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# Cooking fuel demand patterns among rural farm households in Kiambu County, Kenya: An application of Quadratic Almost Ideal Demand System

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## ABSTRACT

**Aim:** The study was aimed to identify energy consumption patterns with a view to address the persistent problem of fuel insecurity.
**Materials and Methods:** Systematic random sampling was used to select samples while questionnaires were used to elicit data from 200 respondents. Qualitative techniques were employed for data description while Quadratic Almost Ideal Demand System (QUAIDS) was used for quantitative analysis.
**Results:** The main determinants of energy demand were gender, education level, occupation of the household head as well as age and household size, fuel prices and household income.
**Conclusion:** It was concluded that formulation of income oriented policies to augment household earnings which may increase purchasing power. Furthermore, community education and innovation on efficient energy devices would be an option that needs to be supported by both policy and incentives.

**Keywords:** Demand analysis, fuel consumption, households, QUAIDS model.

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## Introduction

Cooking fuel plays a crucial role in the welfare of households in the world over. Around 2.4 billion people in developing countries use primary sources of energy such as firewood, charcoal, animal dung, and agricultural residues (Ruiz-mercado *et al.*, 2011) where Sub-Saharan Africa (SSA) represents 81% of households depending on firewood for cooking (World Bank., 2011). According to UNDP (2016), Kenya's most central source of energy is fuel wood, accounting over 70% of the total energy requirements for domestic needs (Ngui *et al.*, 2011). Cooking energy can be classified into traditional which include wood, charcoal and agricultural residues and modern such as petroleum products and electricity (GoK, 2004). In Kenya majority of the households in rural areas rely completely upon fuel wood as the key source of domestic energy(Ngetich *et al.*, 2009). This has largely been determined by the local availability, opportunity and transaction costs involved in accessing, collecting and utilization of the biomass fuels(Kituyi et al., 2001; Niriezono & Kilangla, 2018).

This dependence on biomass fuels however, has been cited to have a negative impact on environment by reducing biodiversity and jeopardizing the forest ecosystem (Peter A. Dewees, 1989; FAO, 2009; Akther, Danesh Miah, & Koike, 2010). In fact over reliance of inefficient traditional biomass sources has been accused of exacerbating woodland degradation and climate change, and has detrimental impacts on health and poverty in Kenya (Dalberg, 2013). For example, Kenya's annual demand for biomass was at 34.3 million tons when contrasted with the anticipated supply of 15 million (GoK, 2004). However, it's important to note that rural fuel energy problem cannot be treated in isolation from the similarly persistent issues of food, poverty, environment and culture (Mirza &

Kemp, 2003; Narasimha Rao & Reddy, 2007; Danlami, Applanaidu & Islam, 2018).

Consequently, the patterns of rural household energy consumption is a result of complex interaction of factors besides income(Nazer, 2016). Elements which if ignored could contribute to the problem of household fuel energy interventions approaches that are incompetent. Understanding fuel demand patterns of a specific locale or nation is valuable to the policy formulation in addressing three significant strategy issues identified with fuel security. Primarily, it helps to identifying policy interventions suitable in improving the households' energy requirement. Second, it is helpful in planning several fuel energy subsidy strategies that must be obligated by the government. Lastly, the information on household fuel demand behavior is fundamental for steering sectoral and macroeconomic policy analyses.

In recent studies the focus of household demand for cooking energy has been the energy ladder concept which argues that households tend to switch from inefficient fuel source to a more efficient as dictated by the increases in household income (Masera, Saatkamp, & Kammen, 2000; Heltberg, 2003) . But as evidenced by Pundo & Fraser (2006), households in developing countries tend to consume a mix of fuels rather than changing from one source to another. Kiambu county with poverty levels of 24.2% (KNBS, 2016) can be considered a fairly high income compared to other areas in the country. This would rank the county at higher lever towards use of efficient energy source in the energy ladder argument. Nonetheless, the households in the county uses various sources of energy, with an estimated 80% of rural households use firewood and charcoal (Githiomi et al., 2012; County Government of Kiambu, 2013) and over 10% and 5% use kerosene and LGP sources respectively (Dalberg, 2013).This means that the households in Kiambu have employedthe concept of cooking fuel stacking (multiple cooking fuel use) instead of switching energy sources as observed in the energy ladder behaviour. Accordingly, Kiambu County depends on both income and other demand drivers such as prices.

