Demand Analysis for Solid Fuel and Its Substitutes as Domestic Energy in Imo State, Nigeria: Application of Quadratic Almost Ideal Demand System (QUAIDS)

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Research Article

Abstract

Purpose: *This study aims to model the demand analysis for solid fuel and its substitute for domestic cooking energy among households in Imo State.*

Methods*: Data on socio-economic characteristics of the respondents, monthly expenditure on energy used for domestic cooking, unit prices, and quantity of different energy sources were collected using a multi-stage sampling technique from 262 households I Imo State. Data were analyzed using descriptive, quartile distribution and QUAIDS inferential statistics to achieve the objectives of the study.*

Results: *The empirical analysis of the demand for household energy usage revealed that the quadratic expenditure term is statistically significant in firewood, sawdust, and wood-shaving expenditure share equations. It implies that their null hypothesis of expenditure linearity is strongly rejected. Furthermore, the prices and demographics of the household head significantly influence the budget shares of the different energy used. Expenditure elasticity of all the energy sources are elastic. Own price (Marshallian and Hicksian) of firewood, sawdust, and kerosene are price elastic while charcoal and wood-shaving are price inelastic. The Uncompensated Marshallian's cross elasticity of almost all energy sources are complementary. However, the result of the compensated- Hicksian's cross elasticity values indicated that almost all the energy uses are substitutable except for firewood – charcoal, firewood-wood shaving, firewood-kerosene, and sawdust-wood shaving that are complementary.*

Implications: *The result indicates that the timber products and its substitutes demand domestic cooking follow both energy ladder and stacking principles as households can quickly switch to a better energy source at the same time exhibit their dynamism in the ability to combine both traditional and modern fuels to meet their domestic energy needs based on price and affordability. The study, therefore, recommends that younger females in the household should be targeted in demonstrating the demand for cleaner energy using educational facilities and reduction in unit prices of such energy in the area.*

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Key Words: Demand system, solid fuel, QUAIDS, Energy ladder and stacking principles

1. Introduction

In Nigeria, abundant traditional energy resources are comprising mostly biomass resources, such as fuelwood and allied products at one end and transition and/or modern energy sources such as kerosene, liquefied petroleum gas, and electricity at another end, both for domestic cooking usage. Most household cooking involves the use of solid and non-solid fuels, out of which over three billion people, which is about 50% of the world population largely depends on solid fuel energy sources (fuelwood, dung and agricultural residues) and coals to meet their most basic energy needs (Staton and Harding, 2011; Desalu et al. 2012). Heavy reliance on solid fuel is due to the nexus between poverty and energy use patterns in terms of quality and quantity of energy. Generally, a major proportion of poor households use across the rural, peri-urban, and urban areas mostly use forest wood (popularly called firewood) because of its affordability and many could not afford to purchase sophisticated energy equipment such as gas cookers, electric cookers. In addition, 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 (Ogwumike et al., 2014).

The persistent use of solid fuel as household cooking energy is the major cause of forest degradation, and land degradation in Nigeria. According to Sambo (2009), the use of fuelwood for domestic and commercial uses is a chief cause of desertification in the arid-zone and erosion in the southern part of Nigeria. The most worrisome dimension of this study is the increasing percentage of households using solid fuel in Nigeria giving the fact that the demand for cleaner domestic cooking energy has not been empirically analyzed in Nigeria. More than 70%, including 86% of households in rural areas and 42% of households in urban areas and about 94% of Nigerian population were using an open fire/stove without a chimney or hood (Gwatkin et al., 2000 and Desalu et al., 2012). The fact that the indoor pollution and unsafe levels of toxic emission generated from the use of solid fuels as domestic energy is dangerous, unhealthy, and even less cost-effective (Viegi et al., 2004; Desalu et al., 2012). These unhealthy conditions accounted for 1.5 to 2 million deaths per year worldwide, with about 50% of them occurring in children below 5 years. The major health effect is the acute respiratory infections (ARI) and chronic obstructive pulmonary disease (COPD) and lung cancer among women (Naeher et al., 2007; Fullertona et al., 2008 and Ezzati and Kammen, 2002). In addition, Desalu et al., (2010) had linked increased risk of respiratory morbidity and chronic bronchitis with high usage of biomass fuels for domestic cooking in South-West, Nigeria. Other health effects include acute respiratory infection, low birth weight, and eye problems in Africa (World Bank, 2006).

