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# Non-price determinants of household's choice of cooking energy in Malawi

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## Abstract

This paper applies a multinomial logit to model choice of fuel for cooking in Malawi. The choices considered are five main cooking fuels: firewood, kerosene, electricity, charcoal and crop residue. Using the 2010/2011 Third Integrated Household Survey datasets with 12,271 households, the paper explores the underlying factors that determine choice of primary cooking fuel alternatives. Empirical findings reveal that location of residence, education level of household head, income, and age of household head are major significant factors in determining the probability of household's choice of cooking fuels. The results show that residing in rural area has the most impact on the choice of firewood and the least probability in choosing to use electricity for cooking. Policy implications of the findings are drawn and discussed.

***Keywords:*** Cooking energy; Multinomial logit; Malawi



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## 1. Introduction

The energy balance in Southern Africa is dominated by biomass, especially traditional solid biomass. The list of waste biomass usable for energy purposes is nearly endless and depends on what is readily available in a certain location (Vitali et al., 2013). Most households depend on biomass energy for cooking and space heating estimated about 2.5 billion people only in LDCs (Malinski, 2008 and World Energy Ooutlook, 2006). While rural households rely more on biomass fuels than their urban counterparts, it is observed that over half of all urban households in sub-Saharan Africa rely on fuelwood, charcoal, or crop waste to meet their cooking needs (International Energy Agency, 2006). Compared to wood-fuels, crop residues typically have a high content of volatile matter and ash, lower density and lower energy values (Virmond et al., 2012). Nevertheless, in contrast to rural households, urban ones often have a wider choice and greater availability and accessibility to modern commercial fuels, electricity, and energy using end-use equipment and appliances, and therefore, greater potential for fuel switching (Farsi et al., 2006). Thus, with increasing population and urbanization over time, just like rural household energy, urban household energy is an important issue for developing countries in general, and for poorer developing countries, such as Malawi, in particular.

At the center of environmental dilemma in most developing countries, including Malawi, issues relating to choice of household cooking energy types have become more relevant than ever before from policy standpoint. Most countries have embarked on campaigns aimed at encouraging households to shift their energy types towards more energy efficient use and less adverse environmental, social and health related impacts. Increased dependence on the produced biomass for fuel use and cash income by households has sustainability challenges with long-term negative effects on forest resources. It contributes to deforestation, forest degradation, and land degradation which undermine the very foundation of economic growth due to accelerating soil erosion resulting in low productivity. Using crop residue as source of fuel, instead of turning it into manure for soil fertility improvement, contributes to land degradation and this results into reduced agricultural productivity. The use of biomass as cooking fuel has been associated with indoor air pollution leading to household health problems (Bruce et al., 2000; Ezzati and Kammen, 2001). According to estimates by World Health Organization, about 1.5 million premature deaths annually are due to indoor air pollution related causes through the use of solid fuels (International Energy Agency, 2006).

The literature on energy sector in Malawi is limited. Studies related to micro-energy dynamics in Malawi are less than forthcoming, save for Gama et al. (2007) who studied factors influencing wood collection and utilization in central Malawi. The present study goes a long way to enhance understanding of the factors affecting the household decisions on fuel choice which is essential for the design of public policy aiming to stimulate clean and sustained cooking fuel energy. The analysis focuses on cooking fuels, which is believed to constitute the largest share of household energy needs in Malawi. Thus, this study attempts to examine the determinants of household's primary choice of cooking fuel in Malawi using cross sectional data.

## 2. Research methodology

### 2.1. Modeling choice of fuel type

A typical consumer derives utility from a good by disaggregating it into components or attributes that cannot be attained independently. A range of these attributes create choices from which a consumer can choose (Hanley et al., 2001). Lancaster (1966) developed a basis of modeling such choices for which ordering among choices has no meaning. These choices can be represented econometrically in consumer theory by using a multinomial logit to model random utility theory. In this study we use choice modeling to estimate the utility associated with mutually exclusive and highly differentiated cooking fuels. It conforms to the economic notion that the value placed on a particular fuel is a reflection of its attributes (Lancaster, 1966). Choice modeling has been successfully used in situations where trade-offs between several attributes are being investigated (Blamey et al., 1999; Morrison et al., 1999; Bullock et al., 1998).

