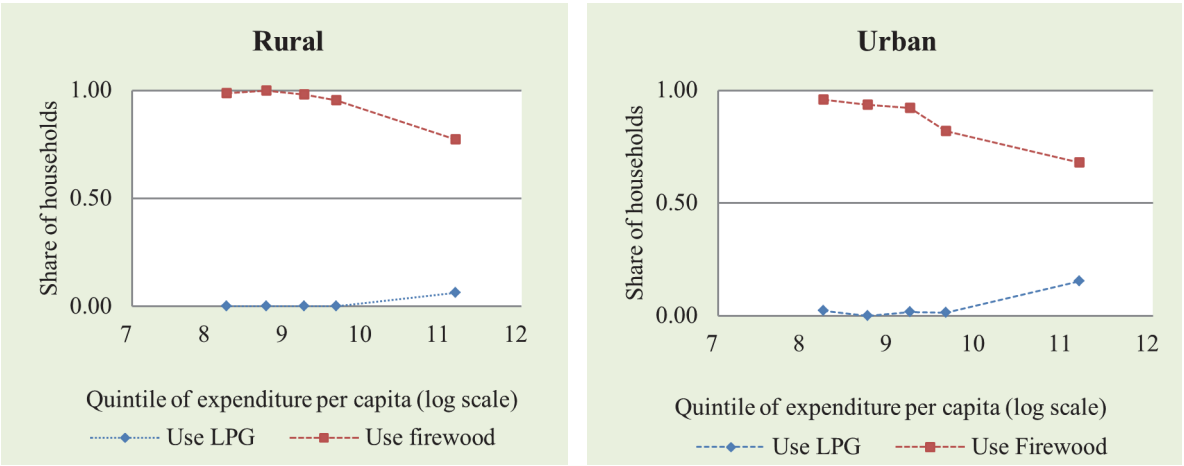
Given the limited empirical evidence in the study country, this work aims to fill the gap in the literature. The paper assumes that an expected order of movement in terms of fuel choices based on their cleanliness and efficiency, and thus utilizes an ordered probit model.

3 Data source and descriptive statistics

Data is obtained from the national survey on households' energy consumption in Cameroon conducted by NIS in 2004. The report of this survey was published in 2005. The overall sample size is 2860 households randomly selected from twelve zones of the country. We have used the data from north and far-north regions which are one of the most affected by drought and land degradation with a sample size of 553 households. About 313 households live in urban areas while 251 are rural inhabitants. The region is characterized by rainfall ranging from 400 to 1,200 mm per year, while the soil is greatly diversified (ferruginous, hydromorphic, alluvial, vertisol, etc.). Temperature ranges between 25 to 27°C during cooler seasons and can go up to 30°C in the warmer seasons (Ndenecho 2009). As mentioned this zone is characterized by widespread soil degradation and strong dependence of population on natural resources such as fuel wood.

Figure 1 divides the sample into rural and urban and shows the average rate of adoption rate for LPG and firewood at 20 percent quantile of per capita expenditure. As seen as income increases households tend to increase the use of LPG and reduce firewood consumption. This is more obvious in the sample data related to urban households. Another thing to consider is that if the rate of substitution is not that high households seem to keep firewood despite higher incomes.