Consequently, in absence of a careful examination of the household cooking energy demand behaviour, the county will continue designing inapt policies. This study was aimed to understand how household energy consumption will respond to income and price changes important policy implications for ensuring cooking fuel security.

## Materials and Methods

*Area of study*

Kiambu County is situated in the central highlands of Kenya, near to Nairobi Kenya's capital city. It covers about 2,543.5 Km² of which 476.3 Km² represent forest cover. The annual precipitation is 1000mm, warm climatic area of temperatures between 12$^0$c and 18.7$^0$c. The county lies between latitudes 00 25′and 10 20′South of the Equator and Longitude 360 31′and 370 15′East (County Government of Kiambu, 2013).

*Population and Sampling techniques*

Sampling was constructed on government projections of 2009 census of population and housing in Kiambu County. The total number of the population is 1623282 with households being 384465 (County, 2014). A sample size of 200 rural farm households was determined proportionately in all sub-counties where systematic random sampling methodology was employed.

*Data collection*

Data was collected between February and April of 2019 using structured questionnaires.

*Theoretical framework*

Neoclassical approach relates supply and demand to an individual rationality and their capability to maximize utility. Neoclassical consumer theory considers individuals as consumers only, whereby the consumer has to select from a consumption bundles (Selikoff, 2011). For each consumption bundle is a vector of $n$ different commodities.

$$x = x_1, \dots \dots . x_n \dots \dots \dots \dots \dots \dots \dots 1$$

The theory states that the relationship existing between the quantities demanded and price of that commodity is negative. It is assumed that consumers' derive demand from constrained utility maximization. The basic axiom of utility maximization ensures that a rational consumer constantly select a preferred set of goods from the bundles acceptable to the budget (Deaton, 1986). Mostly, consumers group goods according to value or consumer preference. Hence, the relative prices for all the goods have an independent effect on commodity demand.

Demand system allowing for flexibility in the Engels curve tend towards providence of extra realistic results in both simulation and prediction exercises (Autor, 2004). To estimate household demand system, there have been widespread interests in the model of analysis representing the consumption behavior. Linear Expenditure System (LES) of stone 1954 being the pioneer and most traditional method. However, it ruled out the complementary relationship among goods and limitations on proportional income and price elasticities (Blundell, 2008). This led to the development of Rotterdam and translog model (Barnett, 2007). However, Angus Deaton and John Muellbauer (2011), proposed the linear logarithmic form called the Almost Ideal Demand System (AIDS). However, AIDS model is limiting for some goods and low flexibility of the Engels curve (Deaton and Muellbauer, 2011). The succeeding improvement of demand system has focused on improving fit of the model by introducing additional terms which are quadratic in expenditure or income and thus the Quadratic Almost Ideal Demand System (QUAIDS) ( Banks & Blundell, 1961).

*Model specification*

As suggested by FAO (2003), application of households theory needs a precise model. The generalized demand function representing purchase of *m* goods by consumers can be written by way of:

$$q_j = q_j(p_1, p_2 \dots \dots \dots p_m R) \quad j = 1,2 \dots m \dots \dots \dots \dots .2$$

Where $q$ is the quantity demanded, $p$ is the price of *j*, *j* represent commodity and R is the income. *m* represents equations of demand that can be estimated either single or systems of equations.

Angus Deaton and John Muellbauer (2011) developed a demand system based on utility function known as AIDS which is attained in a budget share form. However, it does not allow the price and income elasticities to differ with the income levels. As a result, Banks *et al.*, (1961) derived a model from utility maximization known as QUAIDS. QUAIDS model is more flexible in modeling consumers' expenses, takes into account social demographic factors, enable in accounting for the effects related to income changes (Ehuitch, 2017) as well as the impact of changes in regulated prices of consumer demand (Dybczak, Tóth, & Voňka, 2014).

