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Household Energy Conservation in Kenya

Estimating the Drivers and Possible Savings

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Household Energy Conservation in Kenya: Estimating the Drivers and Possible Savings

John Mutua and Peter Kimuyu

Abstract

This paper uses the National Energy Survey Data for Kenya 2009 to investigate the main determinants of household energy conservation and savings, exploiting discrete choice and Tobit models. We estimate conservation models for five household fuels—fuel wood, charcoal, kerosene, LPG, and electricity—and generate information to predict not only the odds for household energy conservation but also the levels of possible savings. Our findings reveal that demographic variables, such as the household head's gender and occupational and educational attainment, as well as household location and size, are key determinants of not only the propensity to conserve energy but also levels of actual energy savings. Other factors that shape these decisions and outcomes include total hours of energy utilization, perceptions about cleanliness and affordability of the energy source, and awareness of conservation measures and regulations. For successful energy conservation, policy will need to take these factors into account.

Key Words: energy conservation, savings, discrete choice

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Contents

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John Mutua and Peter Kimuyu*

1. Introduction

Demand for energy in Kenya has been increasing at a rate faster than available supply, leading to a shortage of primary sources of energy as well as depletion of natural resource capital. This outcome could be somewhat ameliorated if there were adequate information on how to conserve energy and use it efficiently. Although many households have only limited energy switching and use options, they do not conserve available energy or even use it in the most efficient and sustainable way. The main research questions addressed in this paper are: What are the key determinants of energy conservation and energy savings in Kenya and what additional interventions can be beneficially implemented in order to conserve energy and related resources?

The government of Kenya has embarked on energy efficiency and conservation efforts to educate households on the importance of conserving energy as part of a broader goal of demand side management. Sessional Paper No. 4 of 2004 aims at promoting energy efficiency (EE) to reduce the foreign exchange expenditure on oil imports due to high demand for electricity, some of which is generated from petroleum-based products, and to defer additional investment in power generation. In order to promote energy efficient technologies and measures, the government proposes to provide technical and financial support to the private sector. In addition, a program for subsidizing efficient electric bulbs to reduce consumption at the household level was begun in 2007. This programme led to significant reduction in electricity consumption. Other non-monetary measures that have been adopted include disseminating energy efficiency and conservation information, developing standards and codes of practice for cost-effective energy use, and establishing a "centre of excellence" for energy efficiency at the national level. This centre is expected to guide and promote development and implementation of energy efficiency and conservation technologies and methods.

The government has also put in place measures that aim to conserve and efficiently use all forms of energy, including modern fuels such as electricity and liquefied petroleum gas

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(LPG), and dirty fuels such as kerosene, charcoal and fuel wood. The measures have been expanded to include fuels in the transport sector, where fuel economy initiatives have been encouraged. Through adoption of energy efficient cooking 'jikos', the energy consumed through use of charcoal and fuel wood has been reduced significantly, thus saving households money and trips to fetch these fuels and reducing deforestation. Efficient 'jikos' use less charcoal and fuel wood. Improved efficiency in kerosene consumption saves money and protects households from respiratory diseases. This paper focuses on household cooking, heating and lighting fuels such electricity, LPG, kerosene, charcoal and fuel wood and is driven by a desire to make policy proposals in support of existing energy conservation efforts.

Energy efficiency and conservation have long been critical elements of the energy policy dialogue but took on renewed importance as concerns about global climate change and energy security intensified (Gillingham et al. 2009). The ensuing debate is important for developing countries such as Kenya that have ratified the Kyoto protocol and are adopting energy management and conservation measures. Owing to this policy interest in energy conservation, a significant amount of literature has developed over the past 30 years that provides a framework for addressing the issue (Gillingham at al. 2009). Following others, we define energy conservation as 'the absolute reduction in energy demand compared to a certain baseline, measured in energy units' (Linares and Labandeira 2010: 573).

The primary objective of the paper is to investigate the main determinants of household energy conservation/savings behaviour and the implications for energy consumption and environmental quality in Kenya. The specific objectives are to explore key drivers of energy conservation and savings among Kenyan households and to make policy proposals on how best to address energy conservation in the country. The paper also contributes to the state of knowledge on poverty reduction policies.

The rest of the paper is organized as follows: in section two, we review the theoretical and empirical literature relevant to energy conservation. A summary of the data and methodology used in the analysis is presented in section three. The empirical findings are the subject matter of section four while the summary and policy suggestions are presented in the fifth and last section.

2. Literature Review

In the literature, there is an exploration of the relationships between household energy use and householders' intention to reduce energy use on the one hand, and psychological and socio-demographic variables on the other (Abrahamsen and Steg 2011). More specifically, the literature examines whether household energy use and intentions to reduce are important. Such examination is informed by the theory of planned behaviour and includes variables from the value-belief-norm theory, alongside socio-demographic considerations. Household energy use is strongly related to socio-demographic variables (income, household size, and household head's age) (Stern et al. 1999).

Regarding energy conservation modeling, some studies have used discrete choice models while others (e.g., Dubin and McFadden 1984) use micro-simulations for electricity demand by residences and jointly model the demand for appliance and that for energy. If, as suggested in the theory, the demand for durables and their use are joint consumer decisions, model specifications that ignore this fact are likely to lead to biased and inconsistent estimates of price and income elasticities.

