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Does the Pattern of Energy Use in Ethiopia Follow Fuel Stacking Hypothesis in Woliso Town?

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Abstract

This study analyzed whether pattern of fuel use follow the fuel stacking hypothesis and factors that affect household fuel use in Woliso town by using cross-sectional data of 2018 for different sources of energy using the Linear Approximation Almost Ideal Demand System (LAAIDS). An estimate of the model is constrained to comply with neoclassical theoretical restrictions on demand, and the model is estimated using Iterative Seemingly Unrelated Regression (ISUR). The result shows that households do not completely switch to consumption of new energies as the energy ladder hypothesis suggests rather diversify their energy consumption in a process of fuel stacking (energy mix). Additionally, the expenditure elasticity's of demand for energies are expenditure elastic. Not only this, but also, the cross-price elasticity's of demand for energy sources indicate that there exist energy substitution and complementarity in the study area. Furthermore, we identified prices of all energy sources (except kerosene), household total energy expenditure, and years of education, family size, and residence type as the main determinants of expenditure share of energy sources. We recommend making modern fuels easily accessible, affecting significant factors of household fuel use, environmental related rules and regulations very essential.

Keywords: Energy mix • Energy ladder • Cross price elasticity of demand • Iterative seemingly unrelated regression • Expenditure

Introduction

Household energy consumption refers to the quantity of energy resources consumed by households on several appliances. Energy occupies one of the most essential features of human life. 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. There is a challenge of supplying modern fuel to household to avoid various health risks caused by the use of traditional fuel and to deal with the challenges resulted by climate change. Household fuel choices could follow either the energy ladder or fuel mix hypotheses and are determined by a wide range of socio-economic factors. In Ethiopia, more than 67 million people depend on biomass energy to meet their cooking, heating, lighting and hygiene needs. This shows the heavy reliance 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. The rising prices of modern fuels such as Liquefied Petroleum Gas (LPG) and electricity and their erratic supply have made many households revert to the use of traditional fuels:Such as firewood and charcoal. Generally, in Ethiopia very few studies confirm that households follow the fuel stacking hypothesis instead of energy ladder to fulfill their energy demand. Therefore, this study attempted to analyze whether the pattern of fuel use follow the fuel stacking hypothesis as well as how socio-economic variables affect household's fundamental energy use in Woliso town as there is no comprehensive study so far [1].

Theoretical literature

Energy ladder hypothesis: The energy ladder hypothesis is one of the most common concepts of energy consumption dynamics among households. It hypothesizes that while those households with higher income use modern cooking technology and fuels, low income households consume traditional stoves and cooking fuels like animal dung, charcoal and wood. As income increases, households shift from traditional fuels and cooking stoves to modern fuels and cooking technology. Moreover, households those between low income and high income consume traditional fuels such as charcoal and kerosene. While low income households use biomass fuels, higher income households consume energy that is cleaner and more

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expensive such as liquefied petroleum gas and electricity. The energy ladder hypothesis is predicated on the economic theory of consumer behavior [2]. However, as their income increases, households not only consume more of the same good, they also shift to more sophisticated goods with higher quality. Thus, energy ladder hypothesis theorizes that low living standards encourage greater dependence on traditional fuels. Furthermore, the energy ladder hypothesis postulates that cleaner energies are normal economic goods while traditional energy sources are inferior goods. The energy-ladder hypothesis underlines the role of income in determining energy choices. However, it appears to imply that a move up to a new energy source is concurrently a move away from previously used energy source(s). An energy-demand ladder is proposed where it is argued that, as incomes rise, households' demand for energy source is directed by the nature of appliances used and that fuel choice and demand depends on the purpose for which energy is required.

Energy stacking/energy mix: Nevertheless, the energy ladder theory is criticized 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 energy sources. Furthermore, it has been argued that households in developing countries do not switch to modern energy sources but instead tend to consume a combination of fuels which may include combining solid fuels with non-solid fuels as sources of energy. Thus, instead of moving up the ladder step by step as income rises, households choose different energy sources as from a menu. Based on their budget, choice, and needs, they may choose a combination of high-cost and low-cost energy sources. Multiple energy consumption emanates from many reasons, such as, occasional shortages of modern fuels, instabilities of commercial energy prices. The complexity of energy switching process hence proposes that there is a multiplicity of determinants, in addition to income, which could influence energy consumption. This managed some authors to research in to more sophisticated modeling approaches [3].

