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Article

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 a household's probability to switch from firewood to cleaner fuels (kerosene and LPG) in northern Cameroon. The paper employs an ordered probit model to construct cooking patterns and fuel choices. Three main cooking sources are considered: firewood, kerosene, and liquefied petroleum gas. Utilized data are derived from a national survey conducted in 2004 by the 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 decertification. While results indicate that there is a potential for a transition from traditional to cleaner fuels in the studied region, this transition is still in its earlier stage. The research demonstrates that firewood and kerosene prices, age of household heads, educational level of household heads and willingness to have a gas cylinder, as well as type of dwelling have a statistically significant impact on fuel-switching decisions.

Keywords: Cameroon; firewood; clean fuels; ordered probit model

1. Introduction

Expansion of agricultural land and road extensions, coupled with the intensive use of firewood for cooking and heating, has greatly contributed to increased aggregate carbon emissions and deforestation in developing countries [1]. Currently, about 40 percent of the world's population uses traditional fuels as a primary fuel source for daily cooking, and lighting and heating their homes [2]. Sagar and Kartha [3] stress that heavy use of solid biomass increases the likelihood of global warming. Duflo *et al.* [4] and Akpalu *et al.* [5] also highlight the negative impact of biomass fuels on the atmosphere and human life as a whole. The World Health Organization (WHO) shows that approximately 2.5 million women and young children die prematurely each year because of health problems caused by burning biomass for cooking [6]. For example, in Sub-Saharan Africa, more than 50 percent of child deaths and 60 percent of adult female deaths in 2000 were caused by environmental pollution [7]. Thus, these and other studies (e.g., [8,9]) advocate that households switch to more efficient and clean energy sources to lessen the negative ecological, health, and social impacts of black carbon.

Poor households who are highly dependent on firewood make up approximately 70 percent of Cameroonian households. They use firewood as their main energy source for cooking. Because the rapid population growth in Cameroon was not followed by changes in human behavior, high dependence on firewood has damaged the natural environment of the country [10]. While forests cover three quarters of Cameroon's territory and the availability of biomass resources is abundant, unsustainable exploitation of these resources is increasing the number of deforested areas throughout the country [11]. Due to the fact that most regions in the country cannot afford a reliable power source, electricity is not a realistic fuel option, especially in rural areas [12]. Relevant literature has demonstrated that income is a key factor in the decision to use cleaner fuels. The more income households generate, the greater the availability of financial resources to invest in cleaner fuels. However, there have also been studies that suggest that households do not completely switch to cleaner fuels. Instead, they tend to use a combination of fuels (fuel stacking). For example, Akpalu *et al.* [5] concluded that Ghanaian households do not progress from the use of biomass energy to kerosene and liquefied petroleum gas (LPG) as their living conditions improve.

Households encounter economic, social, cultural, demographic, and environmental challenges in moving from one energy source to another [13]. Their fuel choice can be broadly explained by the energy ladder theory. The energy ladder model predicts that households follow a simple linear movement from inefficient to efficient fuels and appliances as income increases [14–16]. In general, it emphasizes the role of income and relative fuel prices in determining fuel choices. The energy ladder model characterizes three levels of fuel use. At the first level, there is strong reliance on biomass fuels such as firewood and animal waste. These fuels are inefficient because they pollute the air. At the second level, because of an increase in income and other factors, households abandon the use of firewood and use coal, charcoal, and kerosene. These fuels are labeled "transitional fuels" in the energy ladder model. At the third level, because of higher incomes, households can afford to purchase improved stoves and move to cleaner fuels such as LPG [16,17]. Instead of being confined to only three stages, the energy ladder model can be more elaborate, with additional steps (e.g., using charcoal) prior to the move to LPG or electricity [18]. However, in the study under consideration, the three fuel types covered in the simpler energy ladder model are the essential ones used in daily activities.

