An econometric analysis of residential fuel choice in Nigeria: application of access framework

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Abstract: Despite global calls for a transition to modern energy, Nigerian households continue to face obstacles in accessing clean cooking energy. This paper examines the barriers to household fuel choice in rural and urban areas of Ogun Sate, Nigeria, employing an access framework. Through a cross-sectional study involving 597 households, we examined the factors associated with the selection of household cooking fuel and the access challenges. The framework conceptualises fuel choice as a function of three key access dimensions: affordability, availability, and acceptability, using multinomial logit regression. The findings showed that firewood and kerosene remain Nigeria's dominant household fuel sources. The results highlight that fuel choice is influenced not only by affordability factors but also by factors related to availability and acceptability. Consequently, the study recommends a comprehensive approach beyond affordability, to ensure modern energy sources are culturally acceptable while establishing secure supply chains towards a more environmentally sustainable energy future.

Keywords: Nigeria; household fuel choice; access framework; energy access; multinomial logit.

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1 Introduction

The importance of household fuel for cooking and lighting cannot be overemphasised; though fuel is a derived demand, its irreplaceable role informs why its use continues to increase (Bhattarchayya, 2011; Malla and Timilsina, 2014). The United Nations (2005) underscores the invaluable need for affordable, reliable, sustainable and modern energy in the sustainable development goal seven, especially in countries where the popular energy source for cooking is biomass burning.

A common household fuel choice in developing countries is biomass fuel. A comparison between developing and developed countries showed that biomass is burned for generating electricity and industrialisation in developed countries, while in the developing world, greater proportions of biomass are burnt for cooking (OECD/IEA, 2011); in light of this, current statistics still depict that about 900 million people in Africa lack access to clean cooking facilities (International Energy Agency, 2019; WHO, 2022); a proof that not much has been achieved in lifting people out of energy poverty.

Nigeria ranks among the 20 countries with a high population lacking access to non-solid fuel (IEA et al., 2022); affirming this, Sanusi and Owoyele (2016) emphasised the dependence of almost all states in Nigeria on biomass fuel for cooking; specifically, 80% of energy consumed in Nigeria is composed of biomass burning (crop residues, manure, charcoal and firewood) (Rapu et al., 2015; Ben-Iwo et al., 2016). This has implications for exposure to emissions, deforestation, and global warming. A question

that comes to mind is why there is a dearth in access to modern cooking fuel in an economy endowed with renewable and non-renewable energy?

Increasingly, studies on fuel energy choice in developing countries have been narrowly defined using economic factors-affordability (income and price); higher income households are likely to adopt clean energy compared with lower income households (Hosier and Dowd, 1987; Ouedraogo, 2005; Bello, 2011; Tchereni, 2013; Fontodji and Kokou, 2014; Ogwumike et al., 2014; Ahmad and Olivera, 2015; Deshmukh et al., 2014; Ozoh et al., 2018). However, Karimu (2015) and Paudel et al. (2018) examined not only affordability but also availability in terms of access to modern infrastructure proxied with access to modern energy. Furthermore, household choice of one or more fuel does not only depend on the ability to afford these fuels but also on the availability and cultural acceptability of the fuel; hence, energy demand is a multidimensional issue related to accessibility (Sesan, 2012; Remigios, 2014; Masera et al., 2005). For instance, even though some households in China have the choice of using clean energy, they prefer to use traditional fuel due to tradition (Onoja and Emoji, 2012).

Increasing access to affordable clean energy is not only on the global agenda as indicated in SDG.7 but also part of several national energy policies. However, there is still debate about the precise meaning of the term access. Energy access has been quantified in binary terms (i.e., access to non-solid fuel for cooking); this narrow definition does not justify the coverage of Sustainable Development Goal 7 aimed at access to reliable, affordable, sustainable modern energy for all; specifically, perception on the coverage and quality of access to energy is not captured in the binary measurement. The multi-tier framework defines access in terms of affordability, availability, indoor air pollution, convenience, efficiency, and safety of cooking energy (ESMAP, 2014).

Following this development in the conceptualisation of energy access, this study explains energy access as made up of three dimensions which are availability (physical access), affordability (economic/financial access), and acceptability (cultural access). This is similar to the access framework employed in access to healthcare (McIntyre et al., 2009). According to Masera et al. (2005), household energy use is not just a product of individual behaviour, economic predictions of income, and relative fuel prices as shown in a number of literature. The access framework is an approach to empirically investigate clean energy access and develop energy policy strategies that can comprehensively address the challenges and opportunities related to energy access using an alternative framework (ESMAP, 2014; Peltz et al., 2021).

