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Do Households Diversify Energy Sources or Switch to New Sources in Ethiopia? A Case Study in Wolkite Town

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Abstract
This study analyses weather households diversify their energy sources or switch to new sources. The study utilized cross-sectional data gathered from a randomly selected sample of 260 households in Wolkite town. The study employed linear approximation almost ideal demand system (LAAIDS).The model was constrained to comply with neoclassical theoretical restrictions on demand, and was estimated using Iterative Seemingly Unrelated Regression (ISUR).We found that households did not completely switch to new energy sources as suggested by the energy ladder hypothesis. Instead, they diversified their energy consumption through a process of fuel stacking (energy mix). We also found that the demand for energy was expenditure elastic, with the estimates of cross-price elasticity of the demand for energy sources attesting to the existence of energy substitution and complementarity in the study area. Furthermore, we document that prices of all energy sources (except kerosene), household total energy expenditure, sex (if male), age, years of education, family size, and residence type as main determinants of expenditure share of energy sources. Given the negative health and environmental consequences associated with massive consumption of fuel-wood and charcoal, the study suggests that making modern energy source easily accessible, incorporating environmental costs attributable to consumption of fuel-wood and charcoal in the energy planning process, and imposing environmental tax equivalent to the costs to help enhance transition (switch) to modern energy sources as solution to improve the situation.
Keywords: Almost Ideal Demand System, Household energy demand, Energy complementarity, Energy mix, Energy switch, Ethiopia
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1. INTRODUCTION

Household energy consumption refers to the quantity of energy resources consumed by households on several appliances (IEA, 2014). Energy occupies one of the most essential features of human life (Eakins, 2013). It is also vital for economic and social development. It supports health and education service provision (IEA, 2010).

Energy can be categorized into traditional and modern energy sources. Traditional energy sources include firewood, charcoal, crop residues and animal waste. They are also called biomass energy and are obtained from natural environment. The modern energy sources are kerosene, liquid petroleum gas (LPG) and electricity. These energy sources are also called modern or commercial energy sources (Leach, 1987). Modern energy services are particularly crucial in terms of enhancing production and productivity.

Globally, about 2.7 billion people rely on traditional energy sources. Out of these, 2.6 billion people are from developing countries, 653 million people of which are from Sub-Saharan Africa. In Ethiopia, more than 67 million people depend on biomass energy to meet their cooking, heating, lighting and hygiene needs (CSA, 2012). This shows the heavy reliance of developing countries on traditional energy sources resulting in energy scarcity. Energy scarcity refers to lack of sufficient alternatives in accessing affordable, reliable, high quality, safe and environmental friendly energy services to aid economic and human development (Kemmler, 2007). For instance, 61% of the Indian, 84% of the Cambodian, 73% of the Kenyan, 84% of the Tanzanian and 90 % of the Ethiopian populations are energy poor. In these countries, majority of the population lack efficient and clean energy sources for domestic energy use (ESCAP, 2012).

Likewise, 1.32 billion people in the world lack access to electricity. For example, 51% of the population of developing countries relies on biomass energy sources for domestic use, while the corresponding figure for sub-Saharan Africa stands at 78%. The figure for Ethiopia is 93%, which is extremely high even by sub-Saharan standard. Moreover, 63 % of Ethiopian population has no access to electricity[1] (IEA, 2010; DGEP, 2011; and EPA, 2012). Such a heavy reliance on traditional energy sources has adverse consequences such as deforestation, land degradation, soil erosion, climate change and energy scarcity in those countries (Yonas, et. al., 2013).

Previous studies conducted in developing countries particularly in Ethiopia have documented that energy sources are substitutes to each other. This could possibly due to positive cross-price elasticities of demand between energy sources. However, none of the studies found the possible complementarity of energy sources. Moreover, studies on the determinants of demand for energy and estimation of energy demand are very limited. On account of this, we are interested to address the following questions: Are energy sources only substitutes? Do households switch from traditional to modern energy sources in the study area? By addressing these questions, this study aims to contribute to the existing body of knowledge.

2. REVIEW OF LITERATURE

2.1. Theoretical literature

Household Energy Choice Hypotheses: Consumer energy consumption can be defined as the fuel consumed in homes to achieve the needs of the householders. Fuel demand is derived from necessities to consume fuel to gain required services. Households demand fuel eventually for the services they gain such as heating, lighting, and cooking from its usage. Households' choose one fuel source to another to meet their demand. Regarding why a consumer chooses a particular energy source(s) than others, there are two hypotheses that have been mainly developed and tested empirically. These are the energy ladder and energy stacking hypotheses.