According to this study, four cooking fuels (firewood, charcoal, kerosene and LPG) that are common in Kiambu County were analyzed. The data was collected from 200 household cooking fuel expenditure in the County. The study used per capita consumption expenditure as a proxy for income. The general function representing demand model that was used in a single equation takes the following format:

*Cooking fuel share = f (income, prices, non-economic aspects)*

The non-economic factors included in the model were age, gender, education level as well as occupation of the household head, size of the household and marital status. Thus, the functional equation for the study takes the form:

*Fuel share ($w_i$) = f (expenditure, prices, gender, age, education level of HH head, occupation of HH head, HH size, marital status)*

The above equation was examined using the QUAIDS model taking the budget share form as:

The QUAIDS model for cooking energy can be estimated as shown:

$$w_i = \alpha_1 + \sum_{j=1}^{n} y_{ij} \ln p_j + \beta_i \ln\left[\frac{R}{a(\boldsymbol{p})}\right] + \frac{\lambda_i}{b(\boldsymbol{p})}\left\{\ln\left[\frac{R}{a(\boldsymbol{p})}\right]\right\}^2 \dots .3$$

Where $\boldsymbol{w_i}$ the budget share of fuels, $\boldsymbol{p_j}$ is the price of fuel j, $\boldsymbol{\beta_i}$ is the expenditure co-efficient, $\mathbf{y_{ij}}$ is the price co-efficient; $\boldsymbol{\lambda_i}$ is the quadratic term co-efficient; $\boldsymbol{\alpha_i}$ is the constant co-efficient; $\boldsymbol{R}$ is the overall expenditure. $\boldsymbol{\alpha_i}$, $\boldsymbol{\beta_i}$, $\mathbf{y_{ij}}$, $\boldsymbol{\lambda_i}$ are parameters to be estimated.

In order to incorporate demographic variables, QUAIDS uses the scaling technique as introduced by Ray (Poi, 2002). Let **z** represent the total persons in a household, $e^R(\boldsymbol{p}, u)$ to denote the expenditure function of a particular HH and the expenditure function for each HH takes the form $e(\boldsymbol{p}, \boldsymbol{z}, u) = m_0(\boldsymbol{p}, \boldsymbol{z}, u) \times e^R(\boldsymbol{p}, u)$. $m_0(\boldsymbol{p}, \boldsymbol{z}, u)$ Is the expenditure function to account for HH characteristics which is further decomposed to $m_0(\boldsymbol{p}, \boldsymbol{z}, u) = \overline{m_0}(\boldsymbol{z}) \times \emptyset(\boldsymbol{p}, \boldsymbol{z}, u)$.

$\overline{m_0}(\boldsymbol{z})$ Denotes the rise in a HH expenditure as function of **z** not controlling for any changes in consumption patterns such that a HH having five members have higher expenditure than one with a less members even ignoring that goods consumed may change.

$\emptyset(\boldsymbol{p}, \boldsymbol{z}, u)$ Regulates changes in prices and the actual goods consumed; a HH with two adults and three children will purchase different items than one involving five adults.

Therefore, the resultant QUAIDS budget share equation takes the form:

$$w_i = \alpha_1 + \sum_{j=1}^{n} y_{ij} \ln p_j + \beta_i \ln\left[\frac{R}{\overline{m_0}(\boldsymbol{z})a(\boldsymbol{p})}\right] + \frac{\lambda_i}{b(\boldsymbol{p})c(\boldsymbol{p},\boldsymbol{z})}\left\{\ln\left[\frac{R}{\overline{m_0}(\boldsymbol{z})a(\boldsymbol{p})}\right]\right\}^2 \ldots\ldots\ldots\ldots\ldots\ldots 4$$

*Treating households with zero expenditure and missing price data*

Understanding demand systems using household micro data is essential since it avoid the problem of aggregation over consumers and frequently provides a great and statistical rich sample. However, it brings about a major estimation problem from the fact that, quite a number of commodities in the budget, the households are observed to consume zero amounts of the various items under consideration (Helen & Wessells, 2013). Therefore, households with zero consumption or purchases which is the problem of missing price data poses a serious estimation flaw which increases biasness as well as reduces efficiency of results (Zhou, 2015).

There are several ways to approach the issue which reduces zero consumption observation which increases efficiency and the value of the results (Rahaman & Mohammed, 2015). The most common approach is by insertion of the zero purchases by correcting them using the censored dependent variable problem using the censored regression models. Mostly used are the heckman two stage regression and the Tobit model. The budget shares of goods represent dependent variables whereby, if a household does not purchase the good equals to 0 and 1 if it does. Zero shares are censored by an unobservable latent variable (Agbola, 2000; Chern, Ishibashi, Taniguchi & Tokoyama, 2002;Weliwita, Nyange & Tsujii, 2003;Helen & Wessells, 2013). Heckman two stage estimation was applied as suggested by Heckman (1978). Stage one, a probit regression for each fuel item was computed which determines whether a consumer decide to purchase some amount of a particular fuel or not.