Increasing demand for solid fuel for domestic energy does not close the gap created by excess disposable income allocated to budget share on domestic fuel for cooking in most households. The justification for increased domestic energy demand for cooking is expected to be a low budget share for domestic fuel. However, the cost implication of domestic fuel as well as household expenditure and management of chronic respiratory conditions resulting from exposure to indoor pollution in a resource-poor setting is largely over-bearing. Hence concerted efforts need to be geared towards preventive measures against indoor pollution from household fuel. The issue of major concern is that households cannot control the excessive use of solid fuel for domestic energy without knowing the nature of the demand for these commodities in the state has raised a lot of policy debate in Nigeria and the state in particular. Although, in recognition of the adverse effects of the use of timber products as household fuels, the United Nation Millennium Project recommends reducing the number of households that depend on timber products for cooking fuel by 50% in 2015, which implies about 1.3 billion people switching to a cleaner fuel (IEA, 2006). However, this recommendation had not yielded desired results as the rate of consumption of timber-energy (and other biomass fuels) and its attendant negative environmental and health impacts are still alarming. Instead, the consumption of fuelwood which was a rural practice has now gained acceptance in urban areas putting undue pressure on the forest resources.

Efforts at encouraging households to make a substitution to clean and efficient energy sources with less adverse environmental, social, and health impacts have been advocated. More so, several policies have been implemented by public authorities to decrease household wood-energy consumption and to substitute it with alternative conventional fuels. However, there exist serious knowledge gaps about what determines the household demand pattern of timber products in Nigeria, and particularly in Imo State. More importantly, there is a need to encourage households to make fuel substitution that will result in more efficient energy use and less adverse environmental, social, and health impacts. This foregoing necessitated the demand analysis for timber products and substitutes as domestic energy in Imo state: using quadratic almost ideal demand system with specific objectives to describe the socio-economic characteristics of the households and estimate the budget share and model the demand system of timber products and its substitute used in the study area.

2. Literature Review

Two important underlying concepts of household energy demand were the energy ladder and energy stack hypothesis. As illustrated in figure 1 below, the concept of energy ladder hypothesis shares a view that low-income households generally use traditional fuels as their main energy source while higher-income households tend to use modern fuels (Nicolai and Fiona, 2008; Madukwe, 2014), this trend tends to shift from traditional fuels to modern fuels basically when the income of the household increases showing that when income increases households not only consume more of the same good but they also climb the ladder to more modern goods with higher quality i.e. as a household gains socioeconomic status, it ascends the ladder to cleaner and more efficient forms of energy. Furthermore, it assumes that cleaner fuels are normal economic goods while traditional fuels are inferior goods**.** The lower the household income, the greater the proportion of income spent on energy, poor families spend between 30 - 50% of their income on energy, whereas those with higher income spend less than 10%. The energy ladder provides a theoretical framework for explaining the transition from traditional fuels to modern fuels and devices inside households. From the bottom rung of inefficient traditional fuels (e.g. sawdust, firewood, and charcoal) through fossil fuels (e.g. kerosene and gas) to the top rung of efficient modern fuels (e.g. electricity), the ladder sets out a progressive ladder where users move towards what is considered more efficient and clean fuels, and away from less efficient and unclean fuels. It proposes that with increasing affluence, households not only shift to more modern energy fuels for vital services, but additionally they purchase more advanced technologies, including heating and communication devices, cooling, and other appliances.

On the other hand, the energy stack model insists that rural household does not switch fuels entirely, but more generally follow multiple fuels or fuels stacking model (Maserea *et al*.2000). Energy Stack Model is the ability of households to combine both traditional and modern fuels to meet their domestic energy needs. It explains that fuel switching is a step towards multiple fuels cooking or fuel stacking; Fuel stacking is also a step towards fuel switching because by stacking, households start the process of de-stacking of conventional fuels, therefore, energy stacking and switching ladder are not necessarily contradictory rather complementary to elucidate fuel switch process and direction (Maserea *et al.,* 2000). This model however rejects the linear simplification of the energy ladder, as it suggested that households do not wholly abandon inefficient fuels in favor of efficient ones. Rather, modern fuels are integrated slowly into energy-use patterns, resulting in the contemporaneous use of different cooking fuels (Nicolai *et al.,* 2008). In the empirical studies of Masera *et al*. (2000) and dynamics of fuel switching of Pachauri and Spreng (2003), it was indicated that moving up the energy ladder suggests greater fuel efficiency and thus reduction of total emissions, this multiple fuel use or 'fuel stacking' strategy may instead lead to greater energy use by the household in the process of moving 'up the energy ladder. Thus, a multiple fuel use pattern challenges the capacity of rural energy development to alleviate any existing pressure on the environment.

