Household Energy choice in Kenya: An empirical analysis of the energy ladder hypothesis

Abstract

This paper investigates the odd ratio of selecting clean verses unclean source of energy as the main household fuel choice in urban areas using logistic functions through modelling of a binary dependent variable. Also, the research examines the important determinants of household fuel choice in urban Kenya. The data was obtained from KIPPRA's data set on patterns of fuel use in Kenya. The study analysis was informed by energy ladder hypothesis and consumer behavior theory as the theoretical framework. Multinomial logistic estimation model was used to investigate the choices households make and patterns of cooking fuels in urban areas. From regression results income of household, cost of fuel and socio-economic factors were identified as the main factors explaining house fuel choice decisions. To accelerate use of clean residential fuel, the policymakers and government must carry out public education campaign, and ensure the accessibility and affordability of these fuels in urban areas to avoid harmful effects such as pollution and health problems fuelled by kerosene and biomass.

Keywords: Choice of fuel, Pollution, Health, Income, Energy ladder hypothesis, Socio-economic

JEL Classification: D15; C55; Q42; Q41

1 Introduction

In the process of meeting economic and development objectives, Kenya has identified clean fuel use as one of the energy agenda for ever rising urbanization and the urban population (KNBS, 2006; IEA, 2006). Thus the need for accessible, reliable data and policy on energy consumption patterns in urban Kenya is necessary. Information or statistical data on energy consumption by fuel is unavailable or inadequate in most sub-Saharan countries (KIPPRA, 2010). Even though most of sub-Saharan countries are home to a number of fuel sources, there is still lack of information on the aspects that drive fuel choice and switching by various urban households (Heltberg, 2003; KIPPRA, 2010). A number of empirical studies have been carried across the globe on this subject and have identified factors that explain the ever changing household fuel choice (Mekonnen & Kohlin, 2009). According to Heltberg (2003), education level and income of household are important factors that encourage liquefied petroleum gas (LPG) and electricity demand while at the same time discourage the use of biomass (wood) energy. In addition, a similar study by Ouedraogo (2006) argues that household size is significant in explaining the household decision on fuel use. However few empirical studies have been carried in urban areas of Kenya on the same subject.

Kenya Integrated Household Budget Survey on energy sources distribution in Kenya identifies Gas (LPG), charcoal and kerosene as the main sources of fuel most accessible to urban citizens (KNBS, 2006). Table 1 present the distribution of sources of fuel in Kenya.

Table 1: Distribution of Fuel

Fuel Type	**Percentage**		
	Rural	**Urban**	**National**
Firewood	87.7	10	68.3
Grass	0.1	0.2	0.1
Charcoal	7.7	30.2	13.3
Biomass Residue	0.4	0.1	0.3
Kerosene	2.7	44.6	13.2
Gas(LPG)	0.7	11.9	3.5
Electricity	0.2	1.8	0.6

Other	0.4	1.1	0.6
Total	100.0	100.0	100.0
Population Sampled	**5,155,105**	**1,715,269**	**6,866,374**

Source: KNBS (2006).

From Table 1, most of Kenyan population depends on unclean sources of fuels. In addition, about 60 years after independence above 85 percent of the population still use traditional fuels such as firewood and kerosene to meet their energy needs. This situation is dangerous and needs to be addressed if Kenya is to avoid the environmental impact of unclean energy fuel use; and also to improve the health of citizens by avoiding indoor pollution within the household (Bruce *et al.*, 2000; Gisore, 2017; Nyoni *et al.*, 2021). These two aims are in line with the Kenya's vision 2030 goals and urban sustainable development targets (Nyoni *et al.*, 2021). As a result the study will try to identify the factors that explain the clean fuel choices of urban citizens.

2 Literature Review

Consumer behavior theory is able to explain consumer choices, preferences and constraints urban household will encounter. According to Varian (1996), consumer demand equation can be derived from consumer preferences on condition consumer constraints are included in decision making (Browning et al., 2003). Consumer behavior theory argue that a rational Kenyan household will always choose a most preferred fuel type from a set of feasible alternatives (Varian, 1996; Browning et al., 2003).

Energy ladder and stack model captures the theoretical explanation of household choice on fuel use and consumption patterns using preference concept as explained in consumer behavior theory (Schlag & Zuzarte, 2008). The Energy ladder hypothesis argues that population with low income levels are likely to choose biomass fuel, while the rich will prefer expensive and cleaner energy sources such as electricity and gas as the main fuel source (Heltberg, 2005; Gisore, 2021). In between clean and unclean energy is the transition fuel source. The household in transition stage is likely to consume improved energy sources or transition energy such as charcoal and kerosene (Heltberg, 2005; Schlag & Zuzarte, 2008). This is presented in the Figure 1.