$$\mathrm{I}_i = \alpha_0 + \alpha_1 \ln m + \sum \beta_{ij} \ln p_j + \sum_k y_{ik} H_k + \varepsilon \ldots\ldots 5$$

$\mathrm{I}_i$ is one if a HH consume $i$th fuel item that is $w_i > 0$ and zero otherwise. The inverse mills ratio (λ) for every household for each fuel was computed, which was used as an instrument incorporating the censoring latent variables in the second regression. Here, the consumer is decisive on the amount they purchase the item thus, dependent variables (budget shares) take value 0 if household expenditure on a particular fuel is zero and a positive value when expenditure is non-zero (Helen & Wessells, 2013). Parameters of the probit regression are used to compute the IMR for each HH for each fuel.

The inverse mills ratio for each HH was computed as follows:

$$\lambda_i = \frac{\emptyset_i(P,x,d)}{\Phi_i(P,x,d)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

P, x and d are prices, expenditure and demographic variable vectors for the HH while $\emptyset_i$ and $\Phi_i$ is the density and cumulative probability functions respectively. In the second stage, incorporating the computed inverse mills ratio (λ), as an instrument variable is estimated (Mittal, 2015).

$$\mathrm{w}_i = \alpha_0 + \alpha_1 \ln m + \sum \beta_{ij} \ln p_j + \sum_k y_{ik} H_k + \theta_i \lambda_i + \varepsilon \ldots\ldots 7$$

$\theta_i$ is the parameter related to the inverse mills ratio. By doing heckman two stages, the problem of zero consumption or expenditure is dealt with.

From the economic theory, three restrictions are enforced from properties of consumer theory. They are additivity, homogeneity and symmetry of slutsky matrix. Additivity (adding up) ascertains that the sum of the individual expenses on different goods and commodities is equal to the total expenditure.

$$\sum_{i=1}^{n} \alpha_1 = 1 \quad \sum_{i=1}^{n} \beta_i = 0 \quad \sum_{i=1}^{n} y_{ij} = 0 \quad \sum_{i=1}^{n} \lambda_i = 0 \ldots\ldots\ldots\ldots 8$$

Homogeneity ensures that demand functions are homogeneous of degree zero in prices as shown.

$$\sum_{i=1}^{n} y_{ij} = 0 \quad \forall j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 9$$

Slutsky matrix is necessarily for well-defined preferences in the demand system which implies that:

$$y_{ij} = y_{ji} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

## Results and Discussion

*Household energy budget share*

As imposed in the QUAIDS model, the additivity or adding up ascertains that the sum of individual expenses on different goods is equal to the total expenditure or sum of budget shares were unitary hence, $\sum w_1 = 1$ as presented (Table 1).

Table 1. Household energy budget shares

| Household energy budget share | Mean of fuel shares |
|---|---|
| **Firewood** | 0.4258 |
| **Charcoal** | 0.2705 |
| **Kerosene** | 0.1733 |
| **LPG** | 0.1304 |

*Source: Field survey 2019*

Approximately, the results showed that 13.04%, 17.33%, 27.05% and 42.58% of the total fuel budget spent on LPG, kerosene, charcoal and firewood respectively which add up to unity. The study was in line with Kwakwa, Wiafe, & Alhassan (2013) in Ghana, where firewood was the main cooking source at 69.2%. According to Gebreegziabher (2007), fuel wood in the rural households of Ethiopia was the main source of fuel. As reported by Onoja (2012), firewood intake among rural households in Nigeria was declining over time due to unavailability and the increased cost from traders despite it being the main fuel used. Osiolo (2006), found that Kenyans most used fuel in the rural areas was firewood which were consistent with the study results.

The expenditure coefficients for charcoal and LPG were significant while that of firewood and kerosene were insignificant. A 100 percent increase in income will increase budget share of charcoal and LPG by 50.77 and 35.4 percent respectively.

