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ANALYSIS OF ELASTICITIES OF HOUSEHOLD FUEL TYPES IN THE NORTHEASTERN REGION OF NIGERIA

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ABSTRACT

Demand for fuel types relies on how low their prices are and the household income. This study used secondary data obtained from the Nigerian Bureau of Statistics General Household Survey (2021) to analyze household fuel demand sources in the North-East Zone of Nigeria. The study used the AIDS model. The results showed that all energy sources except kerosene were comfort goods (elasticities = 1). Kerosene was found to be a necessity (elasticity < 1). This means that households will demand more kerosene if its price falls, but they will demand significantly less kerosene if its price rises. All energy sources were also price elastic (elasticities = 1). This means that households will demand less energy if its price rises, and vice versa. Finally, the results showed that all energy sources had a complementary relationship (negative elasticities). This means that if the price of one fuel type rises households will demand more of other fuel sources. The study recommends that there should be Investment in grid expansion, LPG subsidies, and awareness campaigns for clean energy adoption by the relevant stakeholders which includes government, private, non-governmental organizations, development partners and civic society organizations.

INTRODUCTION

The term energy refers to the use of chemical resources to provide power or light for cooking, space heating, cooling, ironing, and other purposes. Household fuel demand is the total amount of energy purchased and used by households for these purposes. Energy demand is essential for household welfare, public investments, and environmental considerations. Efficient exploitation and development of a nation's energy resources are crucial for its progress and the well-being of its people. The household sector accounts for about 36% of global energy use, with 80% of that used for primary energy use in developed countries. Developing countries use a higher share of household energy, but the average per capita household energy use in developed countries is about nine times higher than in developing countries.

In Nigeria, despite having huge reserves of both renewable and non-renewable energy resources, inadequate development and inefficient management of the energy sector have led to a supply-demand gap and consequently high solid fuel demand among households. In Nigeria, about 86% of rural households depend on fuelwood as their primary energy source. This is due to a lack of electricity supply and limited access to conventional energy such as petroleum products due to poor road networks. Petroleum products such as kerosene and gasoline are also sold at very high prices in rural areas.

Low-income households in urban areas also rely on biomass fuels, such as wood and dung, due to fuelwood supply/demand imbalance in some parts of the country. In the northern part of Nigeria, charcoal is widely used for cooking, space heating, ironing clothes, and heating pieces of local scent sticks used as room air fresheners. Due to the unreliable electricity supply in Nigeria, many households have switched to alternative energy sources such as power-generating plants. However, there is little empirical research on household expenditure on these alternative energy sources, especially fossil fuels.

This study seeks to empirically analyze household fuel demand in the North-East region of Nigeria. It specifically, seeks to determine the expenditure, own-price, and cross-price elasticity of demand for electricity, charcoal, fuelwood, and kerosene. The study is necessary because previous studies on household energy demand in Nigeria have had several shortcomings. For example, some studies have focused on specific fuels or regions, while others have not considered all the relevant factors that influence household energy demand. The study utilizes secondary data from the Nigerian Bureau of Statistics General Household Survey (2020). The study employed the Almost Ideal Demand System (AIDS) model. The findings are expected to provide valuable insights into household energy demand in the North-East region of Nigeria. This information can be used to develop policies and programs that improve energy access and affordability for households in the region.

METHODOLOGY

Study Area

The study was conducted in the North-East Zone of Nigeria, which is located between 6°25′ and 13°43′ north latitude and 8°35′ and 14°39′ east longitude. It has a total land area of 923,773 square kilo meters and is made up of six states: Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe. The combined population of the zone was 18,832,995 in 2006 and was projected to reach approximately 30116350.32 by 2021.

Data Type and Variables

This study relied on secondary data sourced from the National Bureau of Statistics (NBS) General Household Survey, Panel 2020-2021.

Specifically, data was extracted from 907 households located in the north eastern region. The survey encompassed a range of crucial information, including details on household socio-economic attributes, data regarding agricultural and non-agricultural enterprises, income-generating activities, expenses related to food consumption, and various non-food expenditures (NBS, 2021). This research focused on five distinct independent variables, as outlined in Table 1, which delineates the measurement criteria for each variable.

Table 1 shows the measurement of variables.