Others have developed simple empirical models to investigate the main determinants of household energy conservation patterns (Sardianou 2010; 2007). Fischer (2008) demonstrates that improved feedback on electricity consumption may provide a tool for customers to better control their consumption and ultimately save energy. Such work reveals that feedback mechanisms are most successful in electricity consumption. Fischer (2008) attempts to illustrate how and why feedback works, using psychological models. Relevant features of feedback that determine its effectiveness include frequency, duration, content, breakdown, medium and manner of presentation, comparisons, and combination with other instruments. Other studies examine the reasons as to why people conserve energy (Malone et al. 2002), and propose that, in order to motivate people to conserve energy, it is crucial to understand what drives people's energy use behaviour and how it can be influenced. This line of literature supports some aspects of social-psychological models, emphasizing both altruistic and egoistic motives for behavioural change. Such findings offer insights for other situations where residents are not billed for individual energy use, including government-subsidized facilities, master-metered apartments, and university dormitories.

Although it seems obvious that energy efficiency and conservation are important in reducing greenhouse gas emissions and achieving other energy policy goals, the necessary market behaviour and policy responses have generated debates (Gillingham et al. 2009). While theory and empirical evidence suggest the existence of a potential for welfare-enhancing energy efficiency policies, many questions remain open, particularly those relating to the extent of the notable market and behavioural failures.

Others (Iwaro and Mwasha 2010) observe that the rapid growth of energy use worldwide has raised concerns over problems of energy supply and exhaustion of energy resources. Most of the developed countries are implementing energy consumption regulations such as energy standards, codes and so on in order to reduce energy consumption. The implementation and enforcement of energy regulations in developing countries is either poorly documented or not documented at all. Such countries also lack consistent data to guide energy regulation. Nevertheless, there is literature (Iwaro and Mwasha 2010) that investigates energy regulation in developing countries and its implication for energy conservation and efficiency. Purchasing more efficient equipment, according to this literature, involves higher costs, which low-income consumers cannot afford. Inadequate funding is also identified as one of the most important barriers to effective implementation of energy regulations in developing countries. There are also market barriers.

Residential efficient energy and renewable energy (EERE) products play an important role in energy conservation and reduction of carbon emissions (Zhao et al. 2012). The effectiveness of financial incentives in encouraging consumers to adopt EERE products is not very well understood. Efforts to explore such incentives show, as argued earlier, that high investment cost is a major deterrent to the purchase of these products (Zhao et al. 2012).

Using descriptive statistics and simple projections, Mutua et al. (2010) show that there is huge potential for energy conservation and its benefits in Kenya. This is because energy conservation can lead to saving energy at the household level and in other sectors. It is, however, necessary to dig deeper into the drivers of energy conservation. Others have evaluated the effectiveness of interventions aiming at encouraging households to reduce energy consumption (Abrahams et al. 2005) and found that information tends to result in higher knowledge levels, but not necessarily in behavioural changes or energy savings. It is rewards that encouraged energy conservation, but with rather short-lived effects. Feedback was also found to have its merits, particularly when given frequently. Methodological problems, however, undermine drawing broad conclusions from these studies.

This literature review shows that most of the research on energy conservation has so far focused on the developed world with little research effort in the developing world. Yet the developing world has the greatest potential for rapid social and economic transformation. It is the intention of this paper to make judicious use of new methodologies and increase the stock of knowledge on energy conservation in the developing world.

3. Methodology of the Study

This section of the paper provides a summary of the data used in the analysis as well as the methodology of the study. The paper uses discrete choice energy conservation models and a Tobit approach to estimate energy savings.

3.1 Data

We use household data from the National Energy Survey of 2009. The survey involved 3,665 households and was implemented between May and June 2009 in the then eight provinces of Kenya and administered at the district administrative levels. The provinces have since been abolished and the former districts converted to counties. The sampling framework was based on the National Sample Survey and Evaluation Program (NASSEP IV). The Kenya National Bureau of Statistics (KNBS) established this programme for conducting surveys after the 1999 Population Census. The sampling framework has 1,800 clusters, each on average with 100 households, with the aim of conducting socio-economic surveys. 1260 of the 1,800 clusters are rural and the rest urban. The National Energy Survey undertook a sample of 20% of the clusters, resulting in 252 rural and 108 urban clusters. The survey had a target of 2520 rural and 1,080 urban households. The implementation was successful. Furthermore, some non-structured interviews were carried out with key informants in the energy sector to pick out strategies and policy initiatives that have taken place since the data collection.

3.2 Methodology of Study

We use two sets of models. The first set comprises discrete choice energy conservation models, through which we predict the odds that a household would conserve a specific domestic energy source (Pindyck et al. 1991). The second model exploits Tobit methodology to explore the determinants of actual household energy savings. In the first set, energy conservation, which is the dependent variable, is captured as a dichotomous variable. The question on conservation was whether a household had adopted energy conservation measures, generating Yes or No responses. In the second model, the amount of energy saved in monetary terms is the dependent variable. The explanatory variables are demographic factors such as household location, household size, gender, education and economic factors such as total expenditure and pricing as well as policy variables such as awareness of energy conservation regulations.

3.2.1 Empirical Models

The Odds for Energy Conservation

The empirical model for predicting energy conservation is as indicated in equation 1 below:

$$Energyconserv_i =$$

$$\alpha_0 + \alpha_1\text{Central} + \alpha_2 Eastern + \alpha_3\text{Coast} + \alpha_4\text{Riftvalley} + \alpha_5\text{North\_Eastern} + \alpha_6\text{Nyanza} + \alpha_7\text{Westernn} + \alpha_8\text{AGE} \ +\alpha_9\text{SEX}+\alpha_{10}Educ + \alpha_{11}Price + \alpha_{12}Priceofsubstitutefuel + \alpha_{13}Hsesize + \alpha_{14}Cleanliness + \alpha_{15}Affordable + \alpha_{16}Clean + \alpha_{17}RegulatoryImpact + \ \varepsilon_i \ldots\ldots\ldots\ldots..(1)$$

The dependent variable for the probit model, $EnergyConserve$, represents households' behaviour toward specific energy-conserving actions. In order to construct the dependent variable, we follow Stern and Gardner (1981), who distinguished between efficient energy conservation and conservation curtailment actions.