A range of different estimation methods had been proposed to model household demand for various goods. These include the pioneering work Linear Expenditure System (LES) of Stone (1954) with proportional income and price elasticities, and the ruling out of complementary relationships among goods; Rotterdam model (Theil, 1965) and Translog model (Christensen, et al. 1975; Deaton and Muellbauer (1980)'s Almost Ideal Demand System (AIDS) to mention but a few. Out of these models the demand system estimations model, AIDS model possesses important features such as arbitrary first-order approximation to any demand system; satisfies the axioms of choice; aggregates over consumers and easy to estimate making AIDS modeling to attract a great deal of attention and therefore used extensively in empirical studies (Olorunfemi, 2013; Tiwang et al., 2017). However, the linearity of budget shares in the logarithm of household expenditure had made it a very restrictive model (Meenakshi and Ray, 1999). It was evidenced that the AIDS model is locally flexible, in the sense that it does not put a priori restrictions on the possible elasticities at any one point. This flaw paved the way for the Quadratic AIDS model (QUAIDS) which is a flexible functional form with larger regular regions (Banks et al, 1997). QUAIDS is a generalized AIDS model with a quadratic term of income in the Engel curve so that the Engel curve becomes more flexible in terms of fitting (Abler 2010; Meyer, Yu and Abler 2011).

From empirical view, several studies have adopted demand system equation to model demand for certain goods in the households, Lee, 2013 on the study of the household energy mix in Uganda used QUAIDS and inferred that energy demand in Uganda followed energy ladder theory which assumes that as income increases, households consume more modern fuels and less traditional and transitional fuels, that as household income increased, solid and transitional fuel use evolved in an inverse U manner, while electricity consumption showed a direct relationship with income. While education had been considered as a significant factor in determining movement along the energy ladder, persistent reliance upon charcoal as household income increases which suggested inaccessibility to alternative modern cooking fuels was noticed. Also, Ogunniyi et., al., 2012 examined household energy consumption pattern using the Almost Ideal Demand System (AIDS) model in Ogbomoso Metropolis, Oyo State, Nigeria revealed that kerosene is the most highly consumed energy source and the reason for preferring this energy source is its accessibility in the study area. Demand for all forms of energy is price inelastic and cross-price relations indicate that kerosene as a substitute for both electricity and charcoal, whereas electricity is a substitute for all the two. Charcoal and kerosene are complements. All the energy sources considered were found to have income elasticities less than one owing to the fact that energy consumption is a necessity. The government should provide electricity to most areas and there is a need for pricing policy for energy such as kerosene.