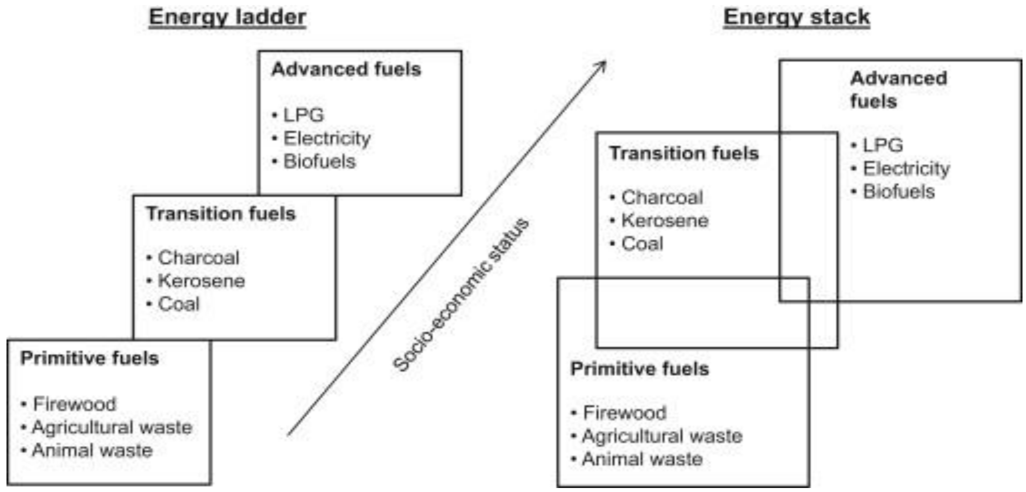

Figure 1: Energy ladder and stack framework

Source: Schlag and Zuzarte (2008).

A number of recent empirical works argue that in sub-Saharan Africa and Kenya in particular most citizens do not switch to clean and efficient energy sources but choose to consume a combination of fuels, such as unclean and clean sources of fuel. Thus, instead of moving up the ladder as income or cost of fuel increases, citizens choose different fuels from a range of fuels (World Bank, 2003). This gave birth to energy stacking hypothesis as opposed to energy ladder concept. The main determinants of energy stack hypothesis may include preference, needs, cost and income (Masera et al., 2000). However, most empirical studies on this subject have only been carried in developed economies and specifically targeting rural population and few have been carried out in urban Kenya. This study intends to fill that gap.

3 Research Methodology

The study adopted secondary data sources since they are reliable, accessible and less expensive (Ouru, 2021). The main sources of data were KIPPRA's microeconomic data set on fuel use (2010). The study employed the same study framework used during Kenya's 1999 population census by Kenya National Bureau of Statistics. The sampling frame utilised during census featured 540 clusters for urban and 1260 for rural totalling 1800 clusters, each cluster on average had 100 households. KIPPRA (2010) report use 20 percent of total clusters resulting 360 in total

(108 urban and 252 rural). In addition, more often KNBS utilizes 10 household in each cluster for most studies (1080 urban and 2520 rural) (KNBS, 2006). For our study, 1080 urban household were chosen and each allocated to local Kenyan districts depending on the population strength to lessen biasness. Further 857 energy suppliers were interviewed.

3.1 Study area

The research was carried in Kenyan urban areas. Kenya is located is sub-Saharan Africa. Kenya's latitude and longitude is 0.0236° S and 37.9062° E respectively (KNBS, 2006; Gisore, 2021). Kenya's governance system consists of provinces and districts. Figure 2 present the geographical area covered by the study.