In this paper, we focus on the decision to conserve energy. The variable $EnergyConserve$ can be estimated in terms of energy savings in monetary terms or as a discrete number where 1 is for households that have adopted energy conservation measures and 0 is for households that do not conserve. In the first instance, we use the dependent variable as a discrete variable in order to determine the odds of adopting energy conservation measures. The explanatory variables are socio-economic attributes of the head of the household such as age (*AG),* sex (*SEX)* and education level for the household head (Educ); household size in terms of number of persons in the household ($Hsesize$); and information and awareness on energy conservation (awareness).ε_i *is* an error component subject to the usual stochastic assumptions. We also control for the impact of location by introducing location variables in the model.

Energy Savings Model

The energy saving model is estimated using the Tobin approach, which is closely related to the probit approach. The model assumes that there is a latent (i.e., unobservable) variable $\boldsymbol{y_i^*}$ that linearly depends on x_i via a parameter (vector) β ,which in turn determines the relationship between the independent variable (or vector), x_i , and the latent variable $\boldsymbol{y_i^*}$ (just as in a linear model). In addition, we assume a normally distributed error term, ε_i, to capture random influences on this relationship. The observable variable $\boldsymbol{y_i^*}$ is defined to be equal to the latent variable whenever the latent variable is above zero and zero otherwise.

The specification of the model (Tobin 1958; McDonald and Moffit 1980) is given as follows:

$$\boldsymbol{y_i} = \begin{cases} \boldsymbol{y_i^*} if \boldsymbol{y_i^*} < 0 \\ \boldsymbol{0} if \boldsymbol{y_i^*} \geq 0 \end{cases} (2)$$

where $y_i^* = \beta x_i + u_i, u_i \backsim N(0, \partial^2)$ is the latent variable. The independent variables include regional dummies, household size, sex of the household head and price of the energy good. In addition to prices and other demographic factors, we have added other exogenous variables related to energy switching options. These were divided into two categories: overall perception of energy services provided in terms of, first, cleanliness of the energy source and, second, cost. In the national energy survey[1], perceived cleanliness was captured in terms of whether the energy source is viewed as very clean, clean, less clean or generating high levels of indoor pollution. Perceived cost was captured by whether the energy service was considered very cheap, affordable, just right, expensive or very expensive. For estimation purposes, very clean and clean were merged into one variable labeled as clean, while less clean and high indoor pollution are classified as dirty. We also have other variables on awareness of energy efficiency regulations and perceived impact of the energy efficiency regulations. The empirical model is indicated in equation 2 below:

$$y_i^*(Energysavfuel_i) = \Upsilon_0 + \Upsilon_1 \text{Central} + \Upsilon_2 Eastern + \Upsilon_3 \text{Coast} + \Upsilon_4 \text{Riftvalley} + \Upsilon_5 \text{North\_Eastern} + \Upsilon_6 \text{Nyanza} + \Upsilon_7 \text{Westernn} + \Upsilon_8 \text{AGE} + \Upsilon_9 \text{SEX} + \Upsilon_{10} Educ + \Upsilon_{11} Price + \Upsilon_{12} Priceofsubstitutefuel + \gamma_{13} Hsesize + \Upsilon_{14} Cleanliness + \Upsilon_{15} Affordable + \Upsilon_{16} Clean + \Upsilon_{17} Regulatory\ Impact + \varepsilon_i \ldots\ldots\ldots\ldots..(3)$$

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1 See section 3.1 of the paper.

4. Empirical Analysis

In this section of the paper, we present descriptive statistics of the variables that were used in the respective fuel conservation and saving models. We also present results for the probit models and their marginal effects, Tobit estimations to establish determinants of conservation achievements through energy savings, and results of predictors of the relative odds of choosing different energy conservation methods.

4.1 Descriptive Statistics

The variables used in this paper are summarized in Table 4.1.1 below. More than 60% of the households using electricity engage in some conservation measures. The corresponding figures for fuel wood, charcoal, kerosene and LPG are 48%, 72%, 43% and 50% respectively. There is therefore a high incidence of energy conservation in Kenya. The energy savings were thus calculated conditional on a household having chosen to conserve. The survey instrument sought to establish whether a household had adopted energy conservation measures. This was a yes or no question. Households that responded “yes” were then asked a follow-up question on how much they had saved by adopting specific energy conservation measures.

The mean electricity savings from conservation measures is US $3.38, while that for fuel wood is US $2.82 per month[2]. Energy savings for fuel wood, charcoal, LPG and kerosene were US $2.22, 4.12 and 1.50, respectively. LPG, therefore, had the highest savings from energy conservation efforts and therefore conservation would be most beneficial for LPG, followed by electricity. These savings are significant given the average monthly fuel costs, which were US $14.35, US $9.40, US $7.66, US $12.72 and US$ 4.67 for electricity, fuel wood, charcoal, LPG and kerosene, respectively.