Increasing the price of firewood by 100% increases its own budget share by 15.25% suggesting it to be a giffen good. It implied that despite an increase in its price, the rural households cannot afford a more expensive alternative source such as LPG and therefore end up purchasing more of firewood since it's what they can mostly afford. It outweighed the substitution effect. It also increased charcoals budget share by 3.69% but reduces kerosene and LPG by 10.23 and 8.70 percent respectively. An increase in the price of charcoal by 100% increases budget share of firewood and LPG by 3.69% and 4.82% respectively while it decreased its own share by 6.40% an indicator it's an inferior good. It was suggested that as income increases, household will demand less of charcoal and have a costly alternative of LPG followed by firewood. Increasing kerosene price by 100% increased its own budget share by 34.48% thus a giffen good and reduced budget shares on firewood by 10.23% and LPG by 22.14%. More so, increasing the price of LPG by 100% increased the budget shares of charcoal by 4.82% and decreased the budget shares of firewood and kerosene by 8.70% and 22.14% respectively and reduced its own share by 26.02% thus an inferior good. It indicated that as income increases, households would demand more of kerosene followed by firewood.

The quadratic expenditure term was statistically significant in one of the expenditure share equations. It was in the expenditure share equations for firewood, kerosene and LPG that the null hypothesis of expenditure linearity was not rejected. However, the hypothesis was presented that the quadratic expenditure term was zero across all equations which was strongly rejected (Table 2).

Table 2; Wald tests

| | $Chi^2$value | df | p-value |
|---|---|---|---|
| QUAIDS | 9.00 | 3 | 0.0293 |
| specification | 145.83 | 18 | 0.0000 |
| Demographic | | | |
| characteristics | | | |

*Source: Field survey 2019*

Demographic characteristics of gender, age, education level, household size and occupation of the household head showed significant effects in some budget shares (Table3). The co-efficient on gender of the household head suggest a negative effect on LPG and a positive on firewood an indication that budget was allocated more to firewood and less to LPG due to their differences in cost where LPG was at higher cost than firewood. According to Semenya & Machete (2019), male and female made different decisions about household energy. Uhunamure *et al* (2017), confirmed that female has an active role in energy selection. However, Alkon *et al* (2016) argued that men control the household budget in most societies and have more influence on energy selection. It was indicated that despite women's desire to switch to renewable energies, they may not due to men's concern on costs. More so, traditionally women were and still were the key players in making fires, cooking and so on (Chalise *et al* 2018). Nonetheless, male are in control of cash and make most household decisions, including which fuel type to be used (Onoja, 2012).

Table 3; Parameter estimates for the QUAIDS model for energy demand among rural households in Kiambu County

| | Model Coefficients | | | |
|---|---|---|---|---|
| **Variables** | **Firewood** | **Charcoal** | **Kerosene** | **LPG** |
| **Constant** | 0.3237*** | -0.2554** | 0.3070*** | 0.6246*** |
| | (5.07) | (-2.65) | (4.57) | (7.10) |
| **Expenditure** | -0.0803 | 0.5077*** | -0.0734 | 0.3540*** |
| | (-0.90) | (5.19) | (-0.83) | (4.98) |
| **Firewood (Price)** | 0.1525*** | 0.0369* | -0.1023*** | -0.0870*** |
| | (5.66) | (2.22) | (-4.54) | (-4.53) |
| **Charcoal (Price)** | 0.0369* | -0.0640* | -0.0211 | 0.0482* |
| | (2.22) | (-2.37) | (-1.21) | (2.14) |
| **Kerosene (Price)** | -0.1023*** | -0.0211 | 0.3448*** | -0.2214*** |
| | (-4.54) | (-1.21) | (11.62) | (-11.00) |
| **LPG (Price)** | -0.0870*** | 0.0482* | -0.2214*** | -0.2602*** |
| | (-4.53) | (2.14) | (-11.00) | (-8.57) |
| **Quadratic term** | 0.0041 | -0.0085*** | 0.0009 | 0.0035 |
| | (1.86) | (-5.17) | (0.39) | (1.86) |
| **Gender** | 0.0364* | 0.0143 | -0.0326 | -0.0642* |
| | (2.19) | (0.43) | (-1.42) | (-2.41) |
| **Age** | -0.0001 | -0.0038** | -0.0012 | 0.0028** |
| | (-0.10) | (-2.91) | (-1.38) | (3.21) |
| **Education level** | -0.0070 | -0.0573*** | -0.0044 | 0.0460*** |
| | (-0.53) | (-4.06) | (-0.35) | (5.01) |
| **HH size** | 0.0226 | 0.0980** | 0.0153 | -0.0908*** |
| | (1.13) | (2.80) | (0.79) | (-3.48) |
| **Marital status** | 0.0189 | 0.0097 | -0.0185 | -0.0100 |
| | (1.12) | (0.34) | (-1.10) | (-0.48) |
| **Occupation of HH head** | -0.0182** | 0.000184 | 0.00499 | 0.0130* |
| | (-3.15) | (0.04) | (0.83) | (2.08) |