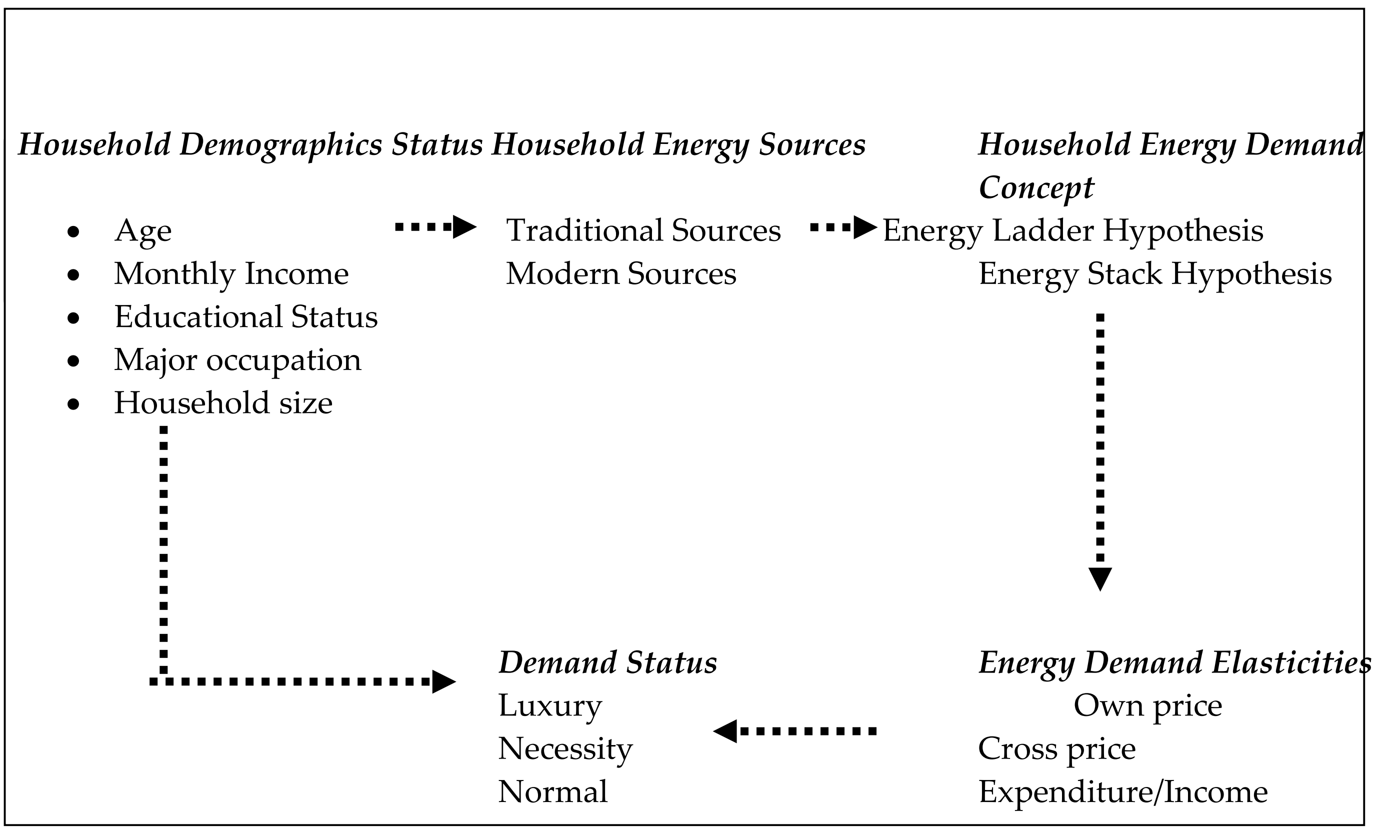

Fig.1: Household Energy Demand Cycle

Source: Wicolai and Fiona (2008) modified by the Author

3. Research Methodology

The study was conducted in Imo State, Nigeria. Imo State lies within latitudes 4°45'N and 7°15'N, and longitude 6°50'E and 7°25'E with an area of around 5,100 sq. km. It is bordered by Abia State on the East, by the River Niger and Delta State on the west, by Anambra State to the north and Rivers State to the south. Imo State is subdivided into 27 Local Government Areas (LGAs) and has a total population of 3,934,899 persons with a population density that varies from 230 persons per square kilometer in the densely populated areas (NPC, 2006). Occupation of people in the area includes public service, trading, and artisan and farming, both as a full and partial occupation. The target population is a member of the household that makes budget decisions on domestic energy in most homes in the study area.

The study adopted a multi-Stage sampling technique. Stage one involves a purposive selection of one LGA in each agricultural zone of the state to ensure a proper representation of the state. The selected LGAs were Nwangele, Owerri North and Okigwe L. G. As from Orlu, Owerri and Okigwe zones respectively. The second stage involves a random selection of 270 households across the already selected LGAs from the three 3 zones in the state. A list of households with the National Population Commission (NPC) was used to draw 20% of the households from each LGA already selected. This gave about 107 households in Nwangele, 92 households 92 from Owerri North, and 71 households from Okigwe LGA. The third stage was a purposive selection of the household member who makes decisions on domestic energy used for cooking. This was because of the socio-cultural disposition of the people in the state who manages the domestic activities of the household. The study found only 262 responses; 102 from Nwangele, 90 from Owerri North, and 70 from Okigwe North useful for analyses.

The study used both primary data of energy sources of data collection. Primary data include the use of questionnaires and personal interviews. The questionnaire will elicit information on the socio-economic characteristics of the respondents such as age, household size, and educational status of the household head, spouse, and monthly expenditure on energy used for domestic cooking. Also, information on unit prices and the number of different energy sources was collected to determine the budget shares of the energy sources.

The data were analyzed using descriptive and inferential statistics to achieve the objectives of the study. The descriptive statistics such as frequency distribution, percentages, and mean will be used to achieve describe the socio-economic characteristics of the households, and quartile distribution was used to estimate the budget share and QUAIDS was used to model the demand system of timber products and its substitute used in the study area.

4. Analytical Techniques

A typical QUAIDS model can be expressed as:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} lnP_j + \beta_i ln\left[\frac{E_F}{a(p)}\right] + \frac{\lambda_i}{b(p)}\left[ln\left\{\frac{E_F}{a(p)}\right\}\right]^2 + \sum_{s=1}^{L} \delta_{is} z_s + u_i (1)$$

Where

w_i = household's expenditure share of i^{th} energy source group for household domestic cooking, i=1, 2, 3, 4 and 5

w_1 = share of firewood
w_2 = share of sawdust
w_3 = share of charcoal
w_4 = share of wood-shaving
w_5= share of kerosene
P_j = price of energy source i (N/unit) for i = 1, 2, 3, 4 and 5
P_1 = price of a bundle of firewood (N/kg)
P_2 = price of a bag of sawdust (N/kg)
P_3 = price of a bag of charcoal (N/kg)
P_4 = price of a bag of wood shaving (N/kg)
P_5 = price of litre of kerosene (N/litre)
E_F = household's total expenditure on all energy sources for domestic cooking in the demand system (N/week)
z_s = demographic variables included in the demand system model
z_1 = educational level of the household head (years spent in school)
z_2 = educational level of the household head's spouse (years spent in school)
z_3 = occupation of the household head (Civil service =1, Trader = 2, Farmer = 3, Artisan = 4)
z_4 = household size (number of persons).
u_i = random error following normal distribution.

