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ABIMBOLA OLUYEMISI ADEPOJU¹ AND ADETUNJI ADELEKE²

MULTIDIMENSIONAL HOUSEHOLD ENERGY POVERTY IN RURAL NIGERIA

Abstract

The multidimensional energy poverty of rural Nigerian households was examined. The Multidimensional Energy Poverty Index (MEPI) was utilised to classify households into various energy poverty categories. Ordered logistic regression was employed to determine the factors influencing energy poverty, while multinomial logistic regression was used to assess the factors influencing energy poverty transitions. With a MEPI of 0.662, a headcount of 0.985, and an intensity of 0.668, rural households in Nigeria showed moderate levels of energy poverty. The gender and level of education, housing infrastructures, and asset value played significant roles in the multidimensional energy poverty status of rural households. Consequently, the government and other stakeholders should prioritise the formulation and adoption of diverse policies regarding the underlying factors of energy poverty. The development of human resources through a greater understanding of cleaner energy sources should also be a primary focus of development interventions. As a result of the multidimensional nature of energy deprivation, its factors and transitions may alter over time. Energy policies could be designed to target households at various levels of energy poverty. Priority should be placed on conducting additional research on appropriate intervention measures to reduce energy poverty.

Keywords: Multidimensional Energy Poverty Index, chronic energy poverty, transient energy poverty, clean energy, rural

JEL Codes: C42, I31, O13, Q40

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Introduction

Energy is closely linked to power, force, or fuels. It can be defined as anything that can be utilised to produce work and is essential to daily life and activities for humans (Edoumiekumo, Tombofa & Karimo 2013; Ogunniyi, Adepoju & Olapade-Ogunwole, 2012). Energy thus plays a vital role in every society because it transcends every facet of human life, promotes economic expansion, greater social fairness, and the creation of a striving and thriving environment (United Nations, 2014). More significantly, socio-economic independence and progress depend greatly on the availability and affordability of modern, clean energy services. In reality, the availability of energy from a clean, efficient source for home and industrial use is essential for a nation's prosperity in today's industrialised world. This is because it is a requirement for economic development and liberation (Huang, 2021; Ashagidigbi et al., 2020). It is commonly acknowledged that virtually every aspect of

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human life, including agriculture, industry, health, water, communication, and education, relies on electricity (Bazilian et al., 2010). However, despite its significance for sustaining life and the economy, particularly in Africa, alarmingly low levels of access to electricity and other sources of renewable energy have brought to the fore the notion of the energy poor (Sokona, Mulugetta & Gujba, 2012; IEA, 2010).

For instance, a household is considered energy poor when its members are unable to cook with clean fuels and are unable to study or perform other productive tasks in the dark (Gaye, 2008). The Asian Development Bank defined energy poverty generally as the incapability to acquire dependable, cost-effective, and eco-friendly energy services to promote personal, economic, and commercial growth (Masud, Sharan & Lohani, 2007). Therefore, in poor nations, a lack of access to electricity or an inability to pay for it when it is available causes an exclusive reliance on conventional fuels like firewood, constituting "energy poverty" (IEA, 2010; Sovacool, 2012). The problem of energy poverty is getting worse, especially for people with modest incomes in emerging countries (Pachauri & Spreng, 2004). The bulk of those without access is found in South Asia and sub-Saharan Africa, making up about 25% of the global population (Orji et al., 2020).

Notably, the majority of those living in these locations without electricity could only afford to do so in the rural parts of these developing countries (Ohiare, 2015). For instance, Nigeria dubbed the "giant of Africa," has undoubtedly always struggled with a lack of modern electricity infrastructure. In fact, between 2004 and 2010, over 70% of her population cooked using firewood (National Bureau of Statistics, 2010). This statistic shows a significant amount of energy poverty in the nation, which has serious implications for sustainable development. In addition, due to price fluctuations of kerosene, a common cooking fuel across geopolitical zones in recent times, energy poverty has been exacerbated. Thus forcing households to find and use less expensive alternatives that not only have negative environmental effects but also lead to several health problems (Orji et al., 2020; Ashagidigbi et al., 2020).

Consequently, electricity being readily available is seen as a crucial step toward the elimination or reduction of energy poverty in this region (IEA, 2010; Nussbaumer, Bazilian & Modi, 2012; Agu & Orji, 2015; Orji et al., 2021). Given that a household may not be vulnerable to other indices of healthy living besides energy, the rise in energy-poor households will be especially concerning. This explains why taking a multidimensional approach to household energy status is essential. Therefore, a comprehensive examination of the concept of energy poverty and subsequent intervention in the impacted communities, regions, or zones ought to take precedence in policy discourse. This necessitates a study of the level of multidimensional energy poverty in rural households and its contributing factors.