The alternative framework is extensively discussed by ESMAP (2014), Jain et al. (2015) and Peltz et al. (2021). This approach is not popular in the energy literature most often due to data issue causing failure in assessing the barriers to clean energy adoption in developing countries including Nigeria; an aspect considered in this study are the three As' to energy access (affordability, availability, and acceptability domains) as applied in the access to healthcare framework (McIntyre et al., 2009). This paper therefore investigates the factors linked to accessing clean energy using the access framework through a rural and urban case study of households in Ogun State, Nigeria.

2 Literature review

Nigeria has rich endowments in both renewable and non-renewable energy (Iwayemi, n.d.; Sambo, 2009). It is the largest oil exporter in Africa and it ranked sixth among liquefied natural gas exporters in the world (Energy Information Administration, 2023). However, there is a large disconnect between endowments and the consumption of modern energy. Nigeria with a population of over 170 million is among the top ten countries where households depend on biomass consumption as 15% of households use modern cooking energy (NPC and ICF, 2019; Ashagidigbi et al., 2020; Nnaji et al., 2020). A pioneering work in the energy literature is the energy ladder hypothesis (Hosier and Dowd, 1987). The work showed that there is a link between household energy choice and income with richer households choosing modern energy; however, Masera et al. (2000) found that in Mexico, households stack fuel due to insecurity of supply and sustainability of fuel wood.

Isara and Aigbokhaode (2014) examined the relevance of the energy ladder and stacking in Edo state, Nigeria. Firewood is consumed in urban and rural areas and sourced via collection and purchase although rural areas use more firewood than urban areas and collection of firewood is done more in rural than urban areas (Nnaji et al., 2020; Eleri, 2021). Kerosene is a more popular fuel for cooking in urban compared to rural areas. Both urban and rural areas do not have reasonable access to electricity and gas.

While most works concentrated more on socio-economic and demographic factors affecting the choice of fuel, this study examines other domains of energy access not discussed in similar works.

3 Methods

3.1 Conceptual framework of access

The discussion on household energy use has evolved overtime. Access to energy has been narrowly defined using economic factors (price, income, expenditures). Pioneers in energy, emphasised that household fuel choice is a function of income (Hosier and Dowd, 1987; Ouedraogo, 2005; Bello, 2011). Higher income households are more likely to adopt cleaner energy than lower income earners. However, Demurger and Fournier (2011) using least square estimation technique found contradicting findings which showed that rich rural households were still more likely to use firewood for cooking.

Factors influencing energy access have been argued to be multidimensional in nature and not only influenced by affordability, but by other non-economic factors like location of residence, culture, distance to fuel (Danlammi et al., 2015). Several studies in literature revealed variations across geographical locations on determinants of household energy use for cooking (Bhattarai, 2014; Zaku et al., 2015; Isara and Aigbokhaode, 2014). Qualitative studies also underscore the role of culture in the choice of energy (Sesan, 2012; Remigios, 2014).

Thus, this study draws on an integrated conceptual framework of access where access is viewed as a degree of fit between the energy characteristics and household. Some studies have discovered the limitation of the binary measure of energy access; this

approach does not validate the quality of energy and condition of energy services. Like the health literature pioneered by McIntyre et al. (2009), energy literatures are also affirming the holistic measurement of energy access (ESMAP/World Bank; Peltz et al., 2021). In the light of this, three interlinked but distinct domains of access were evaluated; affordability, availability and acceptability. Affordability examined the interaction between the price of energy source and the ability to pay of the households. For instance, the price of energy source or the equipment associated with the energy can be an access barrier to clean energy. Increase in the price of alternative clean fuel is likely to make households opt for firewood for cooking (Ebe, 2013). Availability domain is an important external factor that influences household access to clean energy. In this context, availability is viewed as the degree to which household needs are met by the type of energy available and proximity to the energy source (Heltberg, 2003).

Acceptability domain encapsulates characteristics peculiar to the social and cultural issues influencing fuel choice (Sesan, 2012; Remigios, 2014). In addition to these, demographic factors likely to influence household access to various fuel choices are introduced. In this study, each domain is captured by a number of variables as outlined in Table 1.