Variables	Measurement
Fuel source demand	Is measured by the quantity of fuel used by a particular household measured in kg.
Household monthly income	Household Monthly income is proxied by total household monthly expenditure.
Household size	The variable is measured as the total number of individuals dwelling in the same house and sharing meals.
Age	This variable is measured in years as the total number of years since the person was born.
Sex	The sex of the respondent is a binary variable representing a value of 1 for males and 0 for females.
Area of residence	This is also a dummy variable representing 1 for urban and 2 for rural.

Source: The Author.

Model Specification and Method of Estimation

a. Almost Ideal Demand System Model (AIDS)

The AIDS model was employed following Ogunniyi, Adepoju and Olapade-Ogunwole (2012) to estimate the budget share of the various energy sources used by households. The AIDS model is a flexible and well-behaved model for estimating demand functions. It has several advantages over other models, such as the linear expenditure system (LES) and the quadratic demand system (QDS). For example, the AIDS model can account for substitution and complementary relationships between goods, and it does not impose any restrictions on the income and price elasticities of demand. The equation is expressed as:

$$W_i = \alpha_i + \sum \gamma_{ij} \log P_{jt} + \beta_i \log (X/P) \qquad \text{(Equation 1)}$$

where,

W_i = The i^{th} budget share

X = Total expenditure

α_i = intercept and represents average budget share when all logarithm prices and real expenditures are equal to one (1)

γ_{ij} = $(\delta w_i / \delta \log p)$ it equals to price coefficient, change in i^{th} budget share with respect to change in j^{th} price with expenditure held constant.

β_i = $\delta w_i / \delta \log X/P$ is equal to expenditure coefficients, change in the i^{th} budget share corresponding to a percentage change in real expenditure with all prices held constant. If β_i = + is a luxury, if β_i = - is necessities

P_j = Price of j^{th} item

P = Consumer Price Index

The coefficients estimated from the AIDS model were used to calculate the expenditure, own-price, and cross-price elasticities of demand for the various household energy sources. The expenditure elasticity of demand measures how much the quantity of energy source *i* demanded changes when total household expenditure changes. The following equation was used to calculate the expenditure elasticity:

$$E_i = 1 + \beta_i / W_i \qquad \text{(Equation 2)}$$

Where,

E_i = expenditure elasticity of fuel type item *i*

B_i = Expenditure coefficient of fuel type item *i*

W_i = Budget share of fuel type item *i*

To obtain the own-price elasticity which measures how much the quantity of energy source *i* demanded changes when its own price changes., the estimated expenditure elasticity and the coefficients estimated in equation (2) above were substituted into the Marshallian Price elasticity equation. The equation is specified as follows: -

$$e^{m}_{ij} = \Upsilon_{ij} - \beta_i w_j / w_i - \delta_{ij} / w_i \qquad \text{(Equation 3)}$$

where,

β_i = expenditure coefficient of fuel type item *i*

w_i = budget share of fuel type item *i*

w_j = budget share of fuel type item *j*

$\delta_{ij} = 1$, when i = j, otherwise $\delta_{ij} = 0$

The cross-price elasticity of demand measures how much the quantity of energy source *i* demanded changes when the price of another energy source, *j*, changes. Thus, the Hicksian price elasticity will also be computed using Slutsky's equation given as,

$$e^{h}_{ij} = e^{m}_{ij} + w_j e_i \qquad \text{(Equation 4)}$$

where,

e^{h}_{ij} = Hicksian price elasticity

e^{m}_{ij} = Marshallian price elasticity

w_j = budget share of fuel types item j

e_i = expenditure elasticity of fuel types i

w_j = budget share of fuel types item j

*A priori expectation***.**

The price elasticity of demand for fuel sources is expected to vary depending on the type of fuel type. The demand for electricity is expected to be price elastic while the demand for other fuel sources, such as charcoal, fuelwood, and kerosene, is expected to be price inelastic. This is because these energy sources are often essential for cooking and other basic needs.

The demand for fuel types is also expected to be income elastic. However, the demand for electricity is expected to be more income elastic than the demand for other energy sources. This is because electricity is used for a wider range of purposes, such as lighting, air conditioning, and refrigeration. While the cross-price elasticities between electricity and other energy sources are expected to be positive.