The concept of multidimensional energy poverty (MEP) was adopted from the literature on multidimensional measures of poverty (Alkire, 2007; Alkire & Foster, 2011a; Alkire & Santos, 2012; Alkire & Foster, 2011b). Fundamentally, the MEP considers the many sets of energy deprivation with diverse indicators that can influence the standard of living in a household. The multidimensional energy poverty index (MEPI) was constructed employing these characteristics and indicators to establish whether or not a household is energy poor. A household is energy poor if the weighted aggregate of its deprivations (i.e. index) surpasses a predefined threshold. Compared to other energy poverty measuring tools, The MEPI places its primary emphasis on the energy services that are ultimately required by households for their day-to-day activities. The MEPI also accounts for the many dimensions of energy poverty, which extend further than headcount and include its severity. Thus, MEPI transcends the oversimplification that other metrics adapt by assuming a binary state. Finally, MEPI's flexibility ensures its suitability for several analyses.

The research contributes to the existing literature in two ways: Although there are many empirical studies on poverty in the literature (Onu & Abayomi, 2009; Obayelu & Awoyemi, 2010; Adeyonu et al., 2012; Olawuyi, 2013; Agu and Orji, 2015; Mba et al., 2018; Orji et al., 2020), there haven't been many efforts made specifically at the national level to address multidimensional forms of energy deprivation (Apere and Karimo, 2014; Bersisa, 2016; Ashagidigbi et al., 2020). Additionally, earlier research that attempted to advance information on energy poverty (Edoumiekumo, Tombofa, and Karimo 2013; Ehinmowo, Ufondu & Aliyu, 2018) were constrained by the fact that they only examined specific regions of the nation. Therefore, by describing the situation of energy poverty across all of Nigeria's geopolitical zones, this study contributes to filling this gap in the literature. Additionally, while the majority of the existent literature (Edoumiekumo et al., 2013; Apere & Karimo, 2014) only employed three indicators in their analysis of the MEPI of households, this study utilised six indicators, thus allowing room for a robust analysis.

To the best of our knowledge, none of the articles on energy poverty that were reviewed addressed the problem of multidimensional energy poverty transitions and their causes. Evidence from related literature, however, suggests that poverty is not static (Mba, Nwosu & Orji, 2018; Adepoju, 2012) and that factors driving poverty and its transitions may change over time. As a result, this study also contributes to knowledge on energy poverty by taking into account two time periods and exploring the factors influencing multidimensional energy poverty transitions. It also gives guidance on which intervention policies would be suitable and can be focused on for an appreciable impact on energy poverty reduction.

Therefore, due to the paucity of empirical studies on multidimensional energy poverty, as the focus of the majority of existing studies on poverty has been on income poverty (Babatunde, Olorunsanya & Adejola, 2008; Akerele & Adewuyi, 2011; Ogwumike & Akinnibosun, 2013; Olawuyi, 2013; Adeyonu et al., 2012), it is pertinent that further research is conducted. Additionally, the few research (Edoumiekumo, Tombofa & Karimo, 2013; Moyib, Ojo & Ayodele, 2017; Ehinmowo, Ufondu & Aliyu, 2018) on energy poverty have not addressed the topic of multidimensional energy poverty transitions and the factors that influence it. Therefore, the purpose of this study is to fill in the gaps in the literature by attempting to address the following research questions: Which households in rural Nigeria can be categorised as energy poor? What factors influence the energy poverty status of rural households in Nigeria? Do households in rural Nigeria experience energy poverty intermittently? What factors influence multidimensional energy poverty transitions in rural Nigeria?

The remaining sections of this paper are organised as follows: The scope of the study, sample and data collection methods, datasets with variables and indicators, and data analysis techniques are all covered in Section 2. The results and discussion of the findings are reported in Section 3. Section 4 concludes with a summary of the key findings, recommendations, and policy implications of the findings.

Materials and Methods

Scope of the Study

The scope of the study is rural Nigeria. Nigeria is located on the Gulf of Guinea in West Africa. Its total land area is 923,768 km² and it lies between latitudes 4° and 14°N and longitudes 2° and 15E. It is the thirty-second largest country in the world. It shares 773 kilometres with Benin in the west, 1497 kilometres with Niger in the north, 87 kilometres with Chad and 1690 kilometres with Cameroon in the east, and a coastline of at least 853 kilometres along the Atlantic Ocean in the south. It is composed of 36 states and the Federal Capital Territory and is separated into six geopolitical zones. Almost 70% of the population is engaged in agriculture, making the country primarily agricultural.