Energy Ladder Theory: As for Muller and Yan (2016), the energy ladder has been frequently used concept in clarifying household energy consumption in developing countries. The energy ladder describes a process by which consumers, as their income increases, shift away from traditional fuels (biomass), first to adopt intermediate fuels (kerosene, coal), and then to consume modern energies (gas, electricity). In that sense, the energy ladder hypothesisaids as a conventional extension of the income effect of consumer economic theory that enlightens how consumers interchange (substitute) the necessary and luxury commodities for inferior ones, as their income increases. Consequently, as their income increases, households' switch to more advanced energy carriers and simultaneously give up less advanced alternatives. Even though such hypothesis has still to be fully confirmed empirically, one accomplishment of this theory is its ability to fit well common observations of the highly income dependency of household energy consumption.

Energy Stacking (Energy Mix) Theory: Nevertheless, the energy ladder theory is criticized by Masera et al. (2000) due to the fact that it unable to explain the dynamics of households' energy consumption adequately. Rather, they point that fuel stacking is common in both urban and rural areas of developing countries. Fuel stacking matches to multiple use patterns; where households choose multiple energies from both lower and upper levels of the ladder. Indeed, modern energies may serve only as partial, rather than perfect substitutes for traditional fuels (Van der Kroon et al, 2013, 2014).

Multiple energy consumption emanates from many reasons, such as, occasional shortages of modern fuels (Hosier and Kipondya, 1993; Kowsari and Zerriffi, 2011), instabilities of commercial energy prices (Leach, 1992), high cost of appliance linked with consumingentirely modern energies (Davis 1998), and choices prompting households not to fully adopt modern energies (Masera et al., 2000). The complexity of energy switching process henceproposes that there is a multiplicity of determinants, in addition to income, whichcould influence energy consumption. This managed some authors to research in to more sophisticated modelling approaches.

2.2. Empirical Literature

In energy economics, there are many research works on households' demand for energy sources and how the households respond to changes in factors that affect energy demand. For example, Khazzoom (1973) argue that free demand relies on a price vector whose elements generally contains of the price of the good in question, and the price of its substitutes. Similarly, Foley et.al (1983) contend that the question of whether households are willing to pay for fire wood affect their choice to fuel wood scarcities. If prices increase those who already possess fuel wood may be ready to spend in an energy saving stove or they may shift to marketable energies.

Cuthbert and Defournaud (1998) estimated income and price elasticities of fuel-wood demand in Sub-Saharan Africa. The authors witnessed that a rise in household income leads to rise in fuel-wood demand, whereas an increase in price of fuel-wood causes a decline in fuel-wood demand.

Heltberg (2003) concluded at that education level of the household head significantly and negatively affected wood consumption in Guatemala. The study also identifies that price of wood has a significant negative impact on firewood demand both in rural and urban areas. Regional inequalities were evident that in urban areas household consumption of fuel-wood fell while consumption of LPG generally increased with the rise in

[1] The corresponding figures for developing countries and sub-Saharan countries are respectively 25% and 69%.

expenditure.

Chambwera (2004) used the almost ideal demand system to examine urban energy mainly fuel wood demand in Harare town. The study employed a multi-stage budgeting approach, estimated the proportion of energy in total household spending and the proportions of fuel wood, electricity and kerosene in total energy spending. The study recommended that minimizing prices of substitute fuels, especially kerosene could encourage consumers to switch from fuel wood to kerosene and simplifies the problem of ecological degradation.

Ouedraogo (2005) focusing on urban Burkina Faso concluded showed that while households with large family size mostly used firewood, the richest households had smallest family size mostly consumed charcoal. The study also recognized that household's head that had higher education level experienced lesser likelihood of firewood consumption than the household head with lower education. In addition, the study found out that as standards of living improved, the consumption of firewood decreased whereas the consumption of charcoal and use of LPG increased.

Pundo and Fraser (2006) found that the level of education of wife, whether or not the household owns the dwelling unit, and whether or not the dwelling unit is traditional or modern type are determinants of probability of switching from firewood to charcoal or to kerosene. The study also reveals that for the majority of the study area, firewood is chosen for cooking purpose.

Zenebe (2007) employed probit and AIDS models to analyze energy demand for urban Ethiopia using data from urban centers in Tigray region of Ethiopia. He witnessed that electricity and fuel wood; kerosene and charcoal were substitutes, and all fuel types were price inelastic. While electricity was found to be luxury, other energy goods were necessity goods. Household income, education level, age of household head and prices of all energy goods were identified to be significant determinants of energy demand.

Samuel (2008) examined energy demand for urban Ethiopia and concluded that own price, income level and availability of various energy sources were the key determinants of consumption patterns of urban households. As per the authors, household size exhibits a direct relationship with demand for traditional fuel types. Employing the multivariate probit model analysis, the author also estimated the probability of choosing modern and traditional fuel types. Accordingly, he also founded that as household income rises, the probability of choosing modern fuel also rises as compared to traditional fuel. Furthermore, price elasticity of consumption of charcoal, firewood and kerosene were found price elastic.

Osiolo (2009) discovered that total household expenditures, gender of the household head, fuel price, household, location of residence and distance to fuel source, education of household head and electricity access were the main factors to determine energy consumption decision in Kenya.