Table 1 Energy access domains

Affordability domain	*Availability domain*	*Acceptability domain*
Wealth index	The fuel I use is easily available	The fuel I use emits smoke
The price of equipment limits my choice of fuel	Insecurity of supply makes me combine fuel	The fuel I use is fast for cooking
Income limits my choice of fuel	Location in rural or urban	My choice of fuel for cooking is attached to culture
The fuel I use is expensive		
Education status		
Employment status		

3.2 Materials and method

3.2.1 Description of study area

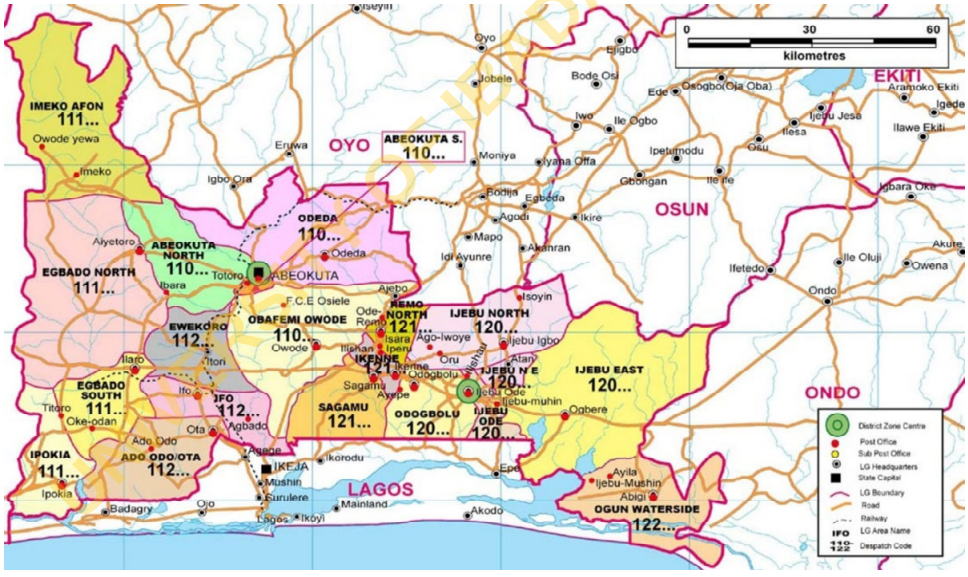
Dissecting the energy access situation in Nigeria, the energy poor are dominant in rural areas while northern Nigeria has the highest distribution of energy poor population (Lucia et al., 2020). Despite this, South western Nigeria still has a sizeable number of the population using solid fuel and kerosene for cooking (Samuel and Oladapo, 2022; Elijah et al., 2017; Adopoju et al., 2012).

This was a cross-sectional study conducted in Ogun State, Nigeria. The study conducted by Ozoh et al. (2018) found that Lagos State, a commercial hub in Nigeria has 2% of the population using firewood. Ogun State shares a boundary with Lagos and it is expected that there is the spill over effect of economic activities from Lagos on the state. It is located in South Western Nigeria, with 20 local governments, and ranks the ninth richest state in Nigeria. The state is one of the largest producers of cement in Nigeria; also, it has one of the largest concentrations of industries and a major corridor for transporting goods and services.

The survey was conducted in three local governments Ota, Ifo and Ijebu Ode local governments. Of the 20 LGAs, Ifo and Ado Odo Ota local governments are located in the North East. They have the highest population in the state and are a major source of internal revenue for the state. Ijebu Ode is between Shagamu and Benin and is located in the northeast of Lagos State in the eastern part of Ogun State and a higher percentage of the population is into agriculture.

Ado Odo Ota local government shares a border with Lagos State (a major financial hub in Nigeria); despite this, a larger % of households in Ado Odo Ota and Ifo local governments use firewood for cooking. Specifically, 27% of households in Ado-Odo Ota and Ifo local governments use firewood for cooking while less than 5% of households in these local governments use gas for cooking. Kerosene has a higher % of households using it for cooking which calls for concern since it also emits particulate matter, it is less efficient compared to gas (Bruce et al., 2000); it also, has been recognised to have negative effect on health (Adeniji et al., 2015; Bates, 2009); and there have been cases of fire explosion when cooking due to adulteration (Osuekere and Ofondu, 2011). The distribution of household fuel use in Ogun State shows that a larger % of the population uses firewood (343,119), kerosene (470,223) compared to Lagos State where more households use LPG (141,104), kerosene (1,771,036) as main cooking fuel (NPC, 2006).