About 60% of the households were headed by females. With regard to education, about 11.7% of the household heads had primary education. Household heads with secondary and vocational training were 18.1% and 33.6%, respectively. In terms of tenancy, 38.7% of households live in their own homes and therefore have secure property rights.

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2 We have used an exchange rate of Kshs.86 to the US dollar.

Table 4.1.1: Descriptive Statistics

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
Electricity savings(ksh)	659	287.464	603.411	1	10000.00
Electricity conservation	1061	0.621	0.485	0	1.00
Log of electricity savings	659	5.118	0.978	0	9.21
Fuel wood conservation	1105	0.480	0.500	0	1.00
Fuel wood savings (ksh)	431	239.050	284.949	0.5	2000.00
Log of fuel wood savings	431	4.938	1.129	-0.69315	7.60
Charcoal conservation	1926	0.717	0.451	0	1.00
Charcoal savings (ksh)	1158	188.530	179.574	0.25	2000.00
Log of charcoal savings	1926	2.913	2.491	0	7.60
Kerosene conservation	2654	0.427	0.495	0	1.00
Kerosene savings	970	127.784	147.887	0.5	1500.00
Log of kerosene savings	970	4.409	1.006	-0.69315	7.31
LPG conservation	611	0.498	0.500	0	1.00
LPG savings (ksh)	252	350.321	393.085	1	3000.00
Log of LPG savings	252	5.303	1.233	0	8.01
log of LPG price	1061	5.028	0.268	3.072693	6.96
Central	1061	0.180	0.384	0	1.00
Coast	1061	0.095	0.294	0	1.00
Eastern	1061	0.158	0.365	0	1.00
North Eastern	1061	0.044	0.206	0	1.00
Nyanza	1061	0.096	0.295	0	1.00
Rift Valley	1061	0.225	0.418	0	1.00
Western	1061	0.048	0.214	0	1.00
formal employment	1061	0.702	0.458	0	1.00
informal employment	1061	0.175	0.380	0	1.00
household size	1061	4.586	2.452	1	19.00
log of electricity price	490	2.477	1.430	-0.10536	8.29
log of kerosene price	1061	4.091	0.365	0	7.78
log of fuel wood price	1061	6.506	1.132	1.098612	9.39
log of charcoal price	1061	5.791	1.102	0	7.31
log of LPG price	1061	5.028	0.268	3.072693	6.96
female	1061	0.608	0.488	0	1.00
Primary education	1061	0.118	0.323	0	1.00
Secondary education	1061	0.281	0.450	0	1.00
vocational education	1061	0.336	0.473	0	1.00

Tenancy Ownership	1061	0.387	0.487	0	1.00
Electricity utilization hours	1061	7.358	122.758	0.001	4000.00
Fuel wood utilization hours	1061	5.901	24.557	0.01	800.00
Charcoal utilization hours	1061	3.593	4.757	0.3	150.00
Kerosene utilization hours	1061	3.198	15.372	0.01	500.00
Lpg utilization hours	1061	2.627	1.021	0	10.00
Lpg conservation	611	0.498	0.500	0	1.00
Lpg savings in Ksh	296	367.422	402.887	0	3000.00
log of LPG savings	296	5.347	1.242	0	8.01

Source: Analysis from the National Energy Survey Data, 2009.

4.2 Estimated Results

In this sub-section of the paper, we provide estimated results for energy conservation and saving models by different domestic energy types. We discuss results for fuel wood, charcoal, kerosene, LPG and electricity. The results are presented for probit/choice of conservation models, where the choice to conserve or not to conserve is taken as the dependent variable, as well as for marginal effects, predicted after estimation of the probit models. Secondly, Tobit estimated results for the determinants of the money value of energy savings are presented. The exogenous variables for the conservation models are demographic, socio-economic, regional dummies (for Central, Eastern, North Eastern, Rift Valley, Western and Coast, with Nairobi taken as the reference region), type of tenancy (in which those households living in their own homes are compared with those renting or living in semi-permanent structures), technology, and awareness of regulation.

4.2.1 Fuel Wood Conservation

Households use fuel wood mainly for cooking and heating. It is more commonly used in rural and peri-urban areas than in modern towns and cities. In addition to estimating a probit/choice model and predicting marginal effects, a savings model for fuel wood is also estimated, in which the amount of money saved by the household by adopting fuel wood conservation measures is used as the dependent variable. As indicated earlier, the savings model is estimated using the Tobit methodology in order to circumvent selectivity problems. The estimated results for fuel wood conservation are reported in Table 4.2.1 below.

The results show that regional dummies, price of fuel wood, and household head's education are key predictors of the odds for conserving fuel wood. Households located in the Central and Eastern regions are significantly less likely to conserve fuel wood than those located in Nairobi, which is the reference location. Location in other regions does not make any notable difference relative to location in Nairobi. Similarly, the gender of the household head does not count regarding the odds for conserving fuel wood. This is somewhat surprising given the important role that women play in fetching wood. Other important determinants of fuel wood conservation include fuel wood price, with a coefficient of 0.062. This means that increasing the price of fuel wood would lead to adoption of energy conservation measures. On the other hand, primary and secondary education attainment have coefficients of -0.204 and -0.283, indicating that, compared to those with vocational education, households headed by persons with primary and secondary education are less likely to conserve fuel wood.

Regarding actual savings, the Tobit estimates of fuel wood consumption show that, other than the Central province, regional dummies have negative but generally significant coefficients, so that households in these regions enjoy less fuel wood savings than those located in Nairobi. However, the impact on the savings varies from region to region. With regard to education, households headed by persons with primary and secondary education are more likely to enjoy higher fuel wood savings compared to those with no education at all.