*Source: Field survey 2019. *statistically significant at 0.05 level, ** statistically significant at 0.01 level, *** statistically significant at 0.001 level, t- values in parenthesis.*

Age of the household head was found to a have negative relationship with the budget share of charcoal and positive on LPG. As the generation gets older, they tend to spend more on accessible and available fuels such as LPG. According to Olabisi *et al* (2019), raised household age by one increased firewood and kerosene in Tanzania. Thus, age is an essential element in energy decisive actions among households.

According to Molina & Gil (2005), if education level of the household head increased, there was a likelihood that the economic situation of the household will improve due to higher chances of secured employment that enhances income. Hence, from the results, a higher education level would result to household reducing charcoal intake by 5.73% and increase LPG by 4.60%. Educated household heads were expected to engage in updated technologies such as biogas installation, solar, electricity as well as LPG due to higher purchasing power which as a result conserved the environment (Buba et al., 2017; Orifah *et al* (2019).

Household size variable suggested a positive and negative relationship on the budget shares of charcoal and LPG respectively. Their budget shares increased by 0.0980 and declined by -0.0908 respectively whenever there's an extra member to the household. Results conquered to those of (Kwakwa et al, 2013; Kayode *et al,* 2015) who found positive and significant coefficients on firewood and charcoal but negative for LPG and electricity. It means that for a household to increase fuel consumption due to increased household size, fuel expenditure require to be adjusted downwards so as to obtain low-priced fuel to meet the large household composition. The negative relationship between household size and other cooking fuels could be endorsed by high prices which are not sustainable in an expanding household size.

Finally, occupation of the household head was statistically significant in firewood and LPG. This could be attributed to higher purchasing power as a result of more income. In firewood, it had a negative relationship showing that as income increases, less firewood would be purchased. On the other hand, LPG had a positive correlation which indicated that increased opportunity in better income, household spend more on LPG. This could also be attributed by educated households who would embrace new technology. The results were in line with other studies which found that occupation of the household head had a positive statistical relationship with LPG and charcoal but decreased the probability of using firewood and kerosene (Menéndez & Curt, 2013; Kiyawa & Yakubu, 2017; Adusah-Poku & Takeuchi, 2019; Imran *et al*, 2019).

Wald tests were subsequently performed on the all parameters including λ, to show if the quadratic term of log income was significant or not, and therefore if the QUAIDS model was a good model choice(Ayodele & Oni, 2013).

As represented, the AIDS model was rejected in favor of the QUAIDS model hence the QUAIDS model was a good model choice (Table 2). The results showed that all $\lambda=0$ were statistically significant confirming that QUAIDS did not get reduced to AIDS model and thus used for elasticity estimations. More so, the null hypothesis that household characteristics were not significant was rejected. It was evident from the results that inclusion of demographic variables had a great impact on cooking demand patterns influencing the consumption behavior.

## Conclusion

It was concluded that wood fuel remains to be the main source of cooking an indication of continuous environmental degradation in the rural area. As firewood shortage keeps on expanding, households faced similar difficulties of significant expenses, utilization of inefficient fuels as provisions decline. A targeted pricing subsidy will facilitate fuel switching and positively neutralize household budgets. More so, the result showed that firewood which was mostly used by rural households is a necessity commonly due to their low income levels. Linked to this concern is the fact that neutralizing the cost side of the equation which means improving energy use efficiency at the household level would be cost-effective and a sustained way of improving welfare conditions for the low income households. As a nation education and innovation on efficient energy use devices would be an option that needs to be supported by both policy and incentives.

Results support the argument that households in rural areas are accustomed to use combination of fuels other than switching from lower level of fuel ladder to the higher one. The results also show that rural households in Kiambu use the four combination of fuels i.e. kerosene, firewood, charcoal and LPG. Strategies to diversify to more fuel sources would be explored. These being rural households, use of biogas technology should be facilitated both at policy level and innovation through incentive. This will relieve the demand for firewood and charcoal and offer a switching option to LPG.

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