Figure 1 Map showing local governments in Ogun State (see online version for colours)



Source: https://nationalwire.com.ng/

3.2.2 Sampling procedure and participant selection

This study employed multi-stage sampling technique. First, three most populous local government areas in the state were selected based on the distribution of regular household fuel used for cooking in the state. A cluster of enumeration areas was then constructed for urban and rural areas. Stratified sampling was then used to select households from each

cluster. The study adopted the Krejcie and Morgan (1970) technique in determining the sample size of 597 households.

3.3 Data collection

The study was conducted over a one month period between April–May 2017. Trained interviewers administered a structured questionnaire to mostly women, as they are main users of fuel in African settings. The interviewers were trained on the study objectives, how to obtain informed consent and how to administer the questionnaire to get valid responses. The questionnaire was pre-tested before use and adjusted as required prior to study onset.

The structured questionnaire included open and close ended questions on socioeconomic status of household, household fuel and equipment used for cooking and welfare of households which was used to proxy for wealth. Wealth index was used as a proxy for income owing to fact that most respondents were in the informal sector with irregular income. A section in the questionnaire captured ownership of assets (mobile phone, TV, fridge and car) and access to water and toilet facility.

The wealth index incorporates six indicators namely access to water dummy (coded as 1 and 0; piped and unprotected); toilet facility (coded as 1 = hygienic and 0 = non-hygienic sanitation), mobile phone, car ownership, television and fridge. Factor loadings for each indicator were derived using principal component analysis which was ranked into categories to generate wealth index.

3.4 Ethics of approval

Ethical approval for the study was given by University of Ibadan on the 30th of March 2017. Verbal and oral informed consent were obtained from participants and the interviews were conducted by trained field workers in the language of choice.

4 Empirical analysis

The choice of fuel exceeds two categories (firewood, kerosene and LPG). The study therefore assumed that; a household i faces j alternative of fuel choices (where $j = 1, 2, 3$) which are influenced by availability, affordability and acceptability in order to maximise household utility defined by U_{ij}.

The utility for alternative j for household i can be presented as:

$$U_{ij} = \beta X_{ij} + e_{ij} \tag{1}$$

- X_{ij} incorporates independent variables specified as domains (Table 1) that are likely to influence the choice of fuel in household i
- β is the parameter estimates
- e_{ij} is the error term assumed to be jointly normally distributed.

Given that the choice of fuel is in three categories (firewood, kerosene and LPG); following Green (2002) and Ogwumike et al. (2014), the multinomial logistic model is specified in equation (2) below:

$$\Pr\left(Y_{ij} = j\right) = \frac{e^{B_j X_i}}{\sum_{k=0}^{3} e^{\beta_k X_i}}, \; j = (1, 2, 3) \qquad 2)$$

$\Pr(Y_{ij} = j)$ is the probability of a household choosing either LPG or kerosene with the reference category as firewood. $J = 1, 2, 3$ represents kerosene, LPG or firewood dummies.

4.1 Variables

4.1.1 Dependent variable

The dependent variable is main fuel used for cooking by households which are firewood, kerosene and LPG.

4.1.2 Independent variables

Table 2 provides a description of the variables used in the analysis. Independent variables used in the model are presented in Table 1. Control variables introduced are age, family size and sex (male).

4.2 Result and discussion

Out of the 597 households, 41% of the sampled population used firewood, 32% used kerosene and 26% used LPG for cooking. The average age of the household sampled is 41 and the mean family size is approximately 4.