Empirical literature

From the investigation of household energy consumption patterns of urban, rural and estate sectors in Sri Lanka, the energy ladder hypothesis holds for the country as a whole moving towards modern fuels such as Liquefied Petroleum Gas (LPG) and electricity. From the study of the determinants of household fuel choice and demand in major Ethiopian cities, it is found that widespread use of multiple fuels for a particular purpose (such as cooking) suggestive of fuel stacking rather than energy ladder. The evidences show that higher kerosene prices made households choose either solid fuels (charcoal and wood) only or a mix of solid and non-solid fuels (wood, charcoal, kerosene and electricity). Access to more efficient energy sources implies high level of energy consumption associated with enhanced level of energy use which will generate other benefits such as improved indoor air quality, more time for productive or recreational activities and time freed from collecting biomass energy. Tajikistan suffered from acute case of energy poverty where people lacked both physical access to energy and the ability to afford it. The study recommended that a provision of three kilowatts per household for the most vulnerable group would result in significant benefits that would show not only in the relief for the energy poverty stricken households but which would show in the overall poverty alleviation for the country [4].

Furthermore, the household sector accounts for 15% to 25% of primary energy use in developed countries and a higher share in developing countries. A huge gap remains between household energy use in developed and developing countries. Increase in energy-based living standards and more efficient energy use are major opposing trends in developed countries that affect household energy consumption. The uses of both traditional and modern sources improve household consumption and income; the return on modern sources is 20 to 25 times higher than that on traditional sources. In addition, after comparing alternate measures of the energy poverty line, they observed that some per cent of rural households in Bangladesh were energy poor compared to 45% that were income poor. The findings implied that growth in electrification and adoption of efficient cooking stoves for biomass use can lower energy poverty in a climate-friendly way by reducing carbon dioxide emissions. The result from the descriptive statistics from the household survey carried out China shows the general dependence of households upon forest resources. The study observed from the probity model that income is a key factor in explaining energy use and fuel substitution. The analysis also shows the importance of own-price effect in explaining firewood consumption behavior. Modernization in the form of increasing education or family network is also found to be a key factor in the energy consumption behavior.

The analysis of urban household energy preferences for cooking in Ouagado through the multinomial legit model indicates that the utilization rates of firewood decrease from low income households to households with higher incomes. The marginal effect of "primary education level" is significant at one per cent level and with positive sign: when this variable changes from higher education level to primary education, the probability of using firewood as main cooking energy increases by 0.6%. The household size, cooking habits and formal education level of household heads have significant effects on wood energy preferences. Moreover, 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. The analysis of energy demand in urban Ethiopia, Tigray region using probity and AIDS models 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.

Furthermore, the study of energy demand for urban Ethiopia 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. From the multivariate probity model analysis, he 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. 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. In identifying the determinants of household fuel choice in major cities of Ethiopia by utilizing a multinomial logic model, it is 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 [5].

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). 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. 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.

Materials and Methods

The objective of the study is to analyze whether the pattern of energy use follow the energy ladder hypothesis as well as how socio-economic variables affect household energy use (fuel wood, kerosene, Liquefied Petroleum Gas (LPG), or electricity) for cooking and lighting activities in the study area. This study used both primary and secondary data. It relied mainly on the primary cross-sectional data of 2018. 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 Woliso town obtained from South West Shoa Zone administration office.