As previously mentioned, income plays an important role in the explanation of inter-fuel substitution. However, according to empirical evidence from a considerable number of countries, household fuel choices are influenced by many other factors as well. It is also worth mentioning that a household may use a mix of energy sources rather than one particular source [15,19–22]. The reasons are often related to other factors, such as affordability and the cost of energy service. Households may also prioritize the security that results from the ease of obtaining biomass, which may drive them to continue to use it [23]. In fact, increasing evidence from a growing number of low- and middle-income countries shows that households consume a range of energy sources spanning different points on the energy ladder. When households adopt a new fuel, they do not forego using the old but, rather, often tend to stack [24]. Culture and individual preferences influence the choice of cooking fuel. It should be noted that since 55% of households were using only one fuel in our study, fuel stacking does not seem to be important in this context.

In recent years, the literature has increased its focus on energy use patterns. This is due to the negative impact of indoor air pollution on health [23] and climate. In general, two types of studies have been conducted in developing countries. Some studies were observational (e.g., [25–28]). For instance, Miah *et al.* [9] carried out an exploratory survey on rural and semi-urban households in Bangladesh and concluded that income-generating activities should be encouraging households to "progress" along the energy ladder. Njiti and Kemcha [28] recommended substituting wood energy with ecologically clean fuels in Cameroon. On the other hand, Campbell *et al.* [26] recommended that the Government of Zimbabwe should question the desirability of encouraging housholds along the energy ladder. In these and other related studies, income played a key role in defining the energy shift from dirty to clean energy sources [25,29].

Other studies employed rigorous analyses using econometrics. These studies employed either ordered or non-ordered discrete models within the context of developing countries (e.g., [15,20,23,30]). Farsi *et al.* [23], 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 delineated several socio-demographic variables that played a key role in a household's fuel choice. Dwelling characteristics have also been identified as a factor which defines a household's energy necessities [31,32]. They have been often used as proxies for wealth. The study by Mom Njong and Tabi Atemkeng [12] is the only empirical study that addresses household cooking fuel choices in Cameroon. This study employed a multinomial logit model using the Cameroonian Household Survey Data from 2001. The study examines exogenous variables that influence Cameroonian household cooking fuel decisions. The study found that the level of education attained by the head of household, the distance separating the household from the center of town, the family's status as homeowners or renters, and the modern or traditional style of the house influence a household's choice of cooking fuels. Methodologically, this paper differs from the work of Mom Njong and Tabi Atemkeng [12] in assuming a likely order of movement in fuel selection based on efficiency and cleanliness of energy sources.

Investigating those factors that determine fuel choice, besides income and price, is important when considering policy intervention, keeping in mind that a major initiative of the Cameroonian government is to reduce poverty and increase well-being across the country. However, effective policy requires research [23] so that policy makers can be informed about the best incentive mechanisms to encourage households to switch to cleaner fuel, such as kerosene and LPG. This paper attempts to determine potential factors that influence Cameroonian households to abandon the use of firewood for the benefit of more efficient fuels. Our findings fill a gap in the literature about fuel choice in Cameroon and open up room for further academic and policy discussions.

2. Data Source and Descriptive Statistics

This study obtained data from the national survey on Cameroonian household energy consumption conducted by NIS in 2004 and published in 2005. The overall sample size in the national survey was 2860. Households were randomly selected from 12 zones in the country. The study used data from the north and far north regions, which are among the most affected by drought and land degradation, with a sample size of 553 households. About 313 households were in urban areas, while 251 were rural. The regions studied are characterized by rainfall ranging from 400 to 1200 mm per year, while the soil is greatly diversified (ferruginous, hydromorphic, alluvial, vertisol, *etc.*). The temperature ranges between 25 to 27 °C during cooler seasons and rises to 30 °C in the warmer seasons [9]. As mentioned, this zone is characterized by widespread soil degradation and the population is highly dependent on natural resources such as fuel wood. Table 1 presents the descriptive statistics of variables used for the analysis. It shows that the average age of a head of household is 47 years that 81 percent of the respondents were male. Only 28 percent were employed in paying jobs at the time of the survey. 26 percent received a primary education, and 13 percent received a secondary education. About 57 percent of households dwell in traditional houses, and 23 percent showed a desire to purchase gas cylinders if their financial status allowed for it.

Table 1. Descriptive statistics of variables used in the analysis.

	Mean	Standard Deviation	Min.	Max.
Monthly income of HH (XAF)	104,084	212,921	5000	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's wish in 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

Source: Authors' calculations using [33]. Electricity price comes from national company of electricity. Kerosene and firewood prices have been collected from the Cameroonian ministry of trade and oil prices from the national stabilization fund.