A household *n* chooses from a set of mutually exclusive fuel choices, $j = 1,\ldots, J$. The decision-maker obtains a certain level of utility $U_{nj}$ from each alternative. The discrete choice model builds on the belief that a household chooses the outcome that maximizes utility. We do not observe household's utility, but observe some attributes of the household which is faced by a decision to choose cooking fuel type. Hence, the utility is decomposed into deterministic $V_{nj}$ and random part $\varepsilon_{nj}$:

$$U_{nj} = \psi_{nj} + \varepsilon_{nj} \quad \text{[1]}$$

The error term $\varepsilon_{nj}$ is unobservable and makes the prediction of an individual's choice not to be exact. However, we derive the probability of any particular outcome. The stochastic part has a density $f(\varepsilon_{nj})$. The joint density for a vector of the stochastic portion is denoted as $f(\varepsilon_n)$. To map out household *n*'s choice of alternative *i* on a range of *J* alternatives, we use probability:

$$P_{ni} = \Pr(U_{ni} > U_{nj}, \forall\ j \neq i) \quad \text{[2]}$$

$$P_{ni} = \Pr(U_{ni} + \varepsilon_{ni} > U_{nj} + \varepsilon_{nj} \forall_j \neq i)$$

$$P_{ni} = \int I(U_{ni} + \varepsilon_{ni} > U_{nj} + \varepsilon_{nj} \forall_j \neq i) f(\varepsilon_n) d\varepsilon_n$$

where $I(.)$ is the indicator function, equalling 1 when the term in parenthesis is true and 0 otherwise. This is a multidimensional integral over the density of the unobserved portion of utility $f(\varepsilon_{nj})$ (Tutz, 2000).

The multinomial logit model assumes independency of irrelevant alternatives (IIA). However, this assumption is unrealistic in many circumstances. Train (1990) notes that an assumption of IIA in multinomial logit model is not as restrictive as it first sees. A variant of multinomial logit is nested logit model. In this study, all right hand side variables are individual characteristics, thus, nested logit model will in essence produce similar results as the multinomial model (Econometric Society, 1982**).** The density for each unobserved component of utility and the cumulative distribution are given, respectively, by (McFadden, 1974);

$$\lambda(\varepsilon_{nj}) = e^{-\varepsilon nj} e^{-e^{\varepsilon nj}} \quad \text{[3]}$$

$$\Lambda(\varepsilon_{nj}) = e^{-e^{-\varepsilon nj}}$$

The probability that household *n* chooses alternative *i* among the *J* alternatives of cooking fuel is given by (McFadden, 1974);

$$P_{ni} = \Pr(\varepsilon_{nj} < V_{ni} - V_{nj} + \varepsilon_{ni} \forall_{j} \neq i) \quad [4]$$

$$= \int \prod_{j \neq i} \Lambda(V_{ni} - V_{nj} + \varepsilon_{ni}) \lambda(\varepsilon_{ni}) d\varepsilon_{ni}$$

Thus, the choice probability is the integral over all values of $\varepsilon_{ni}$ weighted by its density $\lambda(.)$ as defined in equation (3).

It is hypothesized that an individual's choice of an attribute is determined by a vector of socio-demographic characteristics. This relationship between vector of socio-demographic characteristics and the dependent variable is established by estimation vector of parameters $\phi$ using log-likelihood method. Maximizing log-likelihood function for the parameter vector yields (Stern, S. 1997; McFadden, 1974);

$$\ln L(\phi) = \sum_{n=1}^{N} \sum_{j=1}^{J} y_{ni} \ln P_{nj} \quad [5]$$

In equation (5), $y_{ni}$ is 1 when fuel *j* is chosen and 0 for all other strategies that are not chosen. Assuming each error term $\varepsilon_{nj}$ for all alternatives *j* is identically and independently distributed, the logit probability $\psi_{nj} + x_n' \beta_j$ that an individual will choose alternative *j* will be;