Table 2 Descriptive statistics of energy access variables

Variables	*S*	*LPG n (%)*	*Kerosene n (%)*	*Firewood n (%)*	*Chi-square*
Wealth index					
1st (low)	200 (33.5)	4 (2.55)	63 (32.64)	133 (53.85)	178.9
2nd (middle)	208 (34.8)	46 (29.30)	74 (38.34)	88 (35.63)	P < 0.01
3rd (high)	189 (31.66)	107 (68.15)	56 (29.02)	26 (10.53)	
Income limits choice of fuel					
Agree	223 (37.35)	43 (27.39)	136 (70.47)	195 (78.95)	116.5
Disagree	374 (62.65)	114 (72.61)	57 (29.53)	52 (21.05)	P < 0.01
Price of equipment					
Agree	294 (49.25)	23 (14.65)	107 (55.44)	173 (70.04)	120.33
Disagree	303 (50.75)	134 (85.35)	86 (44.56)	74 (29.96)	P < 0.01
Fuel is expensive					
Agree	396 (66)	46 (29.30)	61 (31.61)	94 (38.06)	3.84 (0.15)
Disagree	201 (34)	111 (70.70)	132 (68.4)	153 (61.94)	

Notes: Age and family size reflect minimum, maximum, average and standard deviation respectively.

Table 2 Descriptive statistics of energy access variables (continued)

Variables	*S*	*LPG n (%)*	*Kerosene n (%)*	*Firewood n (%)*	*Chi-square*
Education level					
None	88 (14.74)	15 (9.55)	31 (16.06)	42 (17.00)	118.21
Primary	174 (29.15)	16 (10.19)	48 (24.87)	110 (44.53)	P < 0.01
Secondary	255 (42.71)	74 (47.13)	91 (47.15)	90 (36.44)	
Post-secondary	80 (13.4)	52 (33.12)	23 (11.92)	5 (2.02)	
Employment status					
None	65 (10.89)	14 (8.92)	26 (13.47)	25 (10.12)	2.11
Employed	532 (89.11)	143 (91.08)	167 (86.53)	222 (89.88)	P = 0.35
Fuel is available					
Agree	526 (88)	136 (86.6)	175 (90.67)	215 (87.04)	1.81
Disagree	71 (12)	21 (13.38)	18 (9.33)	32 (12.96)	P = 0.41
Location					
Urban	300 (50.25)	124 (78.98)	128 (66.32)	48 (19.43)	165.61
Rural	297 (49.75)	33 (21.02)	65 (33.68)	199 (80.57)	P = 0.00
Insecurity of supply					
Agree	410 (68.7)	47 (29.94)	54 (27.98)	86 (34.82)	2.09
Disagree	187 (31)	110 (70.06)	139 (70.02)	161 (65.18)	P = 0.28
Fast for cooking					
Yes	502 (84)	151 (96.18)	152 (78.76)	199 (80.57)	23.54
No	95 (15.9)	6 (3.82)	41 (21.24)	48 (19.43)	P < 0.01
Culturally acceptable					
Yes	47 (7.87)	4 (2.55)	17 (8.81)	26 (10.53)	8.77
No	550 (92.1)	153 (97.45)	176 (91.19)	221 (89.47)	P < 0.01
Unacceptable emission					
Yes	319 (53.4)	22 (14.01)	85 (44.04)	212 (85.83)	209.09
No	278 (46.6)	135 (85.99)	108 (55.96)	35 (14.17)	P < 0.01
Controls					
Sex (female)	519 (86.9)	138 (87.90)	158 (81.87)	223 (90.28)	6.93
Sex (male)	78 (13.07)	19 (12.10)	35 (18.13)	24 (9.72)	P < 0.05
Age (years)	12.33	14	82	40.81	579
Family size	1.399	1	7	3.58	597

Notes: Age and family size reflect minimum, maximum, average and standard deviation respectively.

4.2.1 Affordability domain

In Table 2, wealthiest households tended to use LPG (69%); firewood use reduced as household wealth increased. 33% of households with higher education use LPG for cooking, 47% of secondary school holders use kerosene and 45% of primary school

holders use firewood for cooking. 91%, 87% and 90% using LPG, kerosene and firewood respectively are employed. 70% of firewood users and 55% of kerosene agree that the price of equipment limit their choice of energy. 52% of firewood users and 36% of kerosene users agree that income limits their choice of fuel.

4.2.2 Availability domain

In Table 2, above 80% of LPG, kerosene and firewood users reveal that energy is available. 69% of respondents agree that there is security of supply. 81% of rural respondents use firewood while 78% of urban residents use LPG.