Sample Selection and Data Collection

This study utilised the General Household Survey (GHS) panel data. The households evaluated in the study were selected using a two-stage probability sampling process. Using probability proportional to size, Primary Sampling Units (PSUs) were identified in the first stage. Using this procedure, a total of 500 PSUs from each state and the Federal Capital Territory (FCT) were selected. The second step involved the systematic selection of ten households per PSU. 500 PSUs were canvassed, and 5,000 households, including 3,370 rural households and 1,630 urban households, were interviewed. However, only 2,287 households with complete and relevant data comprised this study's sample size. STATA 14 was used for data analysis.

Analytical Techniques

Multidimensional energy poverty index (MEPI):

To profile the socioeconomic characteristics of the respondents, descriptive statistics were employed. The energy poverty status of each household was estimated using the MEPI following Nussbaumer et al. (2012). MEP and MEP transitions' determination were analysed using ordered and multinomial logistic regression, respectively. For this study, contemporary cooking fuel, indoor pollution, energy access, household appliance, entertainment/education appliance ownership, and telecommunication means were used as proxies to depict energy services as stated in Table 1 (Bersisa 2016; Ehinmowo, Ufondu, and Aliyu 2018; Ozughalu and Ogwumike 2019).

In accordance with the research of Edoumiekumo et al. (2013), the MEP cut-off value k of 0.5 was used. Hence, if a household's weighted deprivation total is less than 0.5, it is not energy poor. On the other hand, moderately energy-poor households experience weighted deprivation that is larger than 0.5 but less than 0.8. A household's total weighted deprivation must be more than or equal to 0.8 to qualify as acutely energy-poor. The dimensions, indicators, variables, and cut-off points utilised to create the MEPI for the study are displayed in Table 1.

Table 1. Dimensions, Indicators and Variables with Cut-offs for Constructing the MEPI
--

Dimension	Indicator (Weight in parenthesis)	Variable	Cut-off (Household is poor if ...)
Cooking	Modern cooking fuel (0.4)	Type of cooking fuel	household uses any fuel in cooking besides electricity, LPG, natural gas or biogas
Lighting	Electricity access (0.2)	Has access to electricity	the household does not have access to electricity for lighting and other purposes
Service from Appliances	Ownership of household appliance (0.13)	Has a/an electric stove, fan, fridge, freezer, air conditioner, electric iron, microwave, washing machine	the household does not enjoy service from at least four of these household assets
Entertainment/Education	Ownership of entertainment/education appliance (0.13)	Has a radio or television	the household does not have at least one of the two
Communication	Telecommunication means (0.13)	Has a mobile phone or GSM	the household does not have at least one

Source: Authors' Computation.

$$A = \sum_{i=1}^n \frac{c_i(k)}{q} \quad (1)$$

$$H = \frac{q}{n} \quad (2)$$

$$MEPI = H * A \quad (3)$$

Where: A represents energy poverty intensity, H is the energy poverty headcount, q is energy poor household, n is the total population, and C_i is the energy poverty index for each household reflecting their deprivations.

Ordered logit model:

Ordered logistic regression was used to obtain the factors influencing the multidimensional energy poverty of rural households in Nigeria. The model is expressed as:

$$\ln \left[\frac{Y_{ij}}{1-Y_{ij}} \right] = \beta_{0j} - (\beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n) \quad (4)$$

The variable definition in the ordered logit model is as follows:

Y_{ij} = 1 represents energy non-poor, the lowest ordered category

Y_{ij} ≤ 2 represents moderately energy poor, the lowest two ordered categories

Y_{ij} ≤ 3 represents acutely energy poor, the lowest three ordered categories

X₁ represents the household head's Age (Years)

X₂ represents the household size (Number)

- X₃ represents the household head's gender (Male = 1, Female=0)
 X₄ represents the household head's primary occupation (Farmer =1, Otherwise=0)
 X₅ represents the household head's marital status (Married = 1, Otherwise=0)
 X₆ represents the household head with no formal education (None =1, Otherwise=0)
 X₇ represents the household head with primary education (Primary = 1, Otherwise=0)
 X₈ represents the household head with secondary education (Secondary=1, Otherwise=0)
 X₉ represents the household house ownership status (Yes = 1, Otherwise=0)
 X₁₀ represents remittances (Yes = 1, Otherwise=0)
 X₁₁ represents credit access (Yes = 1, Otherwise=0)
 X₁₂ represents roof materials (Iron sheets = 1, Otherwise=0)
 X₁₃ represents wall materials (Mud = 1, Otherwise=0)
 X₁₄ represents floor materials (Sand = 1, Otherwise=0)
 X₁₅ represents toilet facility (None =1, Otherwise=0)
 X₁₆ represents assets value (Naira)
 X₁₇ represents the distance to the nearest road (Kilometres)
 X₁₈ represents the distance to market (Kilometres)
 X₁₉ represents North-Central (North-Central = 1, Otherwise=0)
 X₂₀ represents North-East (North-East = 1, Otherwise=0)
 X₂₁ represents North-West (North-West = 1, Otherwise=0)
 X₂₂ represents South-East (South-East = 1, Otherwise=0)
 X₂₃ represents South-South (South-South = 1, Otherwise=0)
 ε_i represents the Stochastic error term