$$P_{ni} = \frac{e(x_n' \beta_i)}{\sum_j e(x_n' \beta_j)} \quad [6]$$

Since MNL is a model where regressors do not vary over choices, coefficients are estimated for any choice. The dependent variable is the cooking fuel choice (firewood, charcoal, kerosene, electricity, or crop residues). MNL requires identification: one of the choices, say *j*, is treated as the base category (correspondent $\beta_j$ is constrained to equal 0). Use of firewood is set as the reference choice. Holding the other predictor variables constant, the estimated coefficients give a measure of the change in the logit associated with a unit change in the predictor variable. On one hand, positive coefficients imply an increased probability that a household would choose an alternative source of fuel; while on the other hand, negative coefficients show that a household is less likely to use alternative fuel source.

## 2.2. The data

This study is based on a cross-sectional survey data from Malawi Third Integrated Household Survey (IHS3) data which was conducted by the National Statistical Office (NSO) in Malawi from March 2010 to March 2011. The Survey was a nationally representative sample survey designed to provide information on the various aspects of household welfare in Malawi. The survey collected information from a sample of 12,271 households statistically designed to be representative at both national, district, urban and rural levels, enabling the provision of reliable estimates for these levels. A stratified two-stage sample design was used for IHS3. The primary sampling units (PSUs) selected at the first stage were the census enumeration areas

(EAs) defined for the 2008 Malawi Population and Housing Census. The EAs had an average of about 235 households each. A total of 768 EAs were selected across the country. In each district, a minimum of 24 EAs were interviewed while in each EA a total of 16 households were interviewed.

Table 1 presents definitions of the variables included in the multinomial logit model used to analyze the determinants of household's choice of cooking fuel in Malawi.

**Table 1.** Variable definitions and descriptive statistics

| **Variable** | **Definition** | **Mean** | **Std Err.** |
|---|---|---|---|
| Household size | Number of persons | 4.56 | 0.01 |
| Labour | Household's estimated labour (Economically active persons) | 3.88 | 0.01 |
| Fuel Expenditure | Real annual consumption expenditure on fuel (Malawi Kwacha) | 13,337.55 | 145.48 |
| Total Household Expenditure | Household's total consumption expenditures (Malawi Kwacha) | 25,6035.3 | 3,069.57 |
| Age | Age of household head (years) | 42.14 | 0.14 |
| Gender | Gender of household head (Dummy variable): 1 = Male; 0 = Female | 0.75 | 0.003 |
| Education | Highest level of education attained by household head (1=None, 2=Primary, 3=Secondary, 4=Tertiary) | 1.52 | 0.007 |
| Electricity | Dummy variable: 1 = Electricity installed in the dwelling unit; 0 = No electricity installed in the dwelling unit | 0.08 | 0.002 |
| **Regional Dummy** | | | |
| North | Dummy variable: 1 = Household located in Northern Region; 0 = Otherwise | 0.18 | 0.003 |
| Central | 1 = Household located in Central Region; 0 = Otherwise | 0.34 | 0.004 |
| **Residence Dummy** | | | |
| Rural | Dummy variable: 1 = Household residing in rural area; 0 = Otherwise | 0.18 | 0.003 |

## 3. Results and discussion

The coefficient results from the estimation of the multinomial logit model described in Section 2.1 are presented in Table 2 and the corresponding marginal effects are shown in Table 3. The marginal effects show the effect of a unit change in a given explanatory variable (or a switch in the case of dummy variables) on the probability of choosing each one of the five types of fuels. These marginal effects can therefore, be interpreted as the measure of probability that the factors have on influencing the choice of household cooking fuels. Following Green (1993) and Ouedraogo (2006), the marginal effects are derived as;

$$\delta_{ij} = \partial P_j / \partial x_k = P_j(\beta_j - \sum_{j=1}^{5} P_j \beta_j = P_j[\beta_j - \overline{\beta}], \quad j = 1,\ldots,5$$

where, Pj is the probability of adopting alternative j and $\delta_{ij}$ measure the impact of variation of exogenous variables xk on the probability of fuel j.