Figure 1: Usages of LPG and firewood

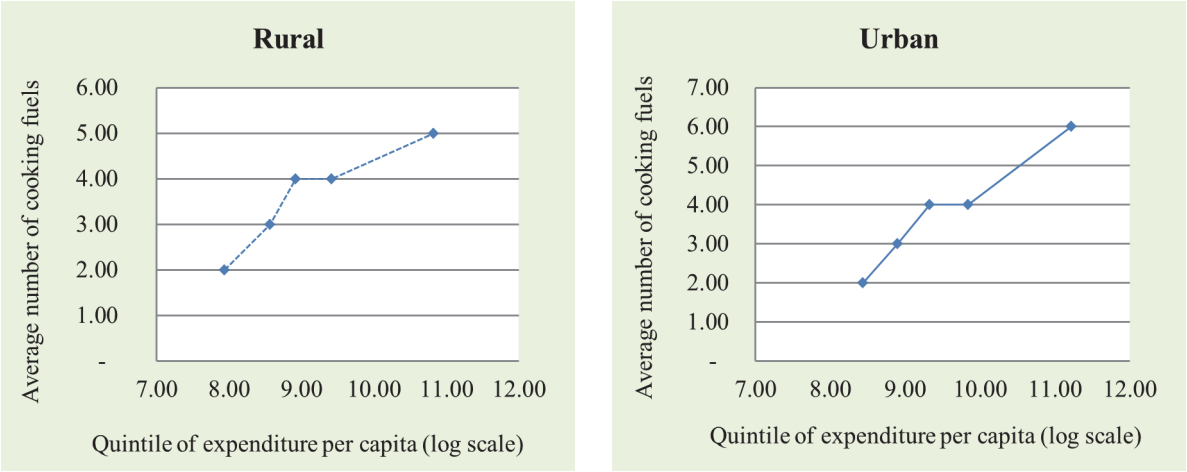


Source: Authors' compilation using NIS (2005) data.

Figure 2 shows how the number of cooking fuels evolves with respect to expenditures per capita in both rural and urban areas. We can easily see that the number of cooking fuels increases from two to five in the rural zone and from two to six in the urban zone, as we are moving from the poorest to the richest households. For families with expenditure per capita less or equal to ten, there is no significant difference in the number of fuels used for cooking. There is an increasing movement from two fuels to four. The number of fuels is still increasing whenever the expenditure per capita is greater than ten, while this number rises from four to five and from four to six in rural and urban zones, respectively. On average, representative rural and urban households of northern Cameroon use three sources of energy for cooking. This result remains

unchanged for the majority of the surveyed households (the mode and the median are equal to three).

Figure 2: Number of cooking fuels according to quintiles of expenditure per capita (log scale)



Source: Authors' compilation using NIS (2005) data.

Table 1 presents the descriptive statistics of variables used for the analysis. The descriptive statistics illustrates that an average age of a household is 47 years and only 28 percent have a paid job. While 81 percent of respondents were male, only 13 percent have a second education. Not surprisingly 57 percent live in traditional houses and only 23 percent are interested in purchasing gas cylinders.

Table 1: Descriptive statistics

	Mean	Standard dev.	Min.	Max.
Monthly income of HH (XAF)	104,084	212,921	5,000	4,500,000
Electricity price (XAF per kilowatt hour)	53	7	50	80
Kerosene price (XAF per liter)	259	14	239	290
Firewood price (XAF per kilogram)	26	13	10	39
Age of the HH head	47	14	19	98
HH head has primary education	0.26	0.44	0.00	1.00
HH head has secondary education	0.13	0.33	0.00	1.00
HH head works in paid job	0.28	0.45	0.00	1.00
HH head is interested getting gas cylinder	0.23	0.42	0.00	1.00
HH head lives in traditional house	0.57	0.50	0.00	1.00
Gender (1=male)	0.81	0.39	0.00	1.00

Note: Electricity price comes from national company of electricity (AES SONEL 2004), kerosene price has been collected from the Cameroonian Ministry of Trade and the national stabilization fund of oil prices while firewood price comes from Njiti and Kemcha (2003).

Source: Authors' calculations using (NIS 2005).