Markov matrix model:

Markov matrix model was used to investigate and examine multidimensional energy poverty transitions of households between wave 2 and wave 3 to ascertain the movement of households in and out of energy poverty over the defined period. The Spell approach was adopted to operationalise the concept of chronic and transient poverty. A poor household in only one period is classified as being transiently energy poor (entering and exiting energy poverty). In contrast, a household that is energy poor in both periods is chronically energy poor.

Multinomial regression model:

In order to investigate the factors that influence energy poverty transitions, a multinomial regression model was used. The model was employed because of its suitability in capturing the various degree of energy poverty among the energy-poor households following Adepoju (2012). Multinomial logistic regression is primarily suitable for a nominal dependent variable that is not ordered but with more than two categories. The dependent variable in this study has four categories which are: always energy-poor (AEP), exiting energy poverty (EXEP), entering energy poverty (ENEP) and always energy non-poor (AENP). Three linear equations were estimated relative to the base category (always energy non-poor) in estimating a multinomial logit with four categories. The equations are explicitly stated as follows:

$$\ln \left[\frac{Pr(Y=AEP)|X}{Pr(Y=AENP)|X} \right] = \beta_0^{AEP} + \beta_1^{AEP} X \quad (5)$$

$$\ln \left[\frac{Pr(Y=EXEP)|X}{Pr(Y=AENP)|X} \right] = \beta_0^{EXEP} + \beta_1^{EXEP} X \quad (6)$$

$$\ln \left[\frac{Pr(Y=ENEP)|X}{Pr(Y=AENP)|X} \right] = \beta_0^{ENEP} + \beta_1^{ENEP} X \quad (7)$$

Where;

X₁ represents the Age of household head (Years)

X₂ represents household size (Number)

X₃ represents gender of the household head (Male = 1, Female=0)
X₄ represents primary occupation of the household head (Farmer =1, Otherwise=0)
X₅ represents the household head's marital status (Married = 1, Otherwise=0)
X₆ represents the household head with no formal education (None =1, Otherwise=0)
X₇ represents primary education of household head (Primary = 1, Otherwise=0)
X₈ represents secondary education of the household head (Secondary=1, Otherwise=0)
X₉ represents house ownership status (Yes = 1, Otherwise=0)
X₁₀ represents remittances (Yes = 1, Otherwise=0)
X₁₁ represents credit access (Yes = 1, Otherwise=0)
X₁₂ represents roof materials (Iron sheets = 1, Otherwise=0)
X₁₃ represents wall materials (Mud = 1, Otherwise=0)
X₁₄ represents floor materials (Sand = 1, Otherwise=0)
X₁₅ represents toilet facility (None =1, Otherwise=0)
X₁₆ represents assets value (Naira)
X₁₇ represents the distance to the nearest road (Kilometres)
X₁₈ represents the distance to market (Kilometres)
X₂₉ represents Regional dummy (North-Central = 1, Otherwise=0)
X₂₀ represents Regional dummy (North-East = 1, Otherwise=0)
X₂₁ represents Regional dummy (North-West = 1, Otherwise=0)
X₂₂ represents Regional dummy (South-East = 1, Otherwise=0)
X₂₃ represents Regional dummy (South-South = 1, Otherwise=0)
ε_i represents the Stochastic error term

Results and Discussion

Socioeconomic Characteristics of Respondents

Table 2 provides information about the respondents' socioeconomic characteristics. The average age of household heads was 54 years, and 68.3% of them were between the ages of 40 and 69. This reflects that household heads who are in their productive years are predominant in the study area. Also, more than four-fifths of the respondents were married. This result is similar to the findings of Ashagidigbi et al. (2020), Bersisa (2016), and Omotesho and Muhammad-Lawal (2010). Furthermore, the majority of household heads have primary education. This could be ascribed to farming being the prevalent livelihood in the study area, which requires little or no formal education. This finding corroborates the findings of Adepoju (2012), who indicated that the majority of rural family heads had only completed primary school. In addition, about four-fifths of respondents as shown in Table II were engaged in farming as their primary occupation, demonstrating the reliance of rural households in Nigeria on agriculture for their livelihoods and sustenance. In addition, the average size of the respondents' households was eight individuals. This strongly suggests a labour force that is active and positively promotes agricultural activity. This finding supports the results obtained by Okoedo-Okojie and Onemolease (2009). Male-headed households were predominant in the research area and were responsible for arduous agricultural tasks such as land preparation, whilst females frequently undertook complementary responsibilities such as crop processing.