3. Model and Estimation Methods

The survey data shows that firewood and kerosene are used as the main energy source in a considerable number of households (64 and 32 percent of the sample respectively). In this study we assume that there is an expected order of progression with respect to fuel choice. Three types of fuels that are observed in the study can be ordered in terms of comfort, ease of use and efficiency. The ordered probit and logit models are often employed under this framework. The ordered models perform better than non-ordered models [23]. As can be seen from the results obtained from probit and logit models, both models deliver very similar results. Hence, the main difference is theoretical and lies in the assumption of the error terms. In a probit model, the error terms follow a standard normal distribution, while in a logit model they are assumed to have a logistic distribution [34]. The non-thresholded output of the probit model is the z-scores of a standard normal distribution, while the output of a logistic model is interpreted as probabilities. That said, the usage of probit *vs.* logit models is heavily influenced by disciplinary traditions. While both logit and probit models can be used in analysis, the latter is widespread in econometrics (especially econometric selection models) because underlying utility can be understood as discrete outcome when the threshold is crossed. In this study, the ordered probit model is used and results from the ordered logit model (Table A1) are provided in the appendix for comparison.

The probit model assumes that the household's choices of fuel types are latent variables. They are also considered 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). This latent variable (y_i) 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:

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

where r_js are the parameters of the threshold.

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

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

where Φ is the CDF of a standard normal variable.

4. Results and Discussion

Findings indicate a reasonably good prediction of household fuel choices in Northern Cameroon (Table 2). Results show that most of the chosen variables have expected and statistically significant effects. The coefficients describe the household status on the given ladder. While education has the predicted positive sign and effect, income effect is low, which can be also seen from low marginal effects. Households whose members have primary and secondary educations are more willing to adopt cleaner fuels. This is in accordance with expectations: The willingness to adopt cleaner fuels increases with the level of education of the head of household. Educated households are well-informed about the positive attributes of using cleaner fuel sources and the adverse health effects of using biomass for cooking. Rahut *et al.* [13] and Miah *et al.* [9] find similar results in Bhutan and Bangladesh, and confirm that preference for cleaner fuels increases with level of education. While the literature shows that income plays a key role in choosing fuel type, and that households with more income tend to use cleaner fuels, our study finds that income was statistically significant only at 10% while other factors were more significant in the move to cleaner fuels. Electricity and kerosene prices have a negative impact on moving toward cleaner fuels, which suggests that higher fuel prices for electricity and kerosene lower energy status and discourage adoption of cleaner fuels. 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 they were highly correlated with other variables and, as a result, were dropped from the analysis. Findings show that lowering the price of kerosene would encourage households to move to cleaner and more efficient options. This finding accords with Farsi *et al.* [23]; their study suggested that higher kerosene prices can result in a lower energy status in the urban Indian context. The negative sign of the "age of head of household" variable confirms the findings of Mom Njong and Tabi Atemkeng [12]: An increase in the age of the head of household is less likely to make a household switch from firewood. One possible explanation is that older households are more resistant to change while younger households are more willing to move from firewood to LPG. However, we should keep in mind that cross sectional data involves estimating variables in the population of interest at a single point in time. Thus what we report here is only a snapshot. Because of this, we cannot compare old and young heads of household's behavior over time. This is a limitation of our study. Another household characteristic, a gender variable, is not significant. This was also the case in the Malawi study by Jumbe and Angelsen [30] but not in the study by Farsi *et al.* [23].

Table 2. Regression results of ordered Probit model.

Alternatives in Ascending Order: Firewood, Kerosene, LPG	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's wish in 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	−336.384	
Pseudo R-squared	0.2160	

Source: Authors' calculations using [33] data; Notes: * significant at 0.1; ** significant at 0.05; *** significant at 0.01.