Table 3 Multinomial logit regression of the determinants of energy access

Variables	*Unadjusted coefficient LPG*	*Adjusted coefficient LPG*	*Unadjusted coefficient kerosene*	*Adjusted coefficient kerosene*
Affordability domain				
Wealth index lowest	(1)	(1)	(1)	(1)
2nd (medium)	2.85*** (0.54)	2.15* (0.63)	0.57*** (0.22)	0.25 (0.30) (0.39)
3rd (high)	4.92*** (0.55)	3.59* (0.65)	1.51*** (0.28)	0.64*** (0.38)
Income limits choice of fuel	–2.30*** (0.24)	–1.29* (0.40)	–0.45*** (0.22)	0.29 (0.37) (0.33)
Price of equipment	–2.61*** (0.27)	–1.28* (0.40)	–0.63*** (0.20)	–0.30 (0.32) (0.30)
Fuel is expensive	–0.39** (0.22)	0.74* (0.41)	–0.28 (0.16) (0.20)	–0.75 (0.79) (0.28)
Educational qualification				
None	(1)	(1)	(1)	(1)
Primary	–0.90*** (0.40)	–0.08 (0.60)	–0.53*** (0.29)	–0.29 (0.37)
Secondary	0.83*** (0.34)	0.59 (0.53)	0.31 (0.28)	–0.12 (0.28)
Post-secondary	3.37*** (0.56)	2.48* (0.79)	1.83*** (0.55)	1.14*** (0.67)
Employment status	0.14 (–0.58)	–0.34 (0.60)	0.32 (0.30)	–0.35 (0.39)
Availability domain				
Fuel is available	–0.04 (0.30)	0.66 (0.51)	0.37 (0.31)	1.32* (0.41)
Location in rural	–2.75*** (0.25)	–1.98* (0. 38)	–2.10*** (0.22)	–2.03*** (0.28)
Insecurity of supply	–0.22 (0.22)	1.08* (0.41)	–0.32 (0.21)	0.33 (0.29)
Acceptability domain				
Unacceptable emission	–3.62*** (0.29)	–2.75* (0.40)	–2.04*** (0.23)	–1.74*** (0.28)
Culturally acceptable	–1.50*** (0.55)	–1.73** (0.80)	–0.20 (0.33)	–0.44 (0.46)
Fast for cooking	1.80*** (0.44)	1.30** (0.63)	–0.11 (0.24)	0.57 (0.35)
Controls				
Age	–0.02** (0.008)	–0.28* (0.02)	–0.01** (0.008)	–0.03*** (0.01)
Family size	0.08 (0.07)	–0.10 (0.12)	0.07 (0.068)	–0.02 (0.09)
Sex (male)	–0.25 (0.33)	0.68 (0.58)	0.72*** (0.28)	0.75* (0.41)

Notes: ***$P < 0.01$; **$P < 0.05$; *$P < 0.1$; figures in parentheses are standard errors.

4.2.3 Acceptability domain

The descriptive statistics in Table 2 shows that few respondents consider cultural acceptability as a reason for firewood adoption for cooking. 96% consider LPG as fast for cooking while firewood is linked to an unacceptable emission level (85%), 44% accepts that kerosene emits smoke (unacceptable emission) and 14% also affirm that LPG emits smoke.

4.3 Comparison group: firewood

Table 3 presents the unadjusted and adjusted multinomial logit regression result by domains.

- *Affordability domain:* LPG relative to firewood – all the variables within this domain were significantly related to LPG except for the employment status of the head. Wealthy households were 3.59 times more likely to use LPG relative to firewood use. Perception that income limits the choice of fuel was negatively associated with LPG (adjusted log odds –1.29); fuel is expensive was significantly negatively associated with LPG relative to firewood (unadjusted log odds –0.39) though the adjusted log odds shows a positive association between LPG use for cooking when it is expensive. Price of equipment restricts households to firewood relative to LPG (adjusted log odds –1.28). Household heads with post-secondary education were 3.37 times more likely to choose LPG relative to firewood.
    a *Kerosene relative firewood:* Within the affordability domain, only wealth and education were significantly associated with kerosene relative to firewood. Households in the richest wealth divide and household heads with post-secondary education were more likely to choose kerosene relative to firewood (adjusted log odds 0.64 and 1.14), respectively.
- *Availability domain:* Variables included under the availability domain were place of residence, perception whether the fuel is easily available or not and perception of insecurity of supply.
    a *LPG relative to firewood:* Area of residence and insecurity of supply were observed to be related to the use of LPG. While households in rural areas were less likely to use LPG compared to the use of firewood, the perception of insecurity to access is positively associated with LPG. Compared to those who live in the urban areas, households in rural areas were less likely to consume LPG (adjusted log odds –1.98). On the other hand, those that perceived supply of fuel to be insecure were more likely to choose LPG with an adjusted odd ratio of 1.08.
    b *Kerosene relative firewood:* Comparing choice of kerosene to firewood, availability domain shows that rural inhabitants were less likely to use kerosene relative to firewood (adjusted odds of –2.03).