Going by the marginal effects predictions, for all households located in regions apart from the Coast, location shows a negative effect on the probability that households will adopt energy conservation measures. The fact that a household is located in the Central, Eastern or Nyanza regions reduces the probability of conserving fuel wood energy by 0.309%, 0.287% and 0.142%, compared to those located in Nairobi. On the other hand, increasing the price of fuel wood by 1% increases the probability of conserving by 0.025%. Households headed by persons with primary and secondary education are less likely to conserve fuel wood by factors of 0.081% and 0.112%, respectively, relative to those with no education, which are therefore likely to use more fuel wood. These results can only be explained in terms of fuel wood poverty, where those with no access to education are also most likely to be poor. They are likely to lack access to fuel wood and therefore any amounts available to them have to be conserved as a mechanism for coping with fuel wood poverty.

Table 4.2.1: Fuel Wood Conservation Estimation Results

	Probit Results			Marginal effects after Probit			Tobit Savings Model		
Variables	Coef.	Std. Err.	Z	Coef.	Std.Err.	z	Coef.	Std. Err.	t
formal employment	-0.119	0.085	-1.410	-0.047	0.034	-1.410	-0.249	0.124	-2.010
household size	0.008	0.012	0.700	0.003	0.005	0.700	0.026	0.020	1.260
log of fuel wood price	0.062	0.026	2.350	0.025	0.010	2.350	-0.012	0.037	-0.340
log of charcoal price	0.067	0.045	1.500	0.027	0.018	1.500	0.040	0.067	0.600
Female	-0.070	0.081	-0.860	-0.028	0.032	-0.860	-0.188	0.115	-1.630
Primary education	-0.204	0.102	-2.000	-0.081	0.040	-2.010	0.287	0.140	2.050
Secondary education	-0.283	0.102	-2.770	-0.112	0.040	-2.800	0.197	0.147	1.340
Awareness about conservation	-0.150	0.132	-1.130	-0.059	0.052	-1.140	-0.012	0.200	-0.060
Awareness of regulations	0.207	0.156	1.320	0.082	0.062	1.330	0.114	0.225	0.510
Central	-0.837	0.181	-4.640	-0.309	0.058	-5.320	0.067	0.270	0.250
Eastern	-0.774	0.184	-4.200	-0.287	0.060	-4.780	-1.318	0.263	-5.000
Nyanza	-0.363	0.188	-1.930	-0.142	0.071	-2.000	-0.886	0.253	-3.500
Rift Valley	-0.057	0.173	-0.330	-0.023	0.069	-0.330	-0.901	0.227	-3.960
Western	0.189	0.190	1.000	0.075	0.075	1.000	-0.615	0.239	-2.570
Coast	0.573	0.365	1.570	0.220	0.128	1.720	-0.789	0.416	-1.900
Constant	-0.216	0.329	-0.660				5.129	0.480	10.680
Sigma							1.285	0.039	

4.2.2 Charcoal Conservation

This sub-section of the paper provides estimated results from charcoal conservation models. The results are reported in Table 4.2.2 below, which shows that location, household size, household head's gender, and perceptions about cleanliness of charcoal and its cost or affordability are key predictors of whether a household does or does not conserve charcoal. Households in the Central, Coast, Eastern, North Eastern and Western regions are more inclined to conserve charcoal than are those located in Nairobi. This can be explained by the high usage of charcoal in these areas and the degradation of the environment that is taking place, resulting in deforestation and a reduction in the supply of charcoal. Households headed by females are more likely to conserve charcoal than are those headed by males. Perception variables indicate that the level of cleanliness of charcoal acts as a determinant of the decision to conserve. The dirtier a fuel is, the less it is conserved. This perception is also related to its cost. When consumers perceive a fuel to be clean, they are more likely to conserve it in comparison with that which is not clean. Awareness of conservation measures also has a positive impact on whether a household conserves charcoal. This indicates that conservation awareness increases the probability that a household will adopt charcoal conservation technologies such as energy-conserving jikos or will even use less charcoal. This also means that a possible policy intervention is to increase the level of conservation-related training.

The results on charcoal use savings show that only being located in Western Kenya is statistically significant, so that households in that region save less from charcoal use compared to those located in Nairobi. Household size, charcoal price, type of tenancy, and perception of charcoal cleanliness are also statistically significant. The more savings from charcoal conservation that a household enjoys, the higher the price of fuel wood, which is a substitute, but the result is not statistically significant. This is also the case for those households that are female headed. On the other hand, there is a strong inverse association between household size and charcoal savings. The larger the household, the less it saves from charcoal conservation. With regard to ownership of tenancy, Tobit results suggest that those living in their own dwellings are less likely to save on charcoal compared to those in rented premises. As we saw earlier, this can be explained because poor households, which are likely to be living in rented homes, are more likely to conserve/save the little charcoal they have because of poverty and low resource endowments. It is not surprising, then, when they seem to save more compared to those living in their own homes, who only use charcoal for roasting meat and, once the meal is cooked, leave the charcoal to burn until the fire dies out.

Results for the marginal effects are interesting given the magnitude of the coefficients. These results show that all regional dummies significantly increase the probability that households in locations other than Nairobi are likely to conserve charcoal. The marginal effects indicate the rates of change in the probability of the decision to conserve charcoal fuel and confirm that being located away from Nairobi increases the odds that households will conserve charcoal. This is not unreasonable given that, while charcoal may be a dominant source of domestic energy for the average household in rural Kenya, the story is different for urban households.