$$lna(p) = \alpha_0 + \sum \alpha_i \, lnp_i + \frac{1}{2}\sum\sum y_{ij} \, lnp_i lnp_j (2)$$

$$b(p) = \prod {P_j}^{\beta_j}$$

$$\lambda(p) = \sum \lambda_i lnp_i \quad (3)$$

We put the following restrictions in order to satisfy the demand theory:
Adding-up and homogeneity require $\sum \beta_i = 0, \sum \lambda_i = 0, \sum y_{ij} = 0, \sum \alpha_i = 1$
Symmetry $\gamma_{ij} = \gamma_{ji}$, for $i \neq j$
Here w_i is the budget share of domestic energy source i in total energy expenditure,
Note that if λ_i = 0, the second-order term in equation (1) vanishes and it degenerates to an ordinary AIDS model. Using the price index in equation (2) encounters the estimation difficulties as a result of non-linearity in parameters. The theory of the household does not provide any empirical plausible value for α_0. In practice, the stone price index is widely used for approximation. It is the so-called LA/AIDS model and

$$\ln(p^*) = \sum_k W_i \ln(p_i) \quad (4)$$

Since prices are never perfectly collinear, applying the Stone Price index will introduce the measurement errors of the units which can be solved if the prices are scaled by the means and become a price index P_i. Thus, the stone Price index becomes

$$\ln(p^L) = \sum_k W_i \ln(p_i) \tag{5}$$

Taking the first-order derivative of equation (1) with respect to expenditure and prices, yield intermediate results in equations 6 and 7.

$$\mu_i = \frac{\delta w_i}{\delta lnE_F} = \beta_i + \frac{2\lambda}{b(p)}\left[ln\left\{\frac{E_F}{a(p)}\right\}\right] \tag{6}$$

$$\mu_{ij} = \frac{\delta w_i}{\delta lnpj} = \gamma_{ij} - \mu_i\left(\alpha_j + \sum_k \gamma_{jk}\, lnp_k\right) - \frac{\lambda_i\beta_j}{b(p)}\left[ln\left\{\frac{E_F}{a(p)}\right\}\right]^2 \tag{7}$$

The expenditure elasticities are derived by:

$$e_i = 1 + \frac{\mu_i}{w_i} \tag{8}$$

The uncompensated price elasticities are derived by:

$$e_i{}^u = \frac{\mu_{ij}}{w_i} - \delta_{ij} \tag{9}$$

The Hicksian or compensated price elasticities are obtained from the Slutsky equations as:

$$e_i{}^c = e_i{}^u + w_j e_i \tag{10}$$

5. Results and Discussion

The distribution of the socio-economic characteristics of domestic energy users is presented in Table 1. It was indicated that 31.68% of the respondents were in the age range of 55 – 64 years with an average of 47.16 years. This implied that the solid fuel users in the study area had youth who possess the ability to switch among energy sources available to them which possess economic, efficient, and high aesthetic value.

Table 1: Socio-economic characteristics of the Households

Socio-economic variables	Freq	Relative Frequency	Mean
Age (years)			
25 – 34	32	12.21	47.16years
35 – 44	61	23.28	
45 – 54	62	23.66	
55 – 64	83	31.68	
65 – 74	24	9.16	
Gender			
Female	173	66.03	
Male	89	33.97	
Marital Status			
Married	190	72.52	
Single	53	20.23	
Widowed	19	7.25	

Educational Status	Freq	Relative Frequency	Mean
No formal education	100	38.17	
Primary School Completed	73	27.86	
Secondary School Completed	61	23.28	
Post-Secondary School Graduate	28	10.69	
Educational Status of Spouse			
No formal education	140	53.44	
Primary School Completed	96	36.64	
Secondary School Completed	17	6.49	
Post-Secondary School Graduate	9	3.44	
Major Occupation			
Civil Servant	15	9.68	
Traders	20	8.39	
Farmers	204	73.55	
Artisan	23	8.39	
Monthly Income (N)			
1,000 - 20,000	86	32.82	₦35,881.68
21,000 - 40,000	51	19.47	
41,000 - 60,000	83	31.68	
Above 60,000	42	16.03	
Household size (No of persons)			
1 – 4	83	21.29	6persons
5 – 8	108	50.32	
9 – 12	68	26.45	
13 – 16	3	1.94	

Source: Field survey, 2019

This is in line with Adepoju et al. (2012), Ogwuche and Asobo (2013). About 66.03% of them were female implies that more female takes decisions on the type and quality of energy source to be utilized by the households in the study area which is consistent with Ogwuche and Asobo (2013) that women are better decision-makers on the energy choice and domestic facilities suitable for the households. In addition, about 72.52% of them were married implies that the majority of the respondents are married and are tends to consume more energy for domestic cooking usage as marital status tends to positively correlate with the household size. About 38.17% of them had no formal education while only 10.69% of them had post-secondary school certificate, in the same vein, 53.44% of them had no formal education while only 3.44% of them had post-secondary education.