**Table 2.** Multinomial logit estimates

| Variables | Kerozine | Electricity | Charcoal | Crop Residue |
|---|---|---|---|---|
| Household size | -2.265* | 0.388 | -0.275 | 0.423* |
| | (1.184) | (0.363) | (0.286) | (0.257) |
| Household Labour | 2.585** | -0.579 | -0.0323 | -0.303 |
| | (1.262) | (0.408) | (0.332) | (0.301) |
| Annual Fuel Expenditure | -0.170 | 0.527*** | 1.208*** | 0.0622 |
| | (0.544) | (0.200) | (0.156) | (0.140) |
| Total Annual Household | -0.531 | 1.172*** | -0.362 | 1.083*** |
| Expenditure | (1.076) | (0.336) | (0.263) | (0.230) |
| Age of household head | 0.254 | -0.542 | -1.138*** | 0.0261 |
| | (1.222) | (0.449) | (0.317) | (0.276) |
| Gender of head | -0.619 | -0.198 | -0.355 | 0.206 |
| | (1.154) | (0.308) | (0.244) | (0.215) |
| Education level | 0.615 | 0.825*** | 0.261* | 0.157 |
| | (0.457) | (0.168) | (0.135) | (0.128) |
| Electricity | 14.34 | 5.382*** | 0.151 | -0.960** |
| | (865.3) | (1.086) | (0.407) | (0.399) |
| *Regional Dummy* | | | | |
| North | 3.192*** | 1.234 | 1.609** | -3.251*** |
| | (1.222) | (0.758) | (0.733) | (0.722) |
| Central | 1.280 | 1.059*** | 1.042*** | -1.592*** |
| | (0.980) | (0.334) | (0.287) | (0.270) |
| *Residence Dummy* | | | | |
| Rural | -0.112 | -2.185*** | 2.678*** | 0.171 |
| | (1.165) | (0.383) | (0.316) | (0.308) |
| Constant | -30.67 | -21.04*** | -8.962*** | -5.653** |
| | (1,731) | (3.836) | (2.854) | (2.596) |
| Number of observations | 12,228 | | | |
| LR $\chi^2(48)$ | 6599.85*** | | | |
| Pseudo R-Squared | 0.5465 | | | |

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

The first observation from the results in Table 3 is that among all the variables, both continuous and dummy explanatory variables, residential location of the household (dummy variable) had the highest effect although of varying importance across energy alternatives. The results indicate that most of the explanatory variables included in the model have significant effects on explaining variation in the choice of household cooking fuels in Malawi.

Table 3 indicates that household labour supply has a significant but negative effect on household choice of charcoal as a cooking fuel (p<0.05); suggesting that higher labour force in the household can likely result in lower use of charcoal. A unit increase in labour supply has an infinitesimal effect (about 0.06%) on household choice of the type of fuel (charcoal) for cooking. This might be explained by the fact that in Malawi charcoal is a tradable commodity whose availability, accessibility and use do not depend on the size of labour force in the household; it rather depends on the household's income status.