Mekonnen and Kohlin (2009) conducted a study to identify the determinants of household fuel choice in major cities of Ethiopia by utilizing a multinomial logit model. The authors found that larger family households were more likely to consume charcoal and wood, whereas less likely kerosene. Nevertheless, they argued that the smaller family households consumed more kerosene while electricity consumption did not rely on family size. Households with higher education level more likely consume electricity and kerosene than wood and charcoal as cooking fuel.

Bersisa (2010) argues that households in urban Ethiopia are highly responsive to higher cost of biomass fuels (fuel wood and charcoal). This in turn favors the assumption that households easily respond to higher prices through demand management and/or substitution of modern fuels (electricity and kerosene). Cross-price elasticities of demand are also very important to investigate the relationship between different fuel types. As has been identified from positive cross-price elasticity of demand, fuel wood and electricity as well as charcoal and kerosene are substitutes. Alternatively, fuel wood and charcoal are complements (negative cross price elasticity). Likewise, electricity and kerosene are identified to be complements. The pattern of energy consumption for urban Ethiopia can be inferred from these facts.

Getamesay et al. (2015) witnessed that fuel is a necessity good and it is income elastic in Addis Ababa. In addition, household size, the proportion of women in households, household head level of education, owning of dwelling and electric appliance are significant determinants that affect the decision to use a particular energy type. Moreover, possessing refrigerator is negatively related with budget allocation of energy. It shows that the households that possess refrigerator, cooks many foods at a time and reserve for long time in their refrigerator and minimizing cooking rate.

From the above reviews, we learnt that none of the studies identified possible complementarity between energy sources. Similarly, studies of on whether substitutability and/complementarity exist in urban Ethiopian is under researched as there is no comprehensive study so far. Thus, this study attempts to fill these by examining whether households diversify their energy sources or substitute an energy source for another source in response to stimulus.

3. The Data and Estimation Strategy

3.1. Data and Sampling

This study used both primary and secondary data. It relied mainly on the primary cross-sectional data of 2017. The primary data mainly focused on home consumption of sources of fuel (fire wood, charcoal, kerosene and electricity) and household characteristics. A questionnaire is used to collect data, and administered to heads of households through interviews. Secondary data, such as total number of households of Wolkite town obtained from Guraghe zone administration office.

Two-stage sampling procedure was applied to select the required number of sample households. First, from all (the three) sub-cities in the town, Addis and Bekur sub-cities are purposely selected. Then, from sampled sub-cities, two sample kebeles (Selam Berand Addis Hiwot) are drawn through lottery method and taken as sample kebeles. Second, sample households were selected from the sample kebeles in a systematic random sampling manner. A systematic random sampling based on a given interval between houses is undertaken during household selection. Accordingly, one household was selected out of 15 households in each sample kebele to make 260 household units. Sample size in each sample kebele is determined proportionally to their respective total number of households. Accordingly, about 75 and 185 households participated in the study from Selam Ber, and Addis Hiwot kebeles respectively to make a total sample of 260.

3.2 Estimation Strategy

This study applied two stage budgeting; Linear Approximated Almost Ideal Demand System (LA/AIDS) to analyze the determinants of household energy demands. The idea of a two-stage budgeting method is that the allocation of household budget exists at two independent stages. At the first stage, households allocate their expenditure on wide commodity groups such as food, energy and durables. At the second stage, expenditure is further allocated to each individual commodity under the group. For the purpose of this study, we assumed that there are only two commodity groups: energy (E) and other goods (O).

The first stage: Here, households divide their total expenditure between fuel and other goods. At the second stage, expenditure on fuel determined in the first stage is further divided among the several sources of fuel (fuel-wood, charcoal, kerosene and electricity). At this stage, demand for any fuel group must be stated as a function of total fuel expenditure and the prices of goods within the energy group.

Thus, $x_F = f_{EG}(P_{EG}, E_{EG})$ ______ (1)

where x_F is quantity demanded of fuel F, p_{EG} is a vector of prices of goods within the energy group, and E_{EG} is total expenditure on the energy group.

To fulfill a two-stage budgeting method, certain assumptions must be put. A necessary and sufficient condition for the two-stage of budgeting is weak separability. According to weak separability assumption, commodities can be categorized into groups so that choices within the same group can be stated independently of the quantities in the other groups. That means, given energy group, the household can rank different energy bundles, which is independent of consumption of every good outside the group. This indicates that we can have sub-utility function for each group so that the values of each of these sub-utilities combine to give total utility. For example, suppose there are six goods x_1 *and* x_2 are foods, x_3 *and* x_4 are energy sources and x_5 and x_6 are entertainment goods. Then if separable groups (food, energy, and entertainment) are formed, the utility function can be written as (Deaton and Muellbauer, 1980b, Taljaard, 2003).