FINDINGS

Expenditure, Price and Cross-Price Elasticities of Energy Demand

The estimated parameters of the AIDS model for the fuel types considered for the households in the North-east region which includes expenditure elasticities, price elasticities, and cross-price elasticities, are detailed in Table 2. The model was computed using the SAS statistical software package.

Table 2 shows the Non-Linear AIDS Regression Parameters Estimates of Meat Demand System

Variable		Budget Share			Expenditure Elasticity			Own price
Charcoal		-0.031			1.003			-1.100
Electricity		0.289			0.999			-0.999
Fuelwood		0.360			0.998			-1.001
Kerosene/charcoal		0.070			0.886			-1.052
LPG		0.304			0.998			-0.999
Cross-price	Charcoal		Electricity	Fuelwood		Kerosene	LPG	
Charcoal	1.000							
Electricity	-0.810		1.000					
Fuelwood	-0.739		-0.639	1.000				
Kerosene	-7.028		-0.741	-0.678		1.000		
LPG	-0.795		-0.728	-0.638		-0.728	1.000	

Source: Generated by Stata 13 from the author's data

Expenditure Elasticity of Demand

Expenditure elasticities for all the fuel types considered were positive, ranging from 0.886 to 1.003. This signifies that all the energy sources examined in this study are categorized as normal goods, aligning with previous research findings (Authur *et al,* 2012). Furthermore, it implies that as income increases, the demand for these energy sources also rises. Notably, all the expenditure elasticities approximated to one (1), except for kerosene. This suggests that all energy sources are comfort goods. However, kerosene exhibited a lower elasticity, less than unity (0.886), indicating its status as a necessity for the residents of the North-east region of Nigeria, consistent with prior research (Kebede *et al*, 2012). Additionally, the expenditure elasticity of electricity being equal to one aligns with the a priori expectation of it being income elastic, whereas the elasticities equal to one (1) for the other energy sources contradict this expectation, as they were anticipated to be income inelastic.

These findings suggest that for energy sources with elasticity equal to one (1), consumers allocate the same proportion of their income to all these sources as their incomes increase. This phenomenon is likely because such sources, being comfort goods, are essential and are consumed habitually. Consequently, changes in income result in a proportional change in expenditure.

Another explanation for this outcome is the multifaceted utility of these energy sources. For instance, electricity serves various purposes, such as lighting homes, cooking, space heating, and ironing clothes. LPG is recently used for cooking and lately, as a smart energy solution, it is used in power-generators as a substitute for petrol, while firewood is used for cooking, heating, and charcoal production. Consequently, an increase in tariffs or prices may lead to a prioritization of essential uses.

However, the expenditure elasticity for charcoal is somewhat higher, possibly due to its widespread use in the study area for room air freshening through local scent sticks. It is also utilized for cooking, space heating during the harmattan season, and ironing clothes, primarily due to inconsistent electricity supply.

Conversely, the expenditure elasticity of kerosene, being less than one, underscores its status as a necessity. While it is a normal good and its demand rises with increased income, the rise is proportionally lower. Consequently, the share of expenditure allocated to kerosene diminishes as income increases. This can be justified by kerosene's advantages, such as emitting fewer fumes compared to firewood, long-term storage safety, and its utility as a lighting source in oil lamps. Moreover, it serves as a backup fuel for households using LPG in case their gas supply unexpectedly depletes and as a lighting fuel for wood-based lamps.

Own-Price Elasticity of Energy Demand

The findings presented in Table 3.1 reveal that all uncompensated price elasticities were negative, spanning from -0.999 to -1.100. Moreover, all coefficients indicated that all the fuel types exhibited price elasticity, aligning with the findings of (Maina, 2018). This also corresponds with the a priori expectation for "dirty" fuel types but contrasts with expectations for "clean" fuel types. Initially, it was anticipated that the price elasticities of demand for dirty fuels would be elastic, while those for clean energy would be inelastic.