**Table 3.** Marginal effects of multinomial logit estimates

| Variables | Firewood | Kerosene | Electricity | Charcoal | Crop Residue |
|---|---|---|---|---|---|
| Household size | -0.00509 | -0.00238 | 0.000126 | 0.00240 | 0.00292 |
| | (0.0178) | (0.179) | (0.000126) | (0.00231) | (0.00182) |
| Household Labour | 0.00728 | 0.00294 | -0.000137 | -0.00550** | -0.00207 |
| | (0.0220) | (0.222) | (0.000137) | (0.00260) | (0.00211) |
| Expenditure on Fuel | -0.0212*** | -0.000066 | 0.0088*** | 0.0209*** | 0.000283 |
| | (0.00242) | (0.000126) | (0.000861) | (0.00170) | (0.000971) |
| Total Annual Household Expenditure | -0.0193*** | 0.0000684 | 0. 0349*** | 0.0117*** | 0.00743*** |
| | (0.00581) | (0.00517) | (0.0031) | (0.00252) | (0.00186) |
| Age | 0.0180*** | 0.0000383 | -0.00077 | -0.0183*** | 0.000311 |
| | (0.00460) | (0.00290) | (0.00090) | (0.00288) | (0.00191) |
| Gender | 0.00109 | -0.000053 | 0.00035 | -0.00248 | 0.00145 |
| | (0.00470) | (0.00401) | (0.00030) | (0.00210) | (0.00150) |
| Education level | -0.00801 | 0.000981 | 0.015205*** | 0.00686*** | 0.00104 |
| | (0.00728) | (0.00741) | (0.00014) | (0.000992) | (0.000899) |
| Electricity Installation | 0.0182 | 0.00172 | 0.0987*** | -0.0132*** | -0.00657** |
| | (0.0191) | (0.0189) | (0.00079) | (0.00257) | (0.00296) |
| **Regional dummy** | | | | | |
| North | 0.0303*** | -0.000257 | -0.00194 | -0.0180*** | -0.0122*** |
| | (0.00224) | (0.000231) | (0.00185) | (0.00171) | (0.00145) |
| Central | 0.0178*** | -0.000361 | -0.000747 | -0.00827*** | -0.00947*** |
| | (0.00346) | (0.00273) | (0.000762) | (0.00161) | (0.00175) |
| **Residence dummy** | | | | | |
| Rural | 0.5439*** | -0.000114 | -0.8250*** | -0.1391*** | 0.00125 |
| | (0.0111) | (0.000874) | (0.0781) | (0.0107) | (0.00212) |

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

The results in Table 3 also suggest that higher expenditures on various sources of fuels were associated with a significant negative effect on household choice of firewood (p<0.01) but positive effects on electricity (p<0.01) and charcoal (p<0.01). A unit increase in expenditure on fuels decreased the probability of household's choice of firewood by 2.12% and increased the probability to choose electricity and charcoal by 0.88% and 2.09%, respectively. On a broader perspective, total household expenditure had significant negative influence on household choice to use firewood for cooking (p<0.01) with a marginal effect of 1.93%;

the variable had positively affected household decision to choose electricity ($p<0.01$), charcoal ($p<0.01$) and crop residue ($p<0.01$) use for cooking. A unit increase in total household expenditure was associated with a probability to raise the use of charcoal for cooking by a margin of 1.17% and crop residue by 0.07%. The significant coefficient of household expenditure (A proxy for income) on electricity imply that there is increasing tendency to use clean cooking energy alternatives as household income increases. Other studies have established similar findings in rural India and France (Pandey, 2011; Couture et al., 2012). This finding goes against that of Lhendup et al. (2010) who reported that household's choice of fuel is mainly by familiarity and availability, and not by affordability.

Contrary to Couture et al. (2012), age of household head significantly increased the probability of choosing firewood as a cooking fuel, whereas those households with older heads were less likely to use charcoal; for sources of fuel; age was significant at ($p<0.01$). These results indicate that a unit increase in the age of household head will raise the share of firewood users by 1.8% while decreasing the share of charcoal users by 1.83%. This implies that young household heads are less likely to use firewood and more likely to use charcoal for cooking. Charcoal being more tradable and expensive than firewood was expected to be used by younger people who tend to have a relatively stronger financial base than older heads of households. Wickramasinghe (2011) noted the same for the case of firewood.

Education level of household head was another factor that significantly influenced choice of type of fuel to use for cooking by the household. The household head being literate or having higher education increased the probability of choosing electricity and charcoal as cooking fuels. A stepwise increase in education level had a probability of increasing the use of electricity and charcoal by 1.52% and about 0.69%, respectively; the effect was significant ($p<0.01$) for both fuel sources.

Having electricity installation in the dwelling unit was also a significant factor influencing household choice of the type of fuel for cooking. Households with electricity significantly increased the probability of using it for cooking ($p<0.01$) by 9.87%, decreased the probability to use charcoal ($p<0.01$) by 1.32% and that of using crop residues ($p<0.05$) by about 0.66%. As expected, a household with electricity would likely prefer to use a cleaner source of fuel for cooking than otherwise.