$u = u(x_1, x_2, x_3, x_4, x_5, x_6) = h\big(u_1(x_1, x_2,), u_2(x_3, x_4), u_3(x_5, x_6)\big)$ ______ *(2)*

where $h(.)$ is an increasing function and u_1, u_2 *and* u_3 are the sub-utility functions connected with food, energy and entertainment, respectively. Weak separability denotes that for a function to be separable, the marginal rate of substitution between any two goods of the same group must be independent of the price change of any good in any other group.

Next, an Engle curve will be specified and estimated. An Engle curve states the link between the quantity demanded and the income level of household, keeping all other factors unchanged. At the first stage, a given household is assumed to allocate total expenditure between energy and non-energy groups. Therefore, total energy expenditure for the i^{th} household is assumed to be a function of total household expenditure and the most important household characteristics so that the Engle model takes the following specification

$TEE_i = \alpha + \beta log(dTE_i) + \emptyset Z_i + \mathcal{E}_i$ ______ (3)

Where,

TEE_i is the share of energy expenditure in total expenditure for i^{th} household; dTE_i is household total expenditure deflated by consumer price index; Z_i is vector of household characteristics; α, β *and* $\emptyset$ are parameters to be estimated; after the estimation of the model, expenditure elasticity of energy demand is calculated using the following formula:

$e_{EM} = 1 + \frac{\beta}{\overline{W_E}}$ ______ *(4)*

where $\overline{W_E}$ is average share of energy. If e_{EM} is expenditure elastic for normal goods (modern fuels), and expenditure inelastic for inferior goods (traditional fuels), it implies that households prefer modern fuels to traditional fuels. The sign of β determines whether energy is a necessity or luxury. That is, if $\beta > 0$, energy is a luxury, if $\beta < 0$, then it is a necessity and if $\beta = 0$, energy consumption is income independent. The vector of coefficients allows us to assess the effects of household characteristics on the allocation of household total expenditure on energy.

The second stage: For the empirical demand analysis, we used the LA/AIDS, specified in line with the second stage of budgeting. Accordingly, our LA/AIDS is specified as:

$$W_{Fi} = \alpha_F + \beta_F \log\left(\frac{TEE_i}{P^*}\right) + \sum_n \gamma_{fj} \log P_j \qquad (5)$$

We extended the LA/AIDS by incorporating the effects of household characteristics as explanatory variables. As a result, the LA/AIDS model takes the form:

$$W_{Fi} = \alpha_F + \beta_F \log\left(\frac{TEE_i}{P^*}\right) + \sum_j \gamma_{fj} \log P_j + \emptyset_F X_i + \varepsilon_{fi} \qquad (6)$$

Where TEE_i is household i's expenditure share of fuel f in his total energy expenditure and is defined by

$$W_{Fi} = \frac{E_{Fi}}{TEE_i} \qquad (7)$$

E_{Fi} is household $i's$ expenditure on fuel F and is given by

$$E_{Fi} = p_{Fi} q_{Fi} \qquad (8)$$

TEE_i is household $i's$ total energy expenditure and is given by

$$TEE_i = \sum_F p_F q_{Fi} \qquad (9)$$

F represents fuels consumed by the household (fuel-wood, charcoal, kerosene and electricity)

p^* is the Stone price index and is defined by

$$\log p^* = \sum_F \overline{W}_F \log p_F \qquad (10)$$

$\overline{W_F}$ is fuel F's average of expenditure shares of households; p_{Fj} is price of fuel j. X_i is vector of household k's characteristics; $\alpha_F, \beta_F \& \gamma_{fj}$ are parameters to be estimated; β_F measures the effect of household's total energy expenditure on the budget share of fuel. γ_{fj} Measures the effect of the price of fuel j on the budget share of fuel F; $\emptyset_F$ is vector of coefficients; ε_{fi} is error term associated with budget share of fuel F.

While estimating LA/AIDS model, we faced the problem of observations with many zero expenditure share of kerosene. According to Gujarati (2004), if the dependent variable has many zero values; the parameter estimates of OLS could be inconsistent and biased. This problem is solved by using Heckman's (1979) two-step estimation procedure (Greene, 2002). First, the probit model is estimated to determine the likelihood of consuming kerosene, with zero expenditure shares. Thus, the dependent variable is binary (Y=1 if a household consumes kerosene; and Y=0 if not). We estimated the probability that a household consumes kerosene or not as follows:

$$y_i = \begin{cases} 1 = \phi(x,\beta), \\ 0 = 1 - (\phi(x,\beta)) \end{cases} \qquad (11)$$

where ϕ is cumulative normal distribution of the error term;

x is a vector of explanatory variables assumed to affect the probability of a household consuming kerosene or not; β is a vector of parameters to be estimated. The inverse Mill's ratio associated with kerosene is generated for each observation using the coefficients of probit estimate $(\hat{\beta})$

$$\lambda_{Ki} = \frac{\emptyset(x,\beta)}{\phi(x,\beta)} \qquad (12)$$

where λ_{Ki} is is inverse Mill's ratio of kerosene; $\emptyset(.)$ is standard normal distribution density function; $\phi(.)$ is cumulative function of standard normal distribution.