About four-fifths (80.2%) of rural households lacked access to credit facilities. This is likely due to the high percentage of financial illiteracy in Nigeria's rural communities (Matewos, Navkiranjit, & Jasmindeep, 2016). In addition, almost all (96.9%) of the respondents lack access to remittances, which may have provided extra revenue for households. A substantial proportion (67.0%) of rural households have access to electricity; however, about half of the respondents rely heavily on dry cells (torch) for lighting purposes. This demonstrates the incapacity of rural households to utilise or benefit from electricity despite having access to it. As seen in Table 2, firewood is the principal source of cooking fuel for the majority of rural families in Nigeria. Consequently, respondents are exposed to the health

risks associated with inhaling smoke generated from the use of firewood. This result is comparable to those of Ozughalu & Ogwumike (2019) and Bersisa (2019). They observed that more than three-fifths of households depend on firewood for food preparation, confirming the prevalence of energy poverty among rural households.

Table 2a. Socioeconomic Characteristics of Respondents (following in next page: Table 2b)

Variable	Frequency	Percentage (%)
Age		
< 40	382	16.7
40-69	1563	68.3
70-99	338	14.8
≥ 100	4	0.2
Marital Status		
Married	1954	85.4
Separated	46	2.0
Widowed	266	11.6
Never married	21	0.9
Educational Level		
No formal education	359	15.7
Primary education	1440	63.0
Secondary education	276	12.1
Tertiary education	212	9.3
Household Size		
< 5	369	16.1
5-9	1259	55.1
10-above	659	28.8
Primary Occupation		
Farming	1861	81.4
Non-farming	426	18.6
Gender		
Male	2044	89.4
Female	243	10.6
House Ownership Status		
Owned	2047	89.5
Free, authorized	173	7.6
Free, not authorized	13	0.6
Rented	54	2.4
Credit Access		
Yes	453	19.8
No	1834	80.2
Electricity Access		
Yes	1533	67.0
No	754	33.0
Access to Remittances		
Yes	71	3.1
No	2216	96.9

Source: Authors' Computation.

Table 2b. Socioeconomic characteristics of respondents

Variable	Frequency	Percentage (%)
Lighting Fuel		
Firewood	203	8.9
Grass	2	1.0
Kerosene	488	21.3
Electricity	459	20.1
Generator	92	4.0
Dry cell (Torch)	1031	45.1
Candles	12	0.5
Cooking Fuel		
Firewood	2157	94.3
Charcoal	6	0.3
Grass	6	0.3
Kerosene	92	4.0
Electricity	5	0.2
Generator	4	0.2
Gas	17	0.7
Geopolitical Zone		
North-Central	428	18.7
North-East	414	18.1
North-West	614	26.9
South-East	409	17.9
South-South	298	13.0
South-West	124	5.4
Total	2287	100.0

Source: Authors' Computation.

Rural Households' Multidimensional Energy Poverty Indices

Table 3 reveals that almost all rural households are energy poor and have been deprived in at least 67% of weighted indicators. MEPI's adjusted headcount ratio of 66.0% indicates moderate energy poverty in rural Nigeria. This corroborates the findings of Apere & Karimo (2014), in which energy deprivation was moderate in rural Nigeria but severe in urban areas. South-South and South-East have the greatest MEPI (69.0%) and energy poverty intensity scores (71.0% and 70.0%, respectively) when disaggregated by region. The South-West area had the highest energy poverty headcount at 100 percent, showing that all rural households in the area are deficient in at least 50 percent of the weighted categories. This result is comparable to that of Ehinmowo et al. (2018), who stated that southern Nigerian zones are somewhat energy deficient. In contrast, the North-East has the lowest MEPI and intensity at 64.0%.

Table 3. Multidimensional household energy poverty indices by geopolitical zones

Zones	Headcount	Intensity	MEPI	Degree of Energy Poverty
Rural Nigeria	0.9895	0.6686	0.6616	Moderate
North-Central	0.9813	0.6590	0.6466	Moderate
North-East	0.9952	0.6437	0.6406	Moderate
North-West	0.9951	0.6585	0.6553	Moderate
South-East	0.9902	0.6995	0.6926	Moderate
South-South	0.9765	0.7069	0.6903	Moderate
South-West	1.0000	0.6409	0.6409	Moderate

Source: Authors' Computation.