4 Model and estimation methods

The descriptive statistics of data suggests that the choice of fuel (three types of cooking fuel) among Cameroonian households is more consistent with an ordered logit or probit model. The ordered models are better in performance (Farsi et al. 2007) in comparison to non-ordered models. The study focuses on the probit model which is ordered that assumes the household's choices of fuel types are latent variables. It is also deliberated as a random utility measure. The model orders the fuel types (i.e., firewood, kerosene, and LPG) from one to three (j = 1, 2 and 3). The latent variable can be described as a function of exogenous variables:

$$y_i^* = X_i\alpha + Z_i\delta + \varepsilon_i \tag{1}$$

where X_i is the vector of fuel prices reported by user i; Z_i is the vector of user attributes; α and δ are parameters of the model; and ε_i is an iid error which is stochastic (unobserved heterogeneity). The probability of selecting another j is:

$$\begin{aligned} &\Pr(y_i = j) = \Pr(r_{j-1} \prec y_i^* \le r_j); \\ &-\infty = \mathrm{r}_0 \prec r_1 \prec \ldots \prec r_J = +\infty,\ j \in \{1, 2, \ldots, J\} \end{aligned} \tag{2}$$

where r_j s are the parameters of the threshold.

The error term ε_i follows a normal distribution with mean 0 and variance σ^2. The probability of selecting j is:

$$\Pr(y_i = j) = \phi\left(\frac{-r_j + X_i\alpha + Z_i\delta}{\sigma}\right) - \phi\left(\frac{-r_{j-1} + X_i\alpha + Z_i\delta}{\sigma}\right) \tag{3}$$

where ϕ is the CDF of a standard normal variable.

5 Results

Findings indicate to a reasonably good prediction of households' fuel choices in the Cameroonian context (Table 2). Results show that most of the chosen variables have expected significant effects. The coefficients describe the household status on the given ladder. As seen, education and income have an expected sign and effect. Households who have primary and secondary education are more willing to adopt clean fuels. This is in accordance to what has been expected that the willingness to adopt clean fuels increases with the school level of the household head. Educated people are well- informed about positive attributes of using clean fuel sources and adverse health effects of using biomass for cooking. Electricity and kerosene prices have a negative impact on fuel choice, which suggests that higher fuel prices lower energy status. In this respect households are more sensitive to kerosene prices and only after that to electricity prices. The initial model also included LPG prices but it was highly correlated with the electricity price and other variables, as a result of which it was dropped from analysis. Lowering the price of kerosene will encourage households to move to cleaner and more efficient options. The price of wood is statistically significant which suggest that households in the sample prefer and can afford considerably more expensive fuel options. The negative sign of 'age of household head' variable confirms what it was expected: an increase in age will less likely make a given household

to abandon firewood to the benefit of clean fuels. One possible interpretation is that older households will not probably abandon dirty fuel (firewood) and move to clean energy sources (gas and electricity) while younger people are more willing to move from firewood to gas or electricity. Interestingly, living in traditional houses increases the probability of choosing cleaner fuels. This could be due to the fact that some households are aware of benefits of cleaner fuels and thus prefer using kerosene and LPG for cooking in traditional houses. Households who showed great interest obtaining gas cylinders also indicated higher probability for choosing cleaner fuels for cooking purposes.

Table 2: Regression results

	Coefficients		Standard error
ln (income)	0.140	*	0.076
ln (electricity price)	-2.276	***	0.637
ln (kerosene price)	-2.522	**	1.152
ln (firewood price)	0.292	***	0.107
ln (age of the HH head)	-0.460	**	0.214
HH head has a primary education	0.316	**	0.141
HH head has a secondary education	0.431	**	0.195
HH head works in paid job	-0.178		0.152
HH head is interested getting gas cylinder	1.640	***	0.152
HH head lives in traditional house	0.286	**	0.130
Gender (1=male)	0.135		0.166
Log likelihood	-336.38427		
Pseudo R - squared	0.2160		

Source: Authors' calculations using NIS (2005) data.

The study calculated the marginal impact of significant variables (Table 3) which deliver information about the status of given exogenous variables after unit change impact or switching pattern in the case of dummies. The matching marginal effects are defined as the impact of the relative change (because continuous variables are in ln form). This allows comparing the magnitude of impact and its direction. Calculations indicate that electricity and kerosene price have the greatest impact while for dummies it is associated with those who show a great interest having a gas cylinder.