The inverse Mill's ratio generated at this step was incorporated as an explanatory variable in kerosene demand equation so as to account for selection bias, and finally the LA/AIDS was estimated by iterated seemingly unrelated regression (ISUR) (Zellner, 1962). This method allows us to obtain the simultaneous correlation of the error terms across equations and enables to impose cross-equation restrictions. The estimated LA/AIDS model is given as:

$$W_{Fi} = \alpha_F + \beta_F \log\left(\frac{TEE_i}{P^*}\right) + \textstyle\sum_j \gamma_{fj} \log P_j + \emptyset_F X_i + \eta_F \lambda_{Wi} + \varepsilon_{fi} \qquad (13)$$

η_F is the coefficient associated to inverse Mill's ratio of fuel F and $\eta_F = 0$ if F is all fuel sources except kerosene and $\eta_F \neq 0$ if F is kerosene. We estimated (13) by imposing the restrictions set by the theory of consumer demand. These restrictions are:

Adding up restriction: $\sum_F \alpha_F = 1, \sum_F \gamma_{fj} = 0, \sum_F \beta_F = 0$ (14)

Homogeneity restriction: $\sum_n \gamma_{fj} = 0$ (15)

Symmetry restriction: $\gamma_{Fj} = \gamma_{jF}$ ____ (16)

where F represents equation for each energy type, n stands for price of each energy source in each equation. Using the coefficient estimates of expenditure and prices, we estimated expenditure and price elasticities of demand using the following formulas (Berck et al., 1997, Taljaard, 2003, Chambwera, 2004).

Own price elasticity of demand: $\in_{FF} = -1 + \frac{\gamma_{FF}}{W_F} - \beta_F$ ______________________________ (17)

Cross-price elasticity of demand: $\in_{Fj} = \frac{\gamma_{Fj}}{\overline{K}_F} - \frac{\beta_F \overline{K}_j}{\overline{W}_F}$ ______________________________ (18)

Expenditure elasticity of demand: $\in_{Fm} = 1 + \frac{\beta_F}{W_F}$ ______________________________ (19)

Integrated expenditure elasticities of demand for each energy source with respect to household total expenditure is computed by multiplying the expenditure elasticity of energy demand from the first stage with the expenditure elasticities of demand from the second stage (Gundimeda and Kohlin, 2008 and Bersisa, 2010). This can be represented by equation as

$\in_{kF} = e_{Em} \cdot \in_{Fm}$ ____ (20)

where $\in_{kF}$ is integrated expenditure elasticity of demand for each energy source, e_{Em} is expenditure elasticity of demand from the first stage estimation, and $\in_{Fm}$ is additional expenditure elasticity of demand for each energy source from the second stage estimation.

4. Results and Discussions

4.1 Descriptive Analysis

Households' in wolkite town consume energy sources such as fuel-wood, charcoal, kerosene and electricity. When the electricity is cutoff, most of households consume candle, some of them use solar energy for lighting, and few of them use animal dung. Fuel-wood is mostly transported via donkey. Therefore, the quantities of fuel-wood consumed is measured by load of a donkey, whereas, the amounts of charcoal the households' used is measured by quintal.

Because of inability to get the monthly amount of electricity usage by households in the town, we examined energy usage pattern depending on expenditure share and the number of households using a given energy source and/or energy-mixes. According to Feyisa (2013), energy usage varies between different income groups. However, households' total expenditure was used as a proxy of income mainly because of their unwillingness to disclose their income. Accordingly, we find out that the monthly average total expenditure was about Br. 2567.2. Consequently, we categorized those with monthly total expenditure of less than Br. 2567.2 as low-expenditure/income households, whereas those with monthly total expenditure of higher than Br. 2567.2 were considered to be high-expenditure households. Accordingly, 55.4 % of them were low-expenditure, while 44.6 % were high-expenditure households.

Table 1: Percentage of households using energy sources for cooking and lighting purpose

Fuel Source	% of total households using energy for cooking
Fuel-wood	0.65
Charcoal	0.75
Kerosene	0.44
Electricity	0.25

Source: Authors' computation of survey data (2017)

4.2 Econometric Analysis: Estimation of Two Stages of Budgeting

4.2.1 Estimation of the First Stage Budgeting

In the current study, energy expenditure share was taken as a function of household total expenditure and other household characteristics, which was stated as Engle curve under the first stage of budgeting. While estimating energy expenditure share by OLS, we faced problems of non-normality and hetroskedasticity. The problem of non-normality predominantly results due to outliers. As a result, we tested the occurance of outliers through the help of standard residuals. Therefore, four observations were identified as outliers and were dropped these observations and we estimated the model again by OLS. As for the problem of heteroscedasticity, we used OLS estimation with robust standard errors. Robust standard errors could be computed to reimburse for an unidentified pattern of non-constant error variance, and give more accurate p-values.