Factors Influencing Rural Households' Multidimensional Energy Poverty

Table 4 displays the marginal effects of the ordered logistic regression variables. The findings of the diagnostic test point to the fact that the model fits the data effectively. In particular, the findings demonstrated that a lack of formal education, primary education, flooring materials, and residence in the South-South zone of Nigeria positively affected the multidimensional energy poverty of rural households. In contrast, gender, roofing materials, asset value, and distance to the nearest market had negative effects. Higher levels of education incline households to earn higher wages relative to their counterparts and to make informed decisions regarding energy consumption. Hence, heads of households who have only an elementary education or none at all have a greater likelihood of having insufficient access to electricity. In particular, the likelihood of living in an acutely energy-poor household rose by 5.0% and 7.3%, respectively, for household heads with elementary education or none at all. This agrees with the findings of Edoumiekumo et al. (2013), in which educated heads of households were less probable to be in extreme energy poverty. In addition, households with sand, dirt, or straw floors, indicative of traditional living conditions, were more likely to have insufficient access to electricity. As such, a change in the flooring material improves the likelihood of being energy-efficient by 0.3% and fairly energy-efficient by 2.2%, respectively. It decreased the likelihood of an acute energy deficiency by 2.5%.

In addition, living in the South-South geopolitical zone increased the likelihood of acute energy poverty by 8.2%. However, on the other hand, it reduced the probability of being energy-non-poor and moderately energy poor by 0.4% and 7.8%, respectively. This is consistent with the findings of Ozughalu & Ogwumike's (2019) observation in which households residing in the South-South geopolitical zone had the highest prevalence of extreme energy deprivations. Negatively significant, the gender of the household head variable indicates that male-headed households are less likely to be in the upper category of energy poverty status. Thus, the risk of being acutely energy-poor fell by 4.6% for male-headed households and is projected to increase by 4.6% for moderately energy-poor households. This finding is again supported by the findings of Ozughalu & Ogwumike (2019) of an inverse association between the gender of the household head and extreme energy poverty. Furthermore, the roofing material variable which was used as a proxy for dwelling condition was negatively significant. This implies that households with iron sheets used as their roofing material are likely to fall into a lower category of energy poverty, indicating better living conditions. Thus, a change in roofing materials is projected to result in a 3.6% decrease among households with extreme energy poverty. The closer a household was to the nearest market, the more likely it was to fall into the lowest energy poverty group. A change of one kilometre in the distance travelled to the market from the household will result in a 0.5% decrease in households' acute energy poverty.

Table 4. Determinants of multidimensional energy poverty status of rural households

Variable	Energy non-poor	Moderately energy-poor	Acutely energy-poor	Coefficient	Z-value
Age	0.0000	0.0003	-0.0003	-0.0049	-0.86
Household size	0.0000	0.0005	-0.0006	-0.0093	-0.39
Gender	0.0030*	0.0431*	-0.0461*	-0.6270	-1.73
Primary occupation	-0.0004	-0.0032	0.0035	0.6110	0.30
Marital Status	-0.0012	-0.0095	0.0107	0.1935	0.56
No formal education	-0.0041**	-0.0684**	0.0725**	0.9225	2.35
Primary education	-0.0063**	-0.0433**	0.0496	0.9141	2.55
Secondary education	-0.0025	-0.0321	0.0346	0.4963	1.24
House ownership	0.0021	0.0257	-0.0277	-0.4080	-1.81
Remittances	0.0057	0.0250	-0.0307	-0.6845	-1.46
Credit access	-0.0019	-0.0210	0.0229	0.3539	1.98
Roof materials	0.0053***	0.0308***	-0.0361***	-0.7230	-2.86
Wall materials	0.0011	0.0099	-0.0109	-0.1848	-1.00
Floor materials	0.0027**	0.0224**	-0.0251**	-0.4340	-2.27
Toilet facilities	0.0000	0.0005	-0.0005	-0.0086	-0.05
Assets value	1.47e-08***	1.31e-07***	-1.46e-07***	-2.48e-06	-5.79
Distance to nearest road	0.0000	-0.0003	0.0003	0.0052	0.51
Distance to nearest market	0.0005***	0.0004***	-0.0005***	-0.0082	-3.61
North- Central	0.0009	0.0073	-0.0082	-0.1448	-0.35
North-East	-0.0003	-0.0023	0.0026	0.4361	0.10
North-West	-0.0017	-0.0171	0.0188	0.2997	0.71
South-East	-0.0016	-0.0174	0.0191	0.2972	0.73
South-South	-0.0043**	-0.0777**	0.0820**	0.9971	2.49
Number of Obs.	2287				
LR Chi ² (23)	158.6900				
Prob > Chi ²	0.0000				
Pseudo R ²	0.1001				
Log-likelihood	-713.5409				

Source: Author's Computation *** Significant at 1%, ** at 5%, and * at 10%.