Table 3: Marginal effects at the sample mean

	Firewood	Kerosene	LPG
ln (income)	-0.051	0.004	0.047
ln (electricity price)	0.828	-0.059	-0.769
ln (kerosene price)	0.918	-0.066	-0.852
ln (firewood price)	-0.106	0.008	0.099
ln (age of the HH head)	0.167	-0.012	-0.155
HH head has a primary education	-0.118	0.007	0.111
HH head has a secondary education	-0.165	0.008	0.157
HH head plans to buy a gas cylinder	-0.588	0.004	0.584
HH head lives in traditional house	-0.103	0.008	0.095

Note: For dummies the marginal effects reflect the probability differences.
Source: Authors' calculations using NIS (2005) data.

The household head being educated decreases the probability of using firewood for cooking and household are more likely to adopt Kerosene and LPG as a fuel choice. For instance, households who have secondary degree are 17 per cent less likely to utilize firewood but 16 per cent more likely to use LPG. Findings show that there are several other determinants besides income which regulate fuel switching in the context of Cameroonian households. Findings also indicate that higher the price of firewood it is more likely that households tend to switch to other alternatives but the rate of switching is not that high. For instance, calculations show that 10 per cent decrease in the price of firewood, will lead to 1.1 per cent increase of its users. This will decrease the segment of kerosene and LPG users by about the same rate. With regards to electricity we can also summarize the results in the similar way. For instance, a 10 per cent increase in the price of electricity will lead to decreasing the share of kerosene slightly by about 0.6 per cent but the change is much higher for LPG users (7.7 per cent). Higher electricity prices mean much more people continue using firewood (switching rate is 8.3 per cent). At the same time younger households are tend to adopt clean fuels because they save time initially allocated for cooking compared to old households and more importantly, they are aware of benefits of using clean and efficient fuel sources. Interestingly, households who showed interest obtaining gas cylinders are on average 59 per cent more likely to move away from wood and 58 per cent more likely to use LPG. Those who live in traditional houses which are in general small are more likely to move away from firewood and adopt cleaner fuels for their cooking.

6 Conclusions

The study delivers results of the ordered probit model which was used to investigate cooking fuel choices among Cameroonian households utilizing a dataset consisting of 553 observations. The findings of the paper show the sensitivity of fuel choices to their own and alternative fuel prices, household income, and exogenous variables related to socio-demographic attributes of households. Methodologically, this paper differs from Mom Njong and Tabi Atemkeng (2011) who have also investigated cooking energy choices in Cameroon. This study assumes a likely order of movement in fuel selection based on efficiency and cleanliness of energy sources. The findings indicate that fuel transition is in its early stages. We also agree with other studies which suggest that income of households should increase substantially to see the sharp fall in firewood use for cooking. However, our results also suggest that order of fuel choice depends not only on

income and price (economic factors) but also other variables which have been also indicated by Heltberg (2005). Households' fuel choice decisions seem to be flexible which can be seen from two or three fuels used for cooking. However, firewood and LPG are the two mostly used fuels with kerosene in the middle. Conclusion results imply that better education helps households to be aware of negative health impacts of using firewood. In this respect, investing in education in rural schools and organizing trainings for older households about benefits of cleaner fuels will be a very effective way of encouraging fuel switching. From a policy standpoint, the study discourages the support of fuel subsidies because of higher costs involved and very small benefits gained by poor households (see also Akpalu et al. 2011 for a similar conclusion). In this regard the government policy should be towards better-targeted social transfer programs (see Barrientos and Niño-Zarazúa 2011 for discussion). On the other hand, we also support the recommendation made by Njiti and Kemcha (2002) who indicated that proper agroforestry practices should be introduced to the farming system so that farmers also diversify their portfolios with wood production being one of the produce they grow in farms which will in turn reduce pressure of heavy reliance on forests.

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