Interestingly, households who live in traditional houses also prefer to use cleaner fuels, which is contrary to what Baiegunhi and Hassan [35] found in Kaduna State, Nigeria. They report that households in traditional houses are less likely to pick natural gas and electricity over wood. Our findings could be due to the fact that some households are aware of the benefits of cleaner fuels and thus prefer using kerosene and LPG for cooking in traditional houses. However, this result should be studied further, since this could be related to only those households that have higher incomes and can afford to pay for cleaner fuels. In the study by Mom Njong and Tabi Atemkeng [12], results also revealed less evidence that households in modern houses are more likely to use other alternatives. This study further finds that households that expressed a desire to obtain gas cylinders also indicated a higher probability of choosing cleaner fuels for cooking purposes.

Our study calculated the marginal impact of significant variables (Table 3) that 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 for comparison of the magnitude and direction of impact. Calculations indicate that electricity and kerosene prices have the greatest impact, while in the case of dummies, the greatest impact is due to interest in 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 [33] data.

When the head of household is educated, this decreases the probability of using firewood for cooking, and households are more likely to adopt kerosene and LPG. Households with secondary degrees, for instance, are 17 percent less likely to use firewood and are 16 percent more likely to use LPG. These findings show that there are several non-income determinants that regulate the choice of fuel in the given context. Our findings also indicate that as the price of firewood rises, households are more likely to switch to alternatives. The rate of change, however, is not very high. For instance, calculations show that a 10 percent decrease in the price of firewood will lead to a 1.1 percent increase in firewood users. This will decrease the segment of kerosene and LPG users by about the same rate. With regard to electricity, the results are similar. A 10 percent increase in the price of electricity leads to a slight decrease in the share of kerosene (about 0.6 percent), although the change is much higher for LPG users (about 7.7 percent). Higher electricity prices lead more people to continue using firewood (the switching-rate is 8.3 percent). At the same time, younger households tend to adopt cleaner fuels, because these fuels decrease cooking times and, more importantly, younger households are aware of the benefits of using cleaner and more efficient fuel sources. Notably, households that showed an interest in obtaining gas cylinders are on average 59 percent more likely to move away from wood and 58 percent more likely to use LPG. Those that live in traditional houses, which are usually small, are more likely to move away from firewood and adopt cleaner fuels for their cooking. This, however, depends on the prices for kerosene and LPG. It is unlikely that higher kerosene and LPG prices encourage rural households to switch to cleaner fuels.

5. Conclusions

Our study used a data set obtained from the National Institute of Statistics (NIS) and a discrete choice model to investigate fuel choice and inter-fuel substitution relationships in Cameroon. We assumed an expected order of movement among fuel choices based on cleanliness and efficiency. Our findings demonstrate the sensitivity of fuel choices to their own and alternative fuel prices, household income, and exogenous variables related to socio-demographic attributes of households. Results indicate that there is potential for a transition from traditional to cleaner fuels in the region we studied. We agree with other studies that suggest that household incomes must increase substantially to significantly decrease the use of firewood for cooking. However, our results also suggest that the order of fuel choice depends not only on income and price (economic factors), but also on other variables identified by Heltberg [20]. We show that better education helps increase awareness of the negative health impacts of using firewood (see also [36]). In this respect, investing in education in rural schools and educating adults about the benefits of cleaner fuels will serve as an effective method of encouraging fuel switching.

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Author Contributions

The first author conducted the analysis and second author contributed with description, discussion and editing of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix

Table A1. Regression results of ordered Logit model.

Alternatives in Ascending Order: Firewood, Kerosene, LPG	Coefficients	Standard Error
ln(income)	0.239 *	0.135
ln(electricity price)	−3.968 ***	1.142
ln(kerosene price)	−4.345 **	1.967
ln(firewood price)	0.494 ***	0.186

Table A1. *Cont.*

Alternatives in Ascending Order: Firewood, Kerosene, LPG	Coefficients	Standard Error
ln(age of the HH head)	−0.795 **	0.365
HH head has a primary education	0.569 **	0.242
HH head has a secondary education	0.748 **	0.332
HH head works in paid job	−0.291	0.261
HH head's wish in getting gas cylinder	2.773 ***	0.275
HH head lives in traditional house	0.508 **	0.227
Gender (1 = male)	0.265	0.294
Log likelihood	−336.129	
Pseudo R-squared	0.2162	

Source: Authors' calculations using [33] data; Notes: * significant at 0.1; ** significant at 0.05; *** significant at 0.01.

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