- *Acceptability domain:*
  a *LPG relative to firewood:* Variables within this domain include unacceptable fuel emission, cultural acceptability and whether or not fuel is fast for cooking. Perceptions that LPG emits smoke and influenced by culture were negatively related to LPG adoption relative to firewood (adjusted odds ratio is –2.75 and –1.74 respectively). The perception that LPG is fast for cooking is positively associated to its adoption relative to firewood (adjusted odds ratio is 1.30).
  b *Kerosene relative to firewood:* Comparing the choice of kerosene to firewood, the perception that kerosene emits smoke (unacceptable emission) shows that kerosene is negatively related to its adoption relative to firewood (adjusted odds is –1.74); the choice of kerosene relative to firewood is not due to cultural acceptability (adjusted ratio is –0.44); kerosene is perceived as fast for cooking relative to firewood with adjusted odds of 0.57.

Table 4 Rural and urban comparison using multinomial logit

Variables	*Urban coefficient LPG*	*Rural coefficient LPG*	*Urban coefficient kerosene*	*Rural coefficient kerosene*
		Affordability domain		
Wealth index lowest	(1)	(1)	(1)	(1)
2nd	2.14*** (0.84)	1.67* (0.89)	–0.48 (0.49)	0.04 (0.40)
3rd	3.01*** (0.83)	3.34*** (0.94)	–0.61 (0.60)	0.46 (0.40)
Income limits choice of fuel	–1.64*** (0.41)	–1.95*** (0.73)	–0.61 (0.51)	0.14 (0.48)
Price of equipment	–1.33*** (–1.34)	0.05 (0.73)	0.83 (0.50)	–0.13 (0.42)
Fuel is expensive	1.02** (0.47)	0.13 (0.69)	–0.55 (0.55)	–0.31 (0.38)
		Educational qualification		
None	(1)	(1)	(1)	(1)
Primary	–0.18 (0.71)	1.15 (1.31)	0.711 (0.66)	–0.22 (0.51)
Secondary	0.53 (0.57)	1.78 (0.15) (1.22)	0.709 (0.63)	–0.08 (0.50)
Post-secondary	1.53** (0.69)	4.29* (1.56)	0.53 (0.94)	2.32** (1.00)
Employment status	0.15 (0.72)	–1.23 (0.81)	–0.00 (0.60)	–0.65 (0.54)
		Availability domain		
Fuel is available	0.60 (0.57)	1.11 (0.96)	–1.49** (0.65)	1.58** (0.75)
Insecurity of supply	0.98** (1.03)	0.74 (0.69)	–0.05 (0.51)	0.37 (0.39)
		Acceptability domain		
Unacceptable emission	–1.52*** (0.47)	–2.25*** (0.68)	2.09*** (0.49)	–1.89*** (0.40)
Culturally acceptable	–1.79* (1.03)	–0.72 (0.98)	1.09 (0.84)	–0.10 (0.55)
Fast for cooking	1.90*** (0.72)	1.77 (1.27)	0.49 (0.58)	–0.72 (0.48)
Controls age	0.0005 (0.02)	–0.00 (0.02)	0.77*** (0.20)	–0.02 (0.01)
Family size	–0.13 (0.14)	0.01 (0.19)	0.21 (0.15)	0.05 (0.13)
Sex (male)	–1.15 (0.56)	–1.74 (1.18)	–1.74** (0.73)	0.51 (0.57)

Notes: ***$P < 0.01$; **$P < 0.05$; *$P < 0.1$; figures in parentheses are standard errors.