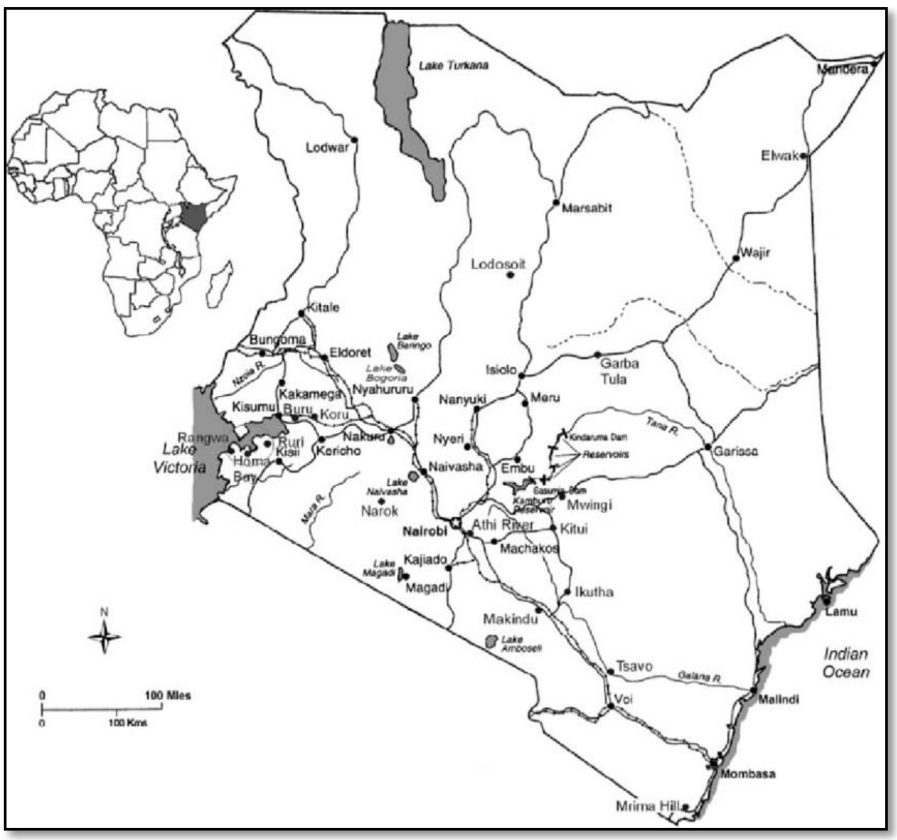

Figure 2: Map of Kenya showing the research area

Source: KNBS (2006).

3.2 Model Specification

This research utilized multinomial logistic (MNL) model to identify the main factors that determine choice of fuel in urban Kenya. MNL estimation function is able to explain the reaction function of household when faced with consumption choices and economic constraints (Pundo & Fraser, 2006). MNL model has advantages when used in discrete choice research (McFadden, 1974). However, the commodities used need to be having differentiated characteristics (Judge *et al.*, 1985; Greene, 2003; Pundo & Fraser, 2006)

MNL function assumes that consumers will maximize their utility from fuel consumption (McFadden, 1974). The function can be presented as follows

$$\Pr[Y_i = j] = \frac{\exp\left(\beta'_j X_i\right)}{1+\sum_{\substack{j=0 \\ i}}^{J} \exp\left(\beta'_j X_i\right)} \qquad (1)$$

Where:

- Pr[Yi = j] represent the probability of utilizing other energy sources while charcoal is the base
- J represent the number of fuels in the choice set;
- j = 0 imply charcoal;
- Xi represent a vector of the predictor element
- βj represent a vector of the estimated element.

Equation 2 can be derived from equation 1 and presented as

$$\mathrm{P_i} = \frac{e^{(b_0+b_1x_1+b_2x_2+\cdots b_nx_n)}}{1+e^{(b_0+b_1x_1+b_2x_2+\cdots b_nx_n)}} \qquad (2)$$

Applying odd ratios, equation 3 can be obtained from equation 2 as follows

$$\ln\left[\frac{P_i}{1-P_i}\right] = b_0 + b_1x_1 + b_2x_2 + \cdots b_nx_n \quad (3)$$

Pi/ (1 – Pi) represent the odd ratio. Equation 3 makes it possible to interpret our result as logit elasticities for easy interpretation (Pundo & Fraser, 2006).

Equation 3 can be restated as below

$$[\frac{P_i}{1-P_i}] = e^{(b_0+b_1x_1+b_2x_2+\cdots b_{n}x_n)} \quad (4)$$

If we differentiate equation 1, marginal effect estimation will be obtained as shown in equation 5 (Greene, 2003).

$$\delta_j = \frac{\partial P_j}{\partial x_i} = P_j \left(\beta_j - \sum_{k=0}^{J} P_k \beta_k\right) = P_j \left(\beta_j - \overline{\beta}_k\right) \quad (5)$$

The marginal effects measure the expected change in the probability of choosing one energy alternative with respect to a unit change in an independent factor.

3.3 Definition and Measurement of Variables

Table 2 presents the descriptive of our study variables.