Table 2: Estimation of LA/AIDS from 1st and 2nd Stages of Budgeting (N=256)

	1st stage	2nd stage[1]				
	Wee (OLS)	KCON (Probit)	LA/AIDS estimation			
			Fuel-wood^^	Charcoal^^	Kerosene^^	Electricity^^
Price of Fuel-wood^	NA	3.71*** (0.87)	-0.43*** (0.04)	-0.03 (0.03)	0.01 (0.01)	-0.02 (0.02)
Price of Charcoal^	NA	1.01** (0.45)	0.01 (0.03)	-0.39*** (0.02)	-0.01 (0.01)	-0.05*** (0.01)
Price of Electricit^	NA	-0.56** (0.29)	0.05* (0.03)	0.01 (0.02)	-0.01*** (0.00)	-0.28*** (0.01)
Price of Kerosene^	NA	1.30*** (0.24)	-0.02 (0.02)	-0.02 (0.01)	-0.00 (0.00)	-0.00 (0.00)
Total Energy Expenditure^[2]	NA	NA	-0.11*** (0.04)	0.15*** (0.03)	-0.04*** (0.01)	-0.15*** (0.01)
SEX (male = 1)	0.00 (0.01)	0.85*** (0.24)	-0.07*** (0.02)	-0.04*** (0.01)	-0.01 (0.00)	-0.00 (0.00)
Age of Household head	0.00* (0.00)	-0.02 (0 .02)	0.00 (0.00)	0.00 (0.00)	0.00*** (0.00)	-0.00 (0.00)
Education of the head in years	0.00 (0.00)	0.11** (0.06)	-0.01** (0.00)	0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)
Employment status (employed = 1)	0.02** (0.01)	-0.10 (0.24)	-0.00 (0.02)	-0.00 (0.01)	0.00 (0.00)	-0.00 (0.01)
Family Size	0.01** (0.00)	0.35** (0.15)	0.02* (0.01)	-0.01 (0.01)	0.00** (0.00)	-0.00 (0.00)
Residence type (private = 1)	-0.00 (0.01)	0.04 (0.21)	0.04*** (0.01)	0.00 (0.01)	0.00 (0.01)	0.01*** (0.00)
Refrigerator Ownership	-0.00 (0.01)	0.00 (0.25)	-0.02 (0.02)	0.02 (0.01)	0.02 (0.01)	0.00 (0.01)
Education of the spouse	0.00 (0.00)	-0.01 (0.04)	-0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)
Millskerosene	NA	NA	NA	NA	0.04*** (0.00)	NA
Constant	0.69*** (0.04)	-8.22* (4.47)	1.45*** (0.32)	1.61* (0.25)	0.22*** (0.06)	1.47*** (0.13)
R2	0.704	NA	0.58	0.59	0.67	0.80
Chi2	NA	NA	362.04	378.27	520.39	1068.51
Wald chi2(13)	NA	120.98	NA	NA	NA	NA
Pseudo R2	NA	0.47	NA	NA	NA	NA

Note: (1) Values in the parentheses represent robust standard errors, and ***, **, and * represent significance at 1%, 5% and 10%, respectively. *Note: (2) ^ shows that the variable is in its natural logarithmic form;* ^^ shows that the variable is expressed as total expenditure share

Table 2 dipicts that the coefficients of age, employment status (if employed by government), and family size of the household positively affected the expenditure share of energy (Wee) at significant levels of 10%, 5%, and 5% respectively. The total expenditure deflated by household price index negatively affected households' expenditure share of energy at 1% significance level. The signs of coefficients of total expenditure and family size confirm the hypothesized signs. The expenditure share of energy decreases as household total expenditure goes up. This result confirms earlier findings that the poor spend higher shares of their budgets on the energy than the rich do (Chambwera and Folmer, 2007; Gundimeda and Kohlin, 2008, Feyisa, 2013).

Furthermore, the expenditure elasticity of energy demand computed from the estimation of first stage of budget allocation is about 0.03, indicating energy is a necessity good for households of Wolkite town. This implies that as households' total expenditure increases by 1%, energy budget share increases by about 0.03%. The share of energy expenditure (Wee) is affected positively by household's family size. Expenditure share of energy increases as family size increases. The share of energy expenditure is also influenced positively by

[1] KCON =1 if the respondent uses kerosene; KCON =0,otherwise
[2] The variable is deflated by regional consumer price index

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employment status (if the household is employed by the government) at 5% significance level. This is because as households become employed, their income could increase, and as a result the budget allocation for energy expenditure increases.

4.2.2 Estimation of the Second Stage of Budgeting

The second stage of budgeting concerns the allocation of household total energy budget to each energy source (fuel-wood, charcoal, kerosene and electricity). In this case, we do have budget share equations which are determined by factors such as household total energy expenditure, relative prices of the energy sources and other household characteristics.