Educated respondents and spouses tend to adopt non-solid energy sources rather than solid energy sources which are predominant among uneducated respondents. About 73.55% of them were farmers indicating their closeness to natural vegetation, which could make them use firewood for domestic cooking more than other energy sources. The average monthly income is N35, 881.68 indicates a low disposable income, which could influence both their budget share for domestic energy and the choice of cost-effective energy option in the very short run. This low-income level can equally affect the flexibility of shifting to the desired cleaner domestic fuel, which Adepoju et al. (2012); Ogwuche and Asobo (2013) and Desalu et al. (2012) in their separate studies opined that it could be very cost-effective in the long run. The household size of the domestic energy users showed that 50.32% of between had the household size of 5 – 8 persons with the average household size of 6 persons. This implies a predominantly large household sized populace in the area which could influence the pattern and quantity of energy usage for cooking.

Table 2: Budget Share and Total Expenditure of the Different Energy Sources for Domestic Cooking

Household Energy Expenditure quartiles					
Energy share	**All households**	**1st**	**2nd**	**3rd**	**4th**
w1(firewood)	0.1734	0.1469	0.1853	0.1924	0.1723
	(0.0744)	(0.0525)	(0.0976)	(0.0882)	(0.0346)
w2(sawdust)	0.0178	0.0264	0.0174	0.0168	0.0109
	(0.0084)	(0.0110)	(0.0031)	(0.0047)	(0.0031)
w3(charcoal)	0.5970	0.6195	0.2921	0.6302	0.0109
	(0.0957)	(0.0678)	(0.1355)	(0.0047)	(0.0031)
w4(wood-shaving)	0.0182	0.0241	0.0204	0.0158	0.0125
	(0.0075)	(0.0078)	(0.0085)	(0.0035)	(0.0019)
w5(kerosene)	0.1936	0.1832	0.2136	0.1448	0.2319
	(0.0725)	(0.0285)	(0.1083)	(0.0530)	(0.0411)
Expenditure	1284.3122	904.3701	1199.2361	1516.2272	1508.9197
	(270.2915)	(84.0531)	(71.1978)	(72.7345)	(114.9572)

Source: Field Survey Data, 2019

Table 2 reveals that the richest households have the largest share of kerosene (23%) across all income groups, reflecting in conformity with the energy shifting model that household shifts from a low efficient energy source to highly efficient energy source as their income increases. However, it was also indicated that expenditure on charcoal was highest among the households in the 1st and 3rd quartiles groups' i.e 61.95% and 63.02% respectively. Sawdust had the lowest budget share across the quartiles with the least values among the 4th quartile household category. Expectedly, expenditure on energy use increases from 1st quartile through the 3rd quartile and later become lower for the 4th quartile which depicts energy stacking that households do not wholly abandon inefficient fuels in favor of efficient ones, instead they integrated modern fuels slowly into energy-use patterns, resulting in the contemporaneous use of different cooking fuels. This scenario provides empirical support to the assertion that the relationship between demands for energy and income is not always linear as it follows complementary energy switching and stacking principles.

The determinants of the household demand for energy sources in the study area using QUAIDS model are presented in Table 3. The iterated feasible generalized non-linear least squares (IFGNL) estimation method, with the theoretical restrictions of adding up, homogeneity and symmetry imposed during estimation in the estimation of the parameters of the QUAIDS model using Stata 13. This IFGNL method of estimation aims to address heteroscedasticity in the residuals while adhering to economic theory. The empirical analysis of the demand for household energy usage revealed that the quadratic expenditure term (Lnexpenditure)2 is statistically significant in firewood, sawdust, and wood-shaving expenditure share equations. Therefore, the budget share equations for firewood, sawdust, and wood-shaving that the null hypothesis of expenditure linearity is strongly rejected but the hypothesis that the quadratic expenditure term is zero is accepted in charcoal and kerosene equation suggesting the preference of QUAIDS for model to AIDS model and in line with Marius (2016) and Fashogbon and Oni (2013). Moreover, also, the demographic effect is highly significant in the model.

As shown in Table 3, the demand for firewood was positively determined by expenditure, square(expenditure), prices of firewood and kerosene at $p<0.01$ while prices of charcoal and wood-shaving, educational status of the household head and spouse had negative significant effects on the budget share of firewood.