Table 2: Variable Descriptive

Variable	**Listing**	**Measure**	**Justification**
Household Budget	X_1	Cost	Kippra(2010)
Gender of Household Head	X_2	Gender	Osiolo(2009)
Household Size	X_3	Member	Ouedraogo(2005)
Age of Household Head	X_4	Age	Osiolo(2009)
Education of Head	X_5	Education	Mekonnen and Kohlin (2009)
Household income	X_6	Income	Kebede (2002)

Source: Osiolo (2009); Waweru (2021)

3.6 Data Analysis

The collected data was entered in excel table and cleaned from any errors before estimation. Following empirical works of Pundo and Fraser (2006), logistic regression model was used during estimation. Employing logistic regression model the study estimated the probability of consumer choosing clean verses unclean fuel. In addition, multinomial logistic function was applied to obtain the factors that determine consumer's choice of fuel. It also enabled to use marginal effect estimates, that is probability of choosing one type of energy due to change in determinant of fuel choice as explained by Masera *et al.* (2000), Pundo and Fraser (2006) and Schlag and Zuzarte (2008) empirical works.

4 Results and Discussion

4.1 Logistic Estimation Results

Table 3 present the logistic analysis results for both clean and unclean energy fuels choice by household.

Table 3: Logistic estimation results

Logistic Estimation						
Observations		1170		Prob>chi2		0.00000
LR chi2(6)		533.64		Pseudo R2		0.03366
Log Likelihood		-525.931				
Variable	Coeff	Std. Error	z	P>IzI	95% Conf Interval	
Cost	0.0007	0.0001221	5.40	0.000	0.0004207	0.0008995
HH	-0.2343	0.0419659	-5.58	0.000	-0.3165653	-0.1520620
Income	0.0001	0.0000006	10.63	0.000	0.0000507	0.0000737
Education	0.1561	0.0235172	6.64	0.000	0.1100448	0.2022306
Age	-0.0088	0.0080377	-1.09	0.276	-0.0245015	0.0070059
Gender	0.1101	0.1816801	0.61	0.544	-0.2459609	0.4662121
Cons	-3.3706	0.4307729	-7.82	0.000	-4.2149260	-2.5263280

From Table 3 logistic regression model results, the cost per month spent by each household was significantly positive in relation to the probability of household choosing clean energy over unclean energy. Implying any time consumer spends more probably chances of using clean energy source increases. As household budget increases the consumer becomes sensitive and desires clean, efficient and modern source of energy. The coefficient for income was also positively significant in relation to probability of using clean energy. Thus as household income increases it will translate to the desire for clean and modern source of energy. The rich are likely to spend on less pollutant appliances in the house. Level of schooling was also positive in relation to the desire for clean energy in households. As the population gets educated they are likely to get reasons to invest in clean technology and energy sources. Techno-economic model are highly used to choose new fuel or optimize current ones. Education also will mean acquiring employment which will imply income of household will increase and thus desire for clean energy sources. Further, when gender of household head is included in the regression model, the result shows a positive association in relation to probability of using clean energy. Implying male head families are likely to adopt clean energy. This can be explained by income gender differential being experienced in Kenya. Most Kenyan economic resources and opportunities are controlled by men.

In contrast, the estimate of age of household head was negative in relation to the probability of choosing clean energy. Thus as household head ages the higher the chance of using clean energy. This can be attributed to accumulated income, education and able to make choices on preferences. Further, the coefficient of number of household members was significantly negative in relation to probability of using clean energy. Meaning as the size of family increases fewer resources will be available to encourage use of expensive clean energy equipment. Most of the income will go to consumption instead of investing in clean energy sources.

4.2 Marginal Estimation

The study estimated marginal effect of study variables to obtain odd ratios as a result of change in determinants of fuel choice. Table 4 present the marginal effect regression result.

Table 4 Marginal Effects Analysis

	Firewood		**Kerosene**		**Gas**	
Variable	Coefficient	Change on Odds Ratio	Coefficient	Change	Coefficient	Change
Cost	-0.0003	0.9997	0.0001	1.0001	0.0005	1.0005
Members	0.1008	1.1060	-0.3434	0.7094	-0.3286	0.7199
Income	0.0000	1.0000	0.0000	1.0000	0.0001	1.0001
Education	-0.0502	0.9511	0.0011	1.0011	0.1600	1.1735
Age	0.0495	1.0507	0.0033	1.0033	0.0099	1.0100
Gender	-0.0297	0.9708	0.0992	1.1043	0.1451	1.1562