From the results, it becomes evident that charcoal is the most responsive to its own price. This can be explained based on its expenditure elasticity, which was the highest (1.003). This aligns with the theoretical notion that the higher the percentage of a consumer's income allocated to a product, the greater the price elasticity tends to be, or the more responsive it is to its own price. This suggests that people pay close attention to items that consume a larger share of their income, and consequently, higher prices lead to reduced demand. However, the surprising result is that of kerosene, which, despite being categorized as a necessity, is the second most responsive to its own price. This may be due to the degree of its necessity, as reflected in its expenditure elasticity coefficient, which was close to that of a comfort good (0.886). Hence, its status as a necessity is not exceptionally high. Regarding the remaining fuel types, electricity, LPG, and fuel wood exhibit an equal degree of responsiveness to changes in demand due to price fluctuations, with all having an absolute elasticity of one. In general, all the fuel types considered display price elasticity, implying that a 1% increase in their prices would result in a decrease in demand: charcoal by 110%, kerosene by 105%, and electricity, LPG, and firewood by 99% each, respectively.

Cross-Price Elasticity of Energy Demand

The findings reveal that all compensated price elasticities were negative, ranging from -0.639 to -0.810. This indicates the presence of complementarity among all the fuel types, aligning with the findings of Maina *et al,* (2017). This contradicts the a priori expectation, which assumed positive cross-price elasticities between electricity and other fuel types as substitute commodities. Additionally, all the cross-price coefficients were lower than the own-price elasticities in absolute terms and were more inelastic. This implies that changes in the price of a commodity relative to its own price are elastic. The complementarity suggests a strong correlation in the quantities demanded for these fuel types, stemming from their similar functions. Electricity, LPG, and kerosene can all be used for lighting, cooling, or heating homes, while electricity, kerosene, charcoal, and firewood serve purposes in cooking. Electricity and charcoal can also be used for ironing, among other functions. These fuel types act as fallback options for one another rather than substitutes. Some households use fuel wood for cooking items that require longer cooking times, such as cow tail or cow leg, while other items that are quicker to cook are prepared using different fuel types. Moreover, due to intermittent power supply in Nigeria, many households have resorted to using power generators, further illustrating their complementarity.

The negative coefficients can be explained by the high correlation among these fuel types. An increase in crude oil prices, for example, would lead to higher electricity bills due to increased costs for electricity-generating companies. Additionally, rising crude oil prices would elevate the prices of kerosene and LPG, as they are derived from the same source. Fuel wood and charcoal would be affected by increased transportation costs associated with a rise in crude oil prices. Consequently, an increase in crude oil prices would elevate the prices of all energy items and reduce their demand, with the greatest impact on end consumers. Additionally, restrictions or bans on fuel wood exploitation would affect its price and that of charcoal.

Slutsky's Symmetry was both imposed and tested in this analysis. This symmetrical constraint was predicated on the assumption that ($\gamma ij = \gamma ji$), indicating that the compensated cross-price effects between any two goods are equal. Consequently, the vacant columns in Table 2, marked with (1.000), denote the own-price effects or the manifestation of Slutsky's symmetry. This restriction is applicable within and across the equation-constrained parameters (α, β, γ), and it was enforced using the restricted language.

CONCLUSION

This study has revealed that all the energy sources under consideration are categorized as normal and comfort goods, except for kerosene, which is identified as a necessity. However, it is important to note that its degree of necessity is relatively low, as its coefficient almost sums up to that of a comfort good. Additionally, kerosene is not an inferior good, contrary to the characterization presented by the energy ladder model.

In terms of own-price elasticity for all the energy sources, they were found to exhibit elasticity, with charcoal demonstrating the highest responsiveness to changes in its own price. On the other hand, the analysis of cross-price elasticities indicates that there is a complementary relationship among all the energy sources.

RECOMMENDATION

Based on these findings the following recommendations are proffered;

a. The government and private sectors should invest in Infrastructural development to expand the electricity grid to reach remote areas. Ensuring a reliable and stable electricity supply would encourage households to switch to electric cooking. Also, government should subsidize or tax incentives to make electricity to make it more affordable for households, especially in low-income communities.

b. The government should also subsidies LPG by helping to offset the initial cost of purchasing LPG stoves to be more affordable for households, especially in low-income communities.

c. The government, private sector, non-governmental organization, development partners and civil societies should support by launching public awareness campaigns highlighting the benefits of using clean energy for cooking, such as reduced indoor air pollution, improved health outcomes, and environmental conservation. These campaigns can target both urban and rural areas.

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