Table 3: Determinants of Household Demand of Energy Source for domestic cooking

Variables	Firewood	Sawdust	Charcoal	Wood-shaving	Kerosene
Constant	14.3239	-0.2091	-13.8371	-1.6064	2.3287
	(20.0000)**	(-1.2200)	(-11.5800)**	(-9.1400)**	(2.2500)**
Ln(Expenditure)	1.6113	0.0912	-1.5464	-0.2219	-0.0647
	(18.4400)**	(2.8100)**	(-8.4300)**	(-6.6800)**	(0.1531)
Ln(Expenditure)^2	0.0126	0.0113	-0.0072	-0.0050	-0.0118
	(2.8000)**	(6.1300)**	(-0.8000)	(-3.2000)**	(-1.3000)
Ln(Price of firewood)	13.8644				
	(12.2600)**				
Ln(Price of sawdust)	-0.1528	0.1663			
	(-1.0000)	(5.3600)**			
Ln(Price of charcoal)	-14.0180	0.1662	14.7980		
	(-11.2700)**	(0.8800)	(7.6100)**		
Ln(Price of wood-shaving	-1.6786	0.0025	1.6268	0.2184	
	(-11.2400)**	(0.0800)	(9.6000)**	(3.9500)**	
Ln(Price of kerosene)	1.9851	-0.1822	-2.5730	-0.1691	0.9393
	(2.0800)**	(-1.9200)*	(-2.2900)**	(-1.2900)	(2.3200)**
Educational level	-0.0688	-0.0064	-0.0599	0.0072	-0.0047
	(-6.1100)**	(-6.3000)**	(-4.3000)**	(7.3200)**	(-0.6900)
Educational level_sp.	-0.0152	0.0007	0.0220	0.0006	-0.0082
	(-2.4700)**	(1.4800)	(3.2300)**	(1.1000)	(-3.1200)**
Occupation	0.0017	-0.0002	-0.0023	0.0000	0.0004
	(1.7100)	(-2.0500)**	(-1.9500)**	(-0.4100)	(0.6300)
Household size	-0.0007	0.0001	0.0007	0.0001	-0.0001
	(-1.2800)	(1.1600)	(1.1200)	(1.2200)	(-0.3200)

** Significant @ 1% and * significant @ 5%.

Source: Field Survey Data, 2019.

This implies that the demand for firewood increases as the prices of firewood and kerosene increase, in that as the price of firewood increases, the household gradually observed energy stacking principle by simultaneously complementing firewood with another energy source, in this case, kerosene, which they found more efficient than firewood. This also reflected in their expenditure which increases the budget share of firewood as it increases. However, increases prices of charcoal and wood-shaving cause a reduction in the demand for firewood, because the household would prefer efficient energy sources like charcoal and wood-shaving rather stick with less efficient energy sources like firewood. In the same vein, the educational status of the respondents had an inverse relationship with the demand for firewood because educated individuals would go for efficient energy sources because of their knowledge and exposure.

For the sawdust model; positive determinants of its demand are the price of sawdust, square (expenditure) while the educational level of the head, occupation, and price of kerosene at $p<0.01$ had a negative effect on the demand of sawdust. This indicated that the price of sawdust increases its budget share, the same as its expenditure even as its non-linear form as indicated by the significant square (expenditure). It also indicated that the educational level of the household head and their occupation reduces their demand for sawdust. Educated household heads would shift to more efficient energy sources while individuals with high earning income would equally use efficient energy sources

For the charcoal model, prices of charcoal and wood-shaving, educational level of the household head, and spouse were positive determinants of the budget share of charcoal while expenditure, price of kerosene, and occupation of the household head were negative determinants at $p<0.01$. This implies that an increase in the price of charcoal and wood-shaving increase the budget share for charcoal in the household energy expenditure and higher educational levels of respondents would increase the consumption of efficient energy sources like charcoal rather than shift to less efficient ones. However, an increase in the price of kerosene would induce the need for the household to go for charcoal which is a cheaper energy source, and this would increase its demand, budget share and ultimately increases its price. Also, as energy expenditure increases significantly, it reduces the budget share of charcoal as the household shift to a more efficient energy source. Household heads with an occupation that earned a high-income level would budget higher expenditure for energy and would, therefore, sought for efficient ones. This obeys the principle of energy ladder hypothesis which indicated that households with high-income levels are likely to have higher energy expenditure, particularly as they sought efficient energy sources.

For the wood-shaving model, the price of wood-shaving has a positive significant effect on the budget share of wood-shaving while educational level, expenditure in both linear and non-linear forms had negative effects on its budget share. The implication of this is that wood-shaving; being a less efficient energy source would be less regarded among the educated households and would be consumed less when the energy expenditure increases in the face of increasing household wealth status and income level. However, budget share on kerosene positively relates to its price and educational level of energy users in the household. It follows that highly educated respondents, particularly woman would take a decision to demand kerosene rather than any timber products, which are considered less efficient and environmentally friendly.

Table 4, presents estimates of the expenditure, Marshallian and Hicksian own, and cross-price elasticities respectively.