The equations are stated by applying the Linear Approximated Almost Ideal Demand System model (LA/AIDS). Hence, the budget shares of this energy sources in household total energy expenditure are the dependent variables of the model. We are encountered with substantial zero values of budget share of kerosene for which most of the respondents do not consume it. As a result, to solve for this sample selection bias, we estimated decision to consume kerosene, (represented by KCON=1, if household consume kerosene, and 0 otherwise) by probit model prior to application of LA/AIDS.

We can see from Table 2 that prices of all energy sources, family size, years of education, and sex of the household (if male) significantly affect the probability of consuming kerosene (KCON). Hence, except for the coefficient of price of electricity which is negetive, all significant factors positively affect consumption choice or decision of to use kerosene.While sex (if the respondent is male), prices of fuel-wood and kerosene affect consumption decision of kerosene at 1%, prices of charcoal and electricity, household education years and family size affect at 5% significance levels.

After the estimation of the decision to consume kerosene, the next step is the estimation of the decision of how much energy budget is to be allocated to each energy sources. The inverse Mill's ratio generated from the estimation of probit model was found to be statistically significant (signaling sample selection problem). As a result, the inverse Mill's ratio, as independent variable was included in kerosene demand equation, in both OLS regression (estimation of demand for each energy source), and LA/AIDS (by ISUR) estimation. In the estimation of demand for each energy by ISUR, we implemented the homogeneity and symmetry restrictions so that the estimates of parameters fulfill theoretical restrictions. The sum of the expenditure shares of energy sources $(\mathrm{Wfc} + \mathrm{Wch} + \mathrm{Wk} + \mathrm{Wel}) = 1$.

As a result of all equations in a system consequences in singular error matrix, the common solution could be excluding the arbitrary equation and then estimating the remaining equations (Takada et al., 1995). Therefore, we excluded kerosene demand equation from the system and the coefficients of kerosene demand equation were set free of homogeneity and symmetry restrictions. The coefficients of kerosene demand equation were in turn obtained by dropping any of the other demand equations and making the coefficients of the dropped equation free from the restrictions. Iterative SUR estimates of parameters do not vary irrespective of which equation is was dropped. Therefore, it does not share the problems of heteroscedasticity and serial correlation. The ISUR estimators utilize the information within equations and the relation between the equations is presented in the correlation of errors of equations. Hence, they are more efficient than single equation estimation methods such as ordinary least squares.

4.2.3 Determinants of Household Energy Demand

Distinguishing factors that significantly affect demand for energy source is very important for policy making to address problems associated with use of fuel-wood and charcoal. In line with this, we discuss variables that significantly influence expenditure share of one or more of the considered energy sources from Table 2. Hence, except price of kerosene, the expenditure shares of all energy sources are negatively affected by their own price. Cross price relations from our result show that there exist both energy substitution and complementarity in the study area. This is resulted for the fact that some households use energy interchangeably (substitutability) some of them use simultaneously (complementarity).

Consistent with our expectation, as total energy expenditure increases, shares of expenditure for fuel-wood and charcoal decrease, while that of kerosene and electricity increase. But, our result shows that for all energy sources, the coefficient of deflated total energy expenditure is negative and significant at 1%. The result is inconsistent with what we hypothesized. This finding is contrary to the finding of Feyisa (2013) who argues that electricity and kerosene are positively, but fuel-wood and charcoal are negatively related with total energy expenditure. Our finding reveals that as total energy expenditure increases, expenditure shares of all energy sources decrease. This could be because households use kerosene and electricity to fire fuel-wood and charcoal. This indicates not only substitutability, but also energy sources do share behavior of complementarity in the study area.

Therefore, since complementarity between energy sources exists, as the expenditure shares of fuel-wood and charcoal decrease, expenditure shares of kerosene and electricity also decrease. This is why the coefficients of total energy expenditure are negative for expenditure shares of all energy sources. As expected male-headed households demand less of fuel-wood and charcoal, and more of kerosene and electricity as compared to female-

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headed households. Our result shows that the coefficient of sex of the household (if male) negatively affects expenditure shares of fuel-wood and charcoal at 1% significance level. The direction or sign of the effect is consistent with our hypothesis. Consistent with our expectation, we also find that as age of the household head increases, household demand more of fuel-wood and charcoal and less of kerosene and electricity. This is because elder household heads use fuel-wood and charcoal to warm rooms more than young household heads do. However, our finding shows that household's age only affects the expenditure share of kerosene positively at 5% significance level. The sign of the coefficient also goes contrary to what we expected. This is because as compared to fuel-wood and charcoal, kerosene is easily available (the cheapest) and less time consuming.

Furthermore, we found that household years of education negatively affect demand for fuel-wood at 5% significance level. This is because literate respondents may have better understanding of disadvantages of using traditional energy, so that they cut the demand for fuel-wood and incline to use modern energy sources, which are clean and environment friendly. This finding is consistent with finding by Heltberg (2003).

Contrary to our expectation, our finding shows that the coefficient of family size positively affects expenditure shares of fuel-wood and kerosene at 10% and 5% significance levels respectively. This means that, as family size increases, demand for both fuel-wood and kerosene increases. This could be due to the fact that for larger families, cooking frequency is very high; as a result fuel-wood is preferred. But at the time of urgency and shortage of supply of fuel-wood, households also use kerosene.