Results and Discussion

Descriptive analysis

Households' in Woliso 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/energy-mixes. However, households' total expenditure was used as a proxy of income mainly because of their unwillingness to disclose their income. Accordingly, 59% of them were low-expenditure, while 4% 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 (using electricity for both cooking and lighting)
Fuel-wood	0.69
Charcoal	0.6
Kerosene	0.42
Electricity	1

Econometric analysis

In the current study, energy expenditure share was taken as a function of household total expenditure and other household characteristics, which was stated as angle 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 occurrences of outliers through the help of standard residuals. Therefore, three observations were identified as outliers and we dropped these observations and estimated the model again by OLS. As for the problem of hetroskedasticity, 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. The sign of coefficient of total expenditure confirms the hypothesized sign. Hence, 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. However, the sign of coefficient of family size of the household failed to confirm the hypothesized sign. This could emanate from dominant consuming of fuel wood in the town. Moreover, households as their family members increase, they tend to consume less energy (fuel wood) and tend to shift to the cleaner energy as it provide the fastest service. Furthermore, the expenditure elasticity of energy demand computed from the estimation of first stage of budget allocation is about 0.7, indicating energy is a necessity good for households of Woliso town. This implies that as households' total expenditure increases by 1%, energy budget share increases by about 0.7%.

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 (LAAIDS). 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 probity model prior to application of LAAIDS.

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. 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). Hence, contrary to the energy ladder, this finding supports the existence of energy-mix hypothesis in the study area. As total energy expenditure increases, shares of expenditure for fuel-wood and charcoal increase (positive coefficients), while that of kerosene and electricity decrease (negative coefficients). This could be because households use kerosene and electricity to fire fuel-wood and charcoal. It also indicates not only substitutability, but also energy sources do share behavior of complementarity in the study area. This finding is contrary to the finding of who argues that electricity and kerosene are positively, but fuel-wood and charcoal are negatively related with total energy expenditure [6].

Elasticity's of demand

For formulation of policy related to energy, the importance of price and income elasticity's 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 (Table 2).

Table 2. Expenditure elasticity of demand from the 2nd stage of budgeting.

Energy sources	Expenditure elasticity's
Charcoal	0.0374
Electricity	0.1321
Fuel-wood	0.4867
Kerosene	0.0113

Expenditure elasticity is positive for all energy sources, indicating no energy source is an inferior good for households in Woliso town. This is consistent with the finding of who argue 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 which is an important finding of the study. As for integrated expenditure elasticity of demand is calculated by multiplying the expenditure elasticity's of demand from the first stage with the conditional expenditure elasticity's of demand in the second stage of budgeting in Table 2.

However, we find that some of the cross-price elasticity's 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 elasticity's 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 which he identified cross-price elasticity's of demand for some energy sources are positive (complementarity of energy sources) and some are negative (substitutability of energy sources). But founded that all cross-price elasticity's are positive revealing that all energy sources are substitute for each other which is inconsistent with our result [7,8].

Conclusion

In Ethiopia, more than 67 million people depend on biomass energy to meet their cooking, heating, lighting and hygiene needs. This shows the heavy reliance on traditional energy sources resulting in energy scarcity. There is a challenge of supplying modern fuel to household to avoid various health risks caused by the use of traditional fuel and to deal with the challenges resulted by climate change. Household fuel choices could follow either the energy ladder or fuel mix hypotheses and are determined by a wide range of socio-economic factors. Most studies in Ethiopia witnessed that households follow the energy ladder hypothesis to fulfill their energy demand instead of fuel stacking (energy mix). Hence, this study attempted to analyze whether the pattern of energy use follow the energy ladder hypothesis as well as how socio-economic variables affect household's fundamental energy use (cooking and lighting activities) in Woliso town as there is no comprehensive study so far. From the analysis, it is found that households in the study area follow the energy stacking hypothesis which they diversify fuel consumption to fulfill their energy demand. Moreover, households are highly dependent on consumption of traditional fuels (fuel-wood and charcoal) which could have an implication on the environment, forests. Furthermore, prices of all energy sources (except kerosene), household total energy expenditure years of education, family size, and residence type are the main socio-economic determinants of expenditure share of energy sources in the study area. Therefore, the study recommends making modern fuels easily accessible, giving attention to significant factors of household fuel use, incorporating environmental related rules and regulations to help enhance a switch to modern fuel sources are fundamental.

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