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Table 4: Estimation of the Own, Cross Price and Expenditure Elasticity for Domestic Energy Sources

Variables	Firewood	Sawdust	Charcoal	Wood-shaving	Kerosene
Expenditure elasticity					
Expenditure	8.057852	-7.58837	-1.14621	-4.61394	2.616795
Compensated (Hicksian's own and cross elasticities)					
Firewood	**-2.75188**	-0.12336	1.130876	0.006426	1.7379364
Sawdust	-1.04935	**1.258401**	-0.60347	1.38154	-0.98712633
Charcoal	0.331087	-0.01367	**0.847382**	-0.0195	-1.1453035
Wood-shaving	0.01526	1.371621	-0.58406	**-0.46416**	-0.33865
Kerosene	1.53835	-0.09222	-3.515	-0.02924	**2.09810**
Uncompensated (Marshallian's own and cross elasticities)					
Firewood	**-4.1488**	-0.26704	-3.67964	-0.14022	17784027
Sawdust	0.266178	**1.393707**	3.926776	1.519639	0.48207305
Charcoal	0.529794	0.006768	**1.531666**	0.001363	-0.92338414
Wood-shaving	0.815136	1.453891	2.170447	**-0.38019**	0.55465371
Kerosene	1.084701	-0.13888	-5.07722	-0.07686	**1.5914625**

Source: Field Survey Data, 2019

As shown in Table 4, expenditure elasticities of all the energy sources are greater than unity which means all the energy sources are expenditure elastic with firewood having the highest expenditure elasticity followed by sawdust, wood shaving, kerosene, and charcoal respectively. Only firewood and kerosene were positive which indicated that they are normal goods and others are inferior goods (Koutsoyiannis, 2003; Ben-chendo et al., 2017). In terms of magnitude, all energy sources have expenditure elasticity greater than unity which means they are expenditure elastic and not a necessity that households cannot do without, it indicated that household is not tied to a particular energy source as they can swift to another energy source if the price of the one that is currently using goes up or becomes shortage in supply, this also elucidated the principle of energy ladder hypothesis that household quickly switches to a better energy source as their income increases.

The diagonal estimates in Table 4 represent the own-price elasticities while on the off-diagonal indicates the cross-price elasticities. Only own-price elasticities of firewood and sawdust have negative as expected as they obeyed the law of demand. In terms of magnitude, firewood, sawdust, and kerosene are price elastic while charcoal and wood-shaving are price inelastic and this emphasized the dynamism in the ability of households to combine both traditional and modern fuels to meet their domestic energy needs based on price and affordability. Based on the uncompensated price elasticity estimates, Koutosyiannis (2003) opine that the positive cross elasticity values indicate substitutability while negative signs indicated complementarily of two goods. Based on the uncompensated-Marshallian cross elasticities, almost all energy sources are complimentary except for firewood-sawdust, firewood-charcoal, firewood-wood shaving, charcoal-kerosene and kerosene-sawdust they are substitutable as the negative cross elasticities indicated. However, the result of the compensated- Hicksian's cross elasticities values indicated that almost all the energy uses are substitutable except for firewood –charcoal, firewood-wood shaving, firewood-kerosene and sawdust-wood shaving that are complementary as the positive cross-elasticities implies. In all, the Hicksian approach provides better estimates because it accounts for compensation variation which gives the true picture of the welfare effect (Varian, 1992; Fashogbon and Oni, 2013). Hence, Hicksian elasticity estimates would give better policy direction

6. Conclusion

This study has attempted to model demand analysis for timber and its substitute for domestic cooking in Imo State household using QUAIDS modeling. It was inferred from this study that expenditure on energy use increases from across the expenditure quartile groups which depicts energy stacking in that households do not wholly abandon inefficient fuels in favor of efficient ones, rather integrated modern fuels slowly into energy-use patterns, resulting in the contemporaneous use of different cooking fuels. In the same vein, as energy expenditure increases significantly on energy usage due to change in occupational status, education, and higher income, budget shares of some energy source reduces as the household shift to the more efficient energy source. Expenditure elasticities of all the energy sources are elastic which emphasized that the household is not tied to a particular energy source as they can swift to another energy source depending. This elucidated the principle of energy ladder hypothesis that household quickly switches to a better energy source as their income increases at the same time exhibit their dynamism in the ability to combine both traditional and modern fuels to meet their domestic energy needs based on price and affordability.

7. Recommendations

The study recommends the following:

i. The educational status of the respondents had an inverse relationship with the demand for firewood because educated individuals would go for efficient energy sources because of their knowledge and exposure. Sanitary inspectors and environmental extension officers should organize training for domestic energy users on the importance of cleaner energies as domestic fuel.

ii. Policymakers should take advantage of the shifting demand horizon of the respondents which enhances the preference of cleaner energy as a unit reduction in their prices as the respondents' income, budget share increases.

iii. Public intervention programs on the device for cleaner energy should target younger females' members of the households who make decisions on the type of domestic fuel use as energy in the area.

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