We expected that the expenditure share of electricity is on average higher for residents of private houses as compared to those in public houses, while the reverse was hypothesized for the other energy sources. . Consistent with our expectation, we found that this variable had a positive association with expenditure shares for fuel-wood and electricity, which was significant at the 1% level.

4.3 Elasticities of Demand

For formulation of policy related to energy, the importance of price and income elasticities of demand for energy sources is very important. Hence, we calculated price and expenditure elasticity of demand for each energy source using the coefficient estimates of price and expenditure obtained by ISUR estimation and average expenditure shares of energy sources.

4.3.1 Expenditure Elasticities of Demand for Energy Sources

Table 3: Expenditure Elasticity of Demand from the 2nd Stage of Budgeting

Energy Sources	Expenditure elasticities
Fuel-wood	0.5
Charcoal	0.04
Kerosene	0.01
Electricity	0.13

Source: Own calculation from survey data (2017)

Table 3 reveals that expenditure elasticity is positive for all energy sources, indicating no energy source is an inferior good for households in Wolkite town. This is consistent with the finding of Kebede et al (2002) and Faye (2002) who argues the budget elasticity is positive for energy sources. This indicates that as household's energy budget rises, they use multiple energy sources. It also shows that households in the study area diversify sources of energy (supporting fuel stacking hypothesis), instead of switching to other sources (supporting energy stacking hypothesis) which is an important finding of the study. As for Gundimeda and Kohlin (2008), Bersisa (2010), and Feyisa (2013) integrated expenditure elasticities of demand is calculated by multiplying the expenditure elasticity of demand from the first stage with the conditional expenditure elasticities of demand in the second stage of budgeting.

Table 4: Integrated Expenditure Elasticity of Demand for Energy Sources

Energy Sources	Expenditure elasticity of demand from the 1st stage of budgeting	Expenditure elasticity of demand from the 2nd stage of budgeting	Integrated Elasticity of demand
Fuel-wood	0.03	0.5	0.015
Charcoal	0.03	0.04	0.0012
Kerosene	0.03	0.01	0.07
Electricity	0.03	0.13	0.004

Source: Own calculation from survey data (2017)

All integrated expenditure elasticities of demand are positive and less than one, indicating that all energy sources (fuel-wood, charcoal, kerosene and electricity) are necessities. It also shows the inapplicability of energy ladder hypothesis.

4.3.2 Own-Price and Cross-Price Elasticities of Demand

Table 5: Own Price and Cross-Price Elasticity of Demand from 2nd Stage of Budgeting

	Fuel-wood	Charcoal	Kerosene	Electricity
Price of Fuel-wood	-1.74	0.01	0.42	0.06
Price of Charcoal	0.12	-2.25	-0.05	-0.11
Price of Kerosene	-0.06	-0.1	-0.1	0.03
Price Electricity	0.3	0.25	0.2	-1.41

Source: Own calculation from survey data (2017)

As can be seen from Table 5, all own-price elasticities of demand are negative and price-inelastic; which means that as price of energy source increases, the demand for that particular energy source decrease. In addition, own price elasticity of fuel-wood and charcoal are among the highest. This shows that these energy sources are highly sensitive to changes in their own prices. It should be noted that most of the findings of earlier studies concluded that energy sources are substitutes to each other.

However, we find that some of the cross-price elasticities of demand are positive, and some are negative. While the positive cross-price elasticity of demand revealed that energy sources are substitutes for each other, the negative cross-price elasticities of demand shows that energy sources are complementary to each other. For substitute energy sources, the increase in price of a particular energy source leads to the increase in demand for other energy source. On the other hand, complementarity of sources of energy occurred due to the fact that some of the households in the study area used kerosene and electricity to fire charcoal and fuel-wood. Our result is consistent with Bersisa (2010) which he identified cross-price elasticities of demand for some energy sources are positive (complementarity of energy sources) and some are negative (substitutability of energy sources). But, Mebratu N. (2013) has founded that all cross-price elasticities are positive revealing that all energy sources are substitute for each other which is inconsistent with our result.

5. CONCLUSION

As witnessed by this study, none of households consume traditional energy sources solely. This is because they switched to the consumption of energy-mix (traditional and modern energies) and modern energy sources. However, most of the users of energy-mix use electricity for lighting, and fuel-wood and charcoal for cooking purposes. The consumption of fuel-wood and charcoal have health and environmental problems. Hence as a solution to these problems, we drew policy implications as follow. First, making modern energy sources (kerosene and electricity) easily accessible, adequate and reliable is of paramount importance. Second, since household characteristics significantly influence household energy demand system, energy related policies should address micro level issues. Third, incorporating environmental costs attributable to residential consumption of fuel-wood and charcoal in the energy planning process, and imposing environmental tax equivalent to the costs is essential.

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