It is evident from this analysis that location, gender of the household head, perception about cleanliness of charcoal and awareness of charcoal conservation measures are the key predictors of the decision to conserve and levels of total energy saved by adopting conservation measures.

Table 4.2.2: Charcoal Conservation Estimations

Variables	Probit Model			Marginal effects after Probit			Tobit Savings Model		
Charcoal conservation	Coef.	Std. Err.	z	Coef.	Std.Err.	Z	Coef.	Std. Err.	t
Household size	-0.004	0.013	-0.300	-0.002	0.005	0.005	-0.004	0.024	-0.160
Log of fuel wood price	0.051	0.031	1.630	0.020	0.012	0.012	0.056	0.056	1.000
log of charcoal price	-0.157	0.051	-3.070	-0.063	0.020	0.020	-0.028	0.090	-0.310
Female	0.185	0.098	1.900	0.074	0.039	0.039	0.194	0.175	1.110
Secondary education	-0.226	0.102	-2.230	0.074	0.040	0.040	-0.060	0.181	-0.330
No education	-0.027	0.227	-0.120	-0.011	0.090	0.090	0.008	0.403	0.020
Tenancy ownership	-0.304	0.148	-2.060	-0.119	0.056	0.056	-0.753	0.265	-2.850
Perception on charcoal cleanliness	-0.047	0.110	-0.430	-0.019	0.044	0.044	-0.251	0.195	-1.290
Perception that charcoal is cheap	0.029	0.104	0.280	0.012	0.041	0.041	-0.335	0.185	-1.810
Awareness of regulations	0.465	0.116	4.020	0.181	0.043	0.043	0.846	0.203	4.170
Central	0.188	0.665	0.280	0.074	0.260	0.260	-0.336	1.229	-0.270
Coast	0.712	0.803	0.890	0.258	0.242	0.242	1.613	1.433	1.130
Eastern	0.492	0.657	0.750	0.191	0.244	0.244	0.573	1.214	0.470
North Eastern	-0.047	0.721	-0.070	-0.019	0.288	0.288	0.409	1.332	0.310
Nyanza	0.656	0.660	0.990	0.247	0.225	0.225	1.068	1.218	0.880
Rift Valley	-0.458	0.652	-0.700	-0.181	0.252	0.252	-0.946	1.205	-0.790
Western	0.047	0.656	0.070	0.019	0.261	0.261	-0.084	1.211	-0.070
Constant	0.752	0.721	1.040				2.647	1.322	2.000
Sigma							2.342	0.060	

4.2.3 Kerosene Conservation

Kerosene is one of the petroleum-based fuels that are commonly used by households in rural Kenya and the poor in urban and peri-urban areas. People living in informal settlements in cities consume kerosene in large quantities in cooking and lighting. The estimates of the relevant probit model show that, while households in the Central region are less likely to conserve kerosene compared to those residing in Nairobi, those located in other regions are more likely to conserve. This probably indicates greater access to other domestic forms of energy in the Central region (See Table 4.2.3). It also reflects higher incomes in this region compared to poor households in Nairobi, especially those living in sprawling slums that rely almost exclusive on kerosene for their energy needs. Regarding employment, households headed by persons employed in the informal sector are more likely to conserve kerosene compared to those in formal employment. Household size shows a negative coefficient on the odds for kerosene conservation. It is unclear why this is so, except that larger households are more likely to be collective rather than unitary, so that common strategies such as those related to energy conservation are hard to agree on and achieve.

As expected, the price of kerosene pushes households in the direction of energy conservation. As prices increase, so does the probability for a household to conserve kerosene. The price of charcoal also increases the odds for conserving kerosene, indicating that, when the price of alternatives increases, households have no choice but to conserve kerosene. However, the relevant coefficients are only weakly significant. Secondary and vocational education attainment by the household head seem to reduce the probability of conserving kerosene relative to other levels of household heads' education. On the other hand, households that use kerosene for a longer period of time are less likely to conserve. The length of utilization of kerosene therefore has a negative effect on the decision to conserve kerosene. This suggests that, as the number of hours of use of kerosene increases, households get boxed into kerosene use with limited opportunity to conserve. This has important policy implications, as policies to promote behaviour change can be encouraged and implemented. Perception of the cleanliness of kerosene has a negative impact on the choice to conserve, while awareness of kerosene conservation measures promotes conservation.

With regard to actual savings from kerosene conservation, results from the Tobit estimations show that households located in Coastal and Western Kenya enjoy significantly higher savings from kerosene conservation relative to those based in Nairobi. Those located in the North Eastern and Rift Valley areas enjoy significantly less savings from kerosene conservation than those located in Nairobi. It is unclear what accounts for these regional differences. Increasing the price of charcoal also increases savings from kerosene conservation. Households headed by people with secondary and vocational education enjoy more savings from charcoal conservation than do those with other levels of education.

These results lead to the conclusion that location, type of employment of household head, price of kerosene and charcoal, education, kerosene utilization hours, fuel cleanliness and awareness of conservation are key predictors of odds for kerosene conservation. There is therefore a battery of variables that are of value for kerosene conservation policy in Kenya.