Energy Poverty Transitions

As presented in Table 5, between waves 2 and 3, 1.4% and 0.1% of the non-energy-poor households moved into the moderately and acutely energy-poor households groups, respectively. Also, 0.6% and 6.0% of the moderately energy-poor households from wave 2 moved into the energy non-poor and acutely energy-poor categories, respectively, in wave 3. Furthermore, between waves 2 and 3, 0.3% and 39.9% of acutely energy-poor households migrated into the non-energy-poor and moderately energy-poor groups, respectively. This corroborates the findings of Adepoju (2012) and Mba et al. (2018), who found that poverty status fluctuates over time. Consequently, households continuously enter and exit poverty over periods. Using Spell's approach, Table 6 displays the percentage of households in each energy poverty category. The chronic energy poverty rate was 61.4% and the transitory energy poverty rate was 17.0%, demonstrating that most rural Nigerian households are chronically energy poor. In contrast, 13.7% of transiently energy-poor households escaped energy poverty, whereas a smaller proportion (3.2%) fell into energy poverty

Table 5. Transition matrix of household energy poverty status

Wave 2	Wave 3			
	Non-Poor	Moderately Poor	Acutely Poor	Total
Non-Poor	4(0.2)	32(1.4)	3(0.1)	39(1.7)
Moderately Poor	14(0.6)	1126(49.2)	138(6.0)	1278(55.9)
Acutely Poor	6(0.3)	912(39.9)	52(2.3)	970(42.4)
Total	24(1.1)	2070(90.5)	193(8.4)	2287(100.0)

Source: Authors' Computation.

Table 6. Multidimensional energy poverty transition status

Energy Poverty Status	Frequency	Percentage
Always Energy Non-poor	496	21.7
Entering Energy Poverty	74	3.2
Exiting Energy Poverty	314	13.7
Always Energy Poor	1403	61.4
Total	2287	100.00

Source: Authors' Computation.

Drivers of Transitions in Multidimensional Energy Poverty In Rural Nigeria

Table 7 provides the findings of multinomial logistic regression for rural household energy poverty transitions using the same set of explanatory factors as the multidimensional energy poverty determinants. The determinants were interpreted in terms of the relative risk ratios (RRR) of the explanatory factors in comparison to the base category. The base category is 'always energy non-poor households. The estimated Chi-square value was 1223.90 and statistically different from zero at a 1% significance level, suggesting that the model was well-fitted and the accuracy of the composite error term is guaranteed.

Entering energy poverty:

Energy poverty is a function of marital status, roofing materials, toilet facilities, asset value, and geographical location in the North-East. While marital status, roofing materials, toilet facilities, and residing in the North-East geopolitical zone had beneficial effects on energy poverty, asset value had the opposite effect. Income utilisation is expected to be high among married household heads, translating to energy poverty. By this, married household heads have a 4.5 times greater chance of slipping into energy poverty. In addition, type of household features, such as roofing materials and toilet facilities, raised the probability of slipping into energy poverty by 2.5 and 3.0 points. Being in the North-East geopolitical zone had a positive effect on the transition into energy poverty, suggesting that

households in this geopolitical zone were 4.3 times more likely to fall into energy poverty. In contrast, when assets are employed productively, households are better off and can meet their demands in an emergency more rapidly. Thus, higher household asset accumulation reduces the likelihood of energy poverty. In other words, an increase of one Naira in the value of a household's assets reduces the likelihood of falling into energy poverty by a factor of one. This agrees with the findings of Amao et al. (2017).

Exiting energy poverty:

Household head age had a negative effect on the probability of exiting energy poverty, whereas primary occupation, wall materials, roof materials, toilet facilities, distance to market, and being in the North-East geopolitical zone had favourable effects. Age was negatively significant at 1.0%, indicating that a one-year increase in the age of the household head decreased the probability of households moving into the energy non-poor category by a factor of 1. Nonetheless, the positive effect of primary occupation on the probability of exiting energy poverty suggests that farming as a primary source of income enhances the probability of escaping energy poverty. Similarly, wall materials, floor materials, and toilet facilities all boost the likelihood of escaping poverty, indicating that access to improved housing infrastructure is an effective strategy for reducing energy poverty. Moreover, the distance from the market doubles the likelihood of escaping energy poverty by a factor of 1. In conclusion, energy-poor households will exit energy poverty in the following period due to improved housing conditions and closeness to markets, but aging will be a factor that perpetuates energy poverty.