Cons	-2.7674	0.0628	0.4754	1.6087	-3.7375	0.0238

	Electricity		**Residues**		**Charcoal**
Variable	Coefficient	Change on Odds Ratio	Coefficient	Change	Base Category
Cost	0.0008	1.0008	0.0005	1.0005	
Members	-0.3191	0.7268	-0.2366	0.7893	
Income	0.0001	1.0001	0.0000	1.0000	
Education	0.1434	1.1542	0.0204	1.0206	
Age	-0.0159	0.9842	0.0668	1.0690	
Gender	0.1927	1.2126	1.1682	3.2161	
Cons	-2.7897	0.0614	-7.3756	0.0006	

From the findings in Table 4, the cost of household energy was significant for all fuel choices made by household with a marginal coefficient of about 1 percent. Thus monthly spending was identified as a key variable that explain the fuel choices household make as they move from one energy source to another. This finding is similar with empirical works of Osiolo (2009) and KIPPRA (2010) in Kenya. The study result means the fuel consumers will prefer the cheapest source of energy.

Income of household was positive and about 1 percent effect for all fuels, implying the coefficient is important in household decision about the type of energy to consume. As income increases household will prefer electricity and gas than charcoal and less preference of kerosene or firewood than charcoal. The study result supports energy ladder hypothesis that as income increases household will also scale up the ladder to attain the most expensive, modern and clean source of energy (Schlag & Zuzarte, 2008). The findings agree with empirical works of KIPPRA (2010) and Osiolo (2009) that argue as income increases household will prefer to use clean energy.

The marginal coefficient for education was above 1 percent for all fuel choice. This implied education was important determinant on decisions made by households on the best fuel. As the level of schooling increases the families are likely to prefer clean energy sources like gas and electricity than charcoal. Increase in years of schooling translates to increase in income and probability of getting employed, as income increase household is able to afford clean energy (Kebede et al., 2010; Thomi & Naftaly, 2021). The finding is in agreement with similar study carried in Kenya by Waweru (2021) which concluded that educated households prefer pollution free domestic appliances.

Age of household head marginal coefficient was about 1 percent and significant for all fuels in urban Kenya. Implying older household head are likely to prefer gas and kerosene than charcoal but less likely to purchase electricity and firewood than charcoal. This can be attributed to accumulation of income over the period hence old head are more likely to afford clean and environmental friendly energy fuel sources (Mekonnen and Kohlin, 2009; Nyoni *et al* 2021). The study agrees with similar findings by Kippra (2010) in Kenya that support the importance of age in explaining energy type choices.

The gender variable was significant in explaining household choices in urban Kenya. The coefficient was above 1 percent and significant for all fuels. From the findings, a male household head is likely to prefer clean energy source than unclean one. This can be attributed to most male being more educated and also they control the main economic sources and potentials in the society. The finding agrees with study by KIPPRA (2010) but contrast the result of Osiolo (2009) study. Osiolo (2009) observed that gender was not able to explain the fuel choice decisions of households.

Household size was identified as an important determinant of household fuel choices. The coefficient of household size was negative and slightly lower than 1 percent except for firewood fuel. Implying larger families will prefer to consume tradition and unclean sources of energy like firewood. The finding agrees with studies by Osiolo (2009) and Waweru (2021) that household with fewer members will prefer using clean energy like electricity and gas. This imply big households will have a constraint in resources dedicated to clean energy sources as most of their budget will be spent in consumption of basic goods and services.

5 Conclusion and Recommendations

The study has investigated the main determinants of household fuel choice in Kenya's urban areas using multinomial logistic estimation function. From the regression model for urban Kenya income of household head, cost of energy source and socio-economic factors have been identified as the main variables that explain the fuel consumption pattern. The finding supported energy ladder hypothesis that stipulate income increase will lead to use of clean energy. The marginal effect results have produced significant probability both positive and negative. Specifically, increase in income, cost and socio-economic factors will imply, the probability of households choosing gas and electricity over charcoal increases. The finding agrees that most household will prefer clean energy over unclean fuel in urban Kenya if economic constraints are removed and resources provided.

From the findings, use of clean fuel sources was about 15 percent while unclean energy sources were about 85 percent in Kenya. Such low uptake of clean energy sources will translate to health problems and may cause domestic pollution. As a result the government needs to make clean energy fuel affordable and available to most urban citizens. It may involve introducing energy savings appliances and making them affordable to all. Also the authorities may need to educate citizens the available sources of energy and the harmful effects of using ineffective unclean energy sources. Increasing income of most household through government and private initiatives will encourage use of clean energy by making them affordable. Finally, techno-economic function can be used to identify new technology in order to optimize the scarce clean sources of energy.

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