Table 4.2.3: Kerosene Conservation Estimation Results

	Probit Model			Marginal effects after Probit			Tobit Savings Model		
Variables	Coef.	Std. Err.	z	Coef.	Std.Err.	Z	**Coef.**	Std. Err.	t
Informal employment	0.155	0.063	2.480	0.061	0.025	2.470	-0.045	0.074	-0.600
Household size	-0.022	0.010	-2.220	-0.009	0.004	-2.220	0.003	0.013	0.250
Log of kerosene price	0.104	0.063	1.640	0.041	0.025	1.640	0.156	0.072	2.180
Log of charcoal price	0.050	0.029	1.750		0.011	1.750	0.061	0.038	1.620
Secondary education	-0.106	0.062	-1.710	-0.041	0.024	-1.720	0.134	0.076	1.760
Vocational education	-0.133	0.075	-1.780	-0.052	0.029	-1.800	0.137	0.090	1.510
Kerosene utilization hours	-0.045	0.011	-3.970	-0.018	0.004	-3.970	0.000	0.012	0.010
Perception that kerosene is clean	-0.217	0.055	-3.970	-0.085	0.021	-3.990	-0.036	0.066	-0.540
Awareness of regulations	0.179	0.068	2.650	0.071	0.027	2.640	0.152	0.077	1.970
Central	-0.386	0.105	-3.670	-0.145	0.037	-3.920	0.336	0.155	2.170
Coast	1.196	0.117	10.220	0.431	0.032	13.490	0.008	0.115	0.070
North Eastern	0.939	0.186	5.050	0.350	0.057	6.100	0.451	0.189	2.390
Nyanza	0.343	0.086	4.010	0.136	0.034	4.010	-0.141	0.110	-1.280
Rift Valley	0.169	0.076	2.210	0.067	0.030	2.200	0.068	0.105	0.640
Western	0.663	0.095	6.960	0.259	0.035	7.350	-0.191	0.110	-1.730
Constant	-0.821	0.307	-2.680				3.338	0.385	8.680
Sigma							0.948	0.023	

4.2.4 Liquefied Petroleum Gas Conservation

LPG is one of the petroleum-based fuels that is commonly used among households in urban areas for cooking. It is considered cleaner and more efficient than other cooking fuels. The government of Kenya introduced key regulatory measures and strategies to increase uptake of LPG in the country. Key among them is the standardization of LPG cylinder valves, removal of taxes and improvement of infrastructure. The government recently commissioned a gas facility in Mombasa through a public private partnership (PPP) framework to promote uptake of LPG in the country.

Results for probit, Tobit and marginal effects are presented in Table 4.2.4 below. These results show that important determinants of the odds for LPG conservation include location, household size, household head's gender, tenancy arrangements and length of LPG utilization. Households located in the Coast and Western regions are significantly more likely to conserve LPG than are those located in Nairobi. Being located elsewhere doesn't make any difference regarding LPG conservation. Household size somewhat increases the odds for LPG conservation. Female headship, on the other hand, reduces the probability for conserving LPG, as does ownership of the dwelling and length of LPG utilization. Surprisingly, those living in their own dwellings are less likely to conserve LPG, contrary to the belief that such households would adopt measures that would promote conservation. This could be explained by the household dynamics in most middle and high income households, where house helps are left to 'rule' the kitchen. Due to their low levels of education and lack of incentives to conserve fuel, this has negative effects on LPG conservation and savings. Results based on marginal effects generally mimic these probit-based findings.

With regard to the monetary amounts associated with LPG savings, households in the Rift Valley save significantly less from conservation of LPG compared to those located in Nairobi. However, location in other regions does not show any difference from location in Nairobi. The other important factor in LPG savings is vocational education. Compared to households whose heads have no education, those headed by persons with vocational training save more from LPG conservation.

Table 4.2.4: LPG Conservation Estimation Results

	Probit Model			Marginal effects after Probit			Tobit Savings Model		
Variables	Coef.	Std. Err.	z	Coef.	Std.Err.	Z	Coef.	Std. Err.	t
Informal employment	0.179	0.169	1.060	0.071	0.067	1.070	-0.017	0.242	-0.070
Household size	0.047	0.025	1.860	0.019	0.010	1.860	0.041	0.035	1.150
Log of LPG price	0.128	0.131	0.970	0.051	0.052	0.970	0.271	0.176	1.540
Log of electricity tariff	0.149	0.126	1.190	0.060	0.050	1.190	0.039	0.175	0.230
Log of charcoal price	-0.070	0.052	-1.350	-0.028	0.021	-1.350	-0.032	0.068	-0.460
Female	-0.229	0.111	-2.060	-0.091	0.044	-2.070	-0.011	0.159	-0.070
Secondary education	-0.208	0.145	-1.440	-0.083	0.057	-1.450	0.015	0.210	0.070
Vocational education	-0.172	0.122	-1.410	-0.068	0.048	-1.410	0.182	0.172	1.060
Tenancy ownership	-0.241	0.115	-2.090	-0.096	0.046	-2.100	0.012	0.174	0.070
LPG utilization hours	-0.103	0.039	-2.610	-0.041	0.016	-2.610	0.012	0.059	0.210
Awareness of regulations	0.209	0.128	1.630	0.083	0.050	1.640	0.210	0.182	1.150
Central	-0.300	0.176	-1.700	-0.119	0.069	-1.730	-0.023	0.284	-0.080
Coast	0.929	0.238	3.900	0.333	0.068	4.870	-0.389	0.280	-1.390
Eastern	-0.243	0.190	-1.280	-0.096	0.074	-1.290	0.071	0.298	0.240
Nyanza	0.154	0.184	0.840	0.061	0.073	0.840	-0.042	0.280	-0.150
Rift Valley	0.230	0.170	1.350	0.091	0.067	1.370	-0.542	0.254	-2.140
Western	0.540	0.278	1.950	0.207	0.098	2.120	0.038	0.383	0.100
Constant	-0.355	0.849	-0.420				3.875	1.170	3.310
Sigma							1.187	0.053	

4.2.5 Electricity Conservation

Electricity connectivity in Kenya is currently estimated at about 32% of total households (Energy Regulatory Commission 2014). This is low compared to other countries. Unlike the other models, where all regional dummies have been prominent, these were dropped from the electricity conservation model and replaced by a dummy distinguishing only between rural and urban location. The results are presented in Table 4.2.5 below.