- *Affordability domain:* The price of equipment is perceived as a limitation to LPG use for cooking in urban areas which is not so in rural areas (adjusted log odds = –1.33); LPG is perceived as expensive (adjusted log odds of 1.02) in urban areas.
    a *Kerosene relative to firewood:* Post-secondary education is associated positively with kerosene use for cooking in rural areas (adjusted odds ratio = 2.32) which is not so in urban areas.
- *Availability domain:* LPG is perceived as insecure in supply in urban areas; despite this, it is positively associated with its use relative to firewood (adjusted odds ratio is 0.98); this is not so in rural areas.
- *Acceptability domain:* LPG is perceived as fast in urban areas only with an adjusted odds ratio of 1.90. Unacceptable emission from kerosene is positively associated with its use in urban areas (with adjusted odds = 2.09); however, in rural areas, unacceptable emission is negatively associated to kerosene use for cooking relative to firewood (adjusted odds ratio = –1.89).

5 Discussion

This study investigated factors associated with household fuel choice (LPG, kerosene and firewood) by using a fuel-access framework with three domains: availability, affordability and acceptability domains in rural and urban locations in Ogun State, Nigeria. This framework was adopted because energy access is multi-dimensional and extends beyond affordability (often proxied with income and price) to availability and acceptability of energy access (Remigios, 2014; Zaku et al., 2015).

Our study showed that 40% of the sampled population had access to firewood as their main source of cooking fuel, followed by kerosene and only about a quarter of the household had access to LPG. Similar pattern of access has been observed in literature (Bello, 2016; Ogwumike et al., 2014; Ahmad and Olivera, 2015; Karimu, 2015; Paudel et al., 2018; Oyebanji et al., 2013; Akpalu et al., 2015). Available data showed that 94% of Nigeria's population do not have access to clean energy (REN21, 2018).

Within the affordability domain, wealth and post-secondary education enhance access to LPG relative to firewood while price of equipment and income is a limitation to household use of LPG relative to firewood as discovered in most studies (Ouedraogo, 2005; Ozoh et al., 2018; Heltberg, 2003; Gupta and Kohlin, 2005). Also, rural inhabitants are more at a disadvantage due to poor road network which can increase the cost of distribution of LPG in addition to increased cost of LPG stove (USAID, 2005; Bates, 2009). In case of kerosene, wealth and education facilitates its use for cooking similar to Ozoh et al. (2018).

Availability domain shows location in rural areas as negatively associated with the choice of LPG and kerosene relative to firewood. This is similar to the results of Paudel et al. (2018), Oyebanji et al. (2013), Eleri (2021) and Nnaji et al. (2020). Rural areas due to their low level of development and nature of economic activity (agriculture) have easy access to firewood at little or no financial cost which can inform their choice of fuel for cooking. Urban dwellers value LPG adoption for cooking owing to higher income, the availability of LPG and its time-saving characteristics (Pandey and Morris, 2006; Puzzolo et al., 2013).

Though the evidence to support culture as a barrier to energy access is not sufficient; however, Puzzolo et al. (2013) through a systematic review found that stove designs that do not meet cultural specifications of households in terms of favoured taste, use of available fuel and pot specification make households to revert to traditional stoves. Our findings expound on the negative effect that culture may have on the choice of LPG compared to firewood, this is similar to the observation from Sesan (2012, 2014). In addition reported perceptions around fear of explosion due to leaks and poor quality equipment; also lack of knowledge on safety practices in LPG use has been identified barrier to the adoption of LPG for cooking however, there are obvious submissions that firewood is dirtier than LPG as emission is always above the WHO air quality guidelines (Puzzolo et al., 2013).

Further, the analysis reveals that the perception of LPG as fast is positively associated with its use for cooking. The perception that LPG is a more efficient energy source compared to firewood could be a focal point when enlightening households on its adoption relative to other fuels; this is also emphasised by Puzzolo et al. (2013). Moreover, Terrado and Eitel (2005) discovered that some households switched from firewood to LPG due to its efficiency rate when used for cooking.

The strength of the paper was its ability to draw information from households on multidimensional factors influencing fuel choice accessibility. Although, the data was collected in only one state in Nigeria, the findings have broader applicability to the wider Nigerian population due to the ongoing energy access challenges faced across the country.

6 Conclusions

This study underscores the importance of considering various access-related factors when analysing residential household choices regarding energy barrier and facilitators. It highlights that access to fuel energy options is shaped not only by affordability, such as income and price considerations, but also by proximity to the chosen fuel sources and its cultural acceptability. As the global shift towards clean energy gains momentum, it is imperative to examine how people perceive and embrace the introduction of new fuel sources. Cultural factors can pose significant barriers to the adoption of cleaner choices, making it essential to understand and address these acceptability factors (culture) in the transition towards a more sustainable energy future.

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