On household location dummies, the country was divided into three locations including Northern region, Central region and Southern region and a sub-category of rural versus urban residential areas. Southern region and urban area were set as the comparison groups to avoid falling into dummy variable trap. As shown in Table 3, residing in Northern region or Central region significantly increased the probability of choosing firewood while the two dummies had significantly decreased the probability to use charcoal and crop residues as sources of fuel for cooking ($p<0.01$). The results suggest that there are differences in the choice behaviour of households living in different regions of the country (Farsi, et al., 2006). A household in Northern Region was 3.03% more likely to choose to use firewood than another household in the Southern region, but it was 1.8% and 1.22% less likely to use charcoal and crop residues, respectively, as cooking fuels. Similarly, a household in Central region was 1.78% more probable to use firewood but about 0.83% and about 0.95% less likely to choose charcoal and crop residues, respectively for cooking than a household in Southern region. This might be explained by the fact that Northern region being sparsely populated, with a density of 63 persons per square kilometer, is well endowed with natural forests where people easily collect firewood; Central region has also relatively lower population density of 155 compared with Southern region's density of 184 persons per square kilometer (National Statistical Office, 2010a) and there are more natural forests in the region which serve as major and cheaper sources of firewood than Southern region which has witnessed population-induced deforestation problems. In addition, due to higher rate of urbanization, the Southern region uses more charcoal (10.7%), than the Northern and Central regions.

In line with priori, the residential dummy variable (living in rural area) significantly increased the probability of a household to choose firewood as a fuel for cooking ($p<0.01$). A rural household was 54.4% more likely to choose firewood for cooking than another household in the urban area. The finding is important because compared with 39.8% of urban households, 95.3% of rural households in Malawi use firewood for cooking (National Statistical Office, 2010b). Rural households most likely use more biomass fuel alternative due to its availability and free access. The result corroborates that of Wickramasinghe (2011) in Sri Lanka. As expected, there was 82.5% probability that a rural household would not choose electricity as fuel for cooking and 13.9% less likely that charcoal would be used for cooking by the rural household. The explanation for this is that in Malawi electricity is mainly concentrated in urban dwelling units; very limited electrification has been installed in the rural areas. Only 0.4% of rural households use electricity for cooking compared with 13% of urban households which use it (National Statistical Office, 2010b). Similarly, charcoal selling is commonly done in urban areas. Owing to intermittent electricity blackouts and prohibitive cost of electricity tariffs, charcoal is the most highly preferred alternative source of fuel for cooking in urban areas in Malawi especially for the lower to middle income households. About 45.8% of urban households use charcoal for cooking while only 1.9% of rural households use it for cooking (National Statistical Office, 2010b). Generally, 1.2% of households in Malawi and only 0.8% of urban households use kerosene for cooking. Cleaner fuels like kerosene depend on foreign prices as its market is liberalized in Malawi. Thus, expansion of this clean cooking fuel source is arrested at national level. Crop residues are used by 0.9% of households nationally, comprising 0.4% and 1% of urban and rural households, respectively.

## 4. Conclusion and policy implications

This paper used cross sectional data collected in the years 2010 and 2011 from across Malawi to analyze household fuel choice. The study reveals that location, education level of head, annual expenditure (proxy for income), age of head are all significant factors in determining the probability of household's choice of cooking energy. The study has shown that residing in rural area has the most impact on the choice of firewood as cooking energy. As earlier reviewed, this has corresponding consequences including deforestation and soil erosion in turn leading to destruction of ecosystems for wildlife and low productivity of agriculture sector.

From the policy perspective, it is imperative for policy pilots to acknowledge that biomass is the by far the most common and used source of cooking energy by most households in Malawi and that switching to cleaner energy options will not be done overnight. There is therefore, a need that policy should thrust interventions aiming at balancing biomass production and utilization. This can be achieved through, among other ways, advocating households to establish and own woodlots and even a step ahead to establishing community woodlots. Given the length of rotational harvest periods of trees, alternatives could include promotion of improved and fast regenerating trees so as to maintain production sustainably. In addition, maintaining the fact that switching to cleaner energy alternative will not be immediate, at least for rural residents, adoption of less energy efficient cook stoves that involve less firewood consumption, cooking time and high efficiency should be advocated. Limited extent of electrification in rural Malawi which is a structural hindrance for rural households to adopt the clean energy can be offset by promoting small and affordable solar cook stoves which could relieve pressure on forests.

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