The probit estimates show that a household located in the rural areas has a lower probability of conserving electricity than a household located in an urban area, probably because electricity consumption in Kenya is still largely an urban phenomenon. Vocational training has a positive coefficient relative to those with no education, while electricity utilization hours has a negative coefficient on electricity conservation.

The results for savings from electricity conservation yield only four significant variables, namely, electricity tariff, nature of tenancy and awareness of electricity conservation. Increasing the electricity tariff by 1 percent would increase savings from electricity consumption by 0.172 percent. The corresponding coefficients for tenancy and conservation awareness are 0.284 percent and 0.323 percent, respectively. Those households residing in their own dwellings are more likely to enjoy higher savings from electricity conservation compared to those in rented homes. This suggests that households residing in their own homes are more likely to carry out investments in energy conservation in the long run, leading to increased energy savings. Households residing in their own dwellings have exclusive rights to develop and install energy conservation facilities, compared to those who are renting. Because some owners of rental property do not allow improvements or modifications to be done on their premises, renters find themselves in a situation in which they cannot adopt electricity conservation and saving measures even if they are willing to do so. Tenancy arrangement, therefore, limits adoption.

The marginal effects confirm that households located in the rural areas are less likely to conserve electricity compared to those located in the urban areas. The marginal effects for electricity tariff have a perverse effect on the odds for conserving electricity. The higher the tariff, the less likely households are to conserve electricity. This could be an indication that households are not conscious of their electricity usage despite change in the tariff and thus it may not influence their decision to conserve. However, in the case of electricity savings, the higher the tariff, the higher the savings, which means that households are more conscious of electricity bills that they pay monthly.

These results lead us to conclude that household location, electricity tariff and utilization hours are important determinants of energy conservation and can inform relevant policy interventions.

Table 4.2.5: Electricity Conservation Estimation Results

	Probit Model			Marginal effects after Probit			Tobit Savings Model		
Variables	Coef.	Std. Err.	z	Coef.	Std.Err.	Z	Coef.	Std. Err.	t
Household size	-0.008	0.017	-0.480	-0.003	0.007	-0.480	0.064	0.017	3.730
log of electricity tariff	-0.134	0.072	-1.860	-0.051	0.027	-1.860	0.172	0.061	2.820
Female	-0.046	0.083	-0.560	-0.018	0.031	-0.560	-0.097	0.077	-1.260
Vocational education	0.161	0.085	1.880	0.060	0.032	1.900	0.101	0.076	1.320
Electricity utilization hours	-0.042	0.010	-4.040	-0.016	0.004	-4.030	-0.006	0.010	-0.580
Tenancy ownership	0.175	0.094	1.870	0.066	0.035	1.880	0.284	0.085	3.350
Awareness about conservation	0.153	0.128	1.190	0.057	0.047	1.200	0.323	0.117	2.770
Awareness of regulations	-0.014	0.148	-0.090	-0.005	0.056	-0.090	-0.133	0.132	-1.000
Rural	-0.274	0.090	-3.050	-0.105	0.035	-3.030	-0.108	0.085	-1.270
Constant	0.778	0.207	3.750				4.317	0.184	23.400
Sigma							0.936	0.026	

5. Conclusion and Policy Suggestions

Following existing literature on energy conservation, we used 2009 National Energy Survey data sets to estimate probit models to determine the odds for conserving different forms of energy used by households in Kenya and estimated the marginal effects of the explanatory variables included in the probit model. We also used a Tobit modeling approach to determine factors that influence the value of energy saved. The assortment of variables used include household location unpacked into province-based regional dummies; fuel prices; household head's personal attributes such as type of employment, gender and educational attainment; fuel utilization levels; property rights over dwellings; cleanliness of fuel; perception of affordability; and awareness of energy conservation regulations.

Theoretically, conservation of energy is motivated by many factors, including the desire to reduce price/cost, environmental concerns, energy demand management, awareness of the national needs to conserve energy, regulatory goals and other demographic factors such as gender of household head, household head's educational attainment and employment status, and overall household energy utilization. Although there are many methodologies that can be used to analyze energy conservation, we have kept matters simple by adopting discrete choice and ordinary least squares models to track the odds for conserving and the levels of energy savings conditional on conservation of specific fuels.

Our results show that household location, fuel prices, household head characteristics (gender, education level and type of employment), property rights over dwellings, perception of cleanliness and affordability, and awareness of fuel conservation regulations are all key determinants of the likelihood of conserving energy and the consequential savings in monetary terms.

These results indicate that energy prices can be used to encourage energy conservation and sustainable development. The efficacy of adjusting prices as policy instruments varies from one form of household energy to another but is particularly efficacious for wood and kerosene. There are also significant location differences in the tendency to conserve and the quantum of energy savings, which should be taken into account in policy designs. For example, in the case of charcoal, households in the Central, Coast and Eastern provinces are significantly more likely to conserve and to derive energy savings from such conservation, relative to those residing in Nairobi. This information is a useful guide to national energy conservation policies.

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