Always energy poor:

Table VII indicates that levels of education, primary occupation, wall material, floor material, roof material, toilet facilities, distance to road, distance to market, and living in the North-East geopolitical zone all enhance the likelihood of chronic energy poverty. On the other hand, factors such as age, household size, credit access and asset value decreased the likelihood of chronic poverty in the study area. The interaction between chronic energy poverty and lack of formal education and primary education was strong. Specifically, an additional year of no formal education and the household head's primary education increased the likelihood of energy poverty odds by 2.0 and 2.4, respectively. This finding confirms the hypothesis that a low education level is closely connected with household energy poverty status (Adepoju, 2012; Muyanga et al., 2018). The absence or low levels of formal education may prevent households from gaining access to important information required to escape multidimensional energy poverty.

Similarly, farming as a primary occupation increased the likelihood of chronic energy poverty by a factor of 2.7. Furthermore, living in a house where straw, sand, dirt, pit, and mud are used as wall materials, floor materials, and toilet facilities increases the odds of remaining chronically energy poor as it depicts a low standard of living. On the other hand, the effect of household size on the likelihood of remaining energy-poor was negative. This suggests that an additional household member decreases the likelihood of energy poverty. This can be seen as the result of increasing family labour, which has led to greater productivity. This result corroborates Okoedo-Okojie and Onemolease's (2009) assertion that family labour is the predominant form of labour used in farming. Also, access to credit correlates adversely with chronic energy poverty by a factor of 1, indicating that people with access to credit are more likely to escape energy poverty.

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Table 7. Determinants of Multidimensional Energy Poverty Transitions in Rural Nigeria

Variable	Entering Poverty			Exiting Poverty			Chronic Poverty		
	RRR	Coeff.	Z	RRR	Coeff.	Z	RRR	Coeff.	Z
Age	0.991	-0.0093	-0.88	0.981	-0.0191	-2.92***	0.988	-0.0123	-2.16**
Household size	0.966	-0.0348	-0.82	0.996	-0.0045	-0.18	0.912	-0.0926	-4.02***
Gender	0.298	-1.2108	-1.38	.586	-0.5341	-1.26	0.446	-0.8068	-2.29**
Primary occupation	1.035	0.0344	0.11	1.649	0.4999	2.73***	2.695	0.9913	5.59***
Marital status	4.527	1.5101	1.76*	1.572	0.4527	1.19	1.253	0.2259	0.71
No education	1.829	0.6039	1.03	1.570	0.4513	1.44	2.049	0.7176	2.31**
Primary education	1.973	0.6793	1.33	1.333	0.2874	1.13	2.374	0.8646	3.27***
Secondary education	1.146	0.1366	0.23	1.091	0.0869	0.30	1.223	0.2016	0.67
House ownership	0.856	-0.1557	-0.35	0.892	-0.1148	-0.46	0.928	-0.0745	-0.32
Remittances	2.092	0.7379	1.10	0.839	-0.1752	-0.38	1.699	0.5301	1.33
Access to credit	0.739	-0.3017	-0.89	0.983	-0.0167	-0.09	0.709	-0.3512	-2.03**
Wall materials	1.270	0.2389	0.76	1.947	0.6662	3.38***	2.274	0.8213	4.74***
Roof materials	2.477	0.9069	1.68*	3.262	1.1824	2.93***	5.547	1.7131	4.61***
Floor materials	1.586	0.4609	1.40	1.169	0.1564	0.72	2.136	0.7590	4.08***
Toilet facilities	3.009	1.1017	3.42***	2.111	0.7475	3.69***	3.575	1.2740	7.00***
Assets value	0.999	-4.74e-06	-2.39**	0.999	-4.67e-7	-1.16	0.999	-7.27e-06	-7.06***
Distance to road	1.013	0.0129	0.62	1.016	0.0158	1.29	1.052	0.0503	4.54***
Distance to market	1.002	0.0022	0.54	1.007	0.0074	3.01***	1.010	0.0095	4.26***
North-Central	0.673	-0.3956	-0.54	0.867	-0.1430	-0.33	1.079	0.0765	0.19
North-East	4.304	1.4597	1.88*	2.388	0.8703	1.78*	6.214	1.8268	4.01***
North-West	1.693	0.5266	0.72	0.809	-0.2108	-0.46	1.881	0.6316	1.52
South-East	0.815	-0.2046	-0.30	0.742	-0.2977	-0.69	0.487	-0.7197	-1.84*
South-South	0.341	-1.0744	-1.39	0.670	-0.4004	-0.94	0.513	-0.6678	-1.70*
Number of observations	2,287								
Log-likelihood	-1709.0611								
LR chi ² (69)	1223.90								
Pseudo R ²	0.2637								

Source: Author's Computation *** Significant at 1%, ** at 5%, and * at 10%.

Conclusions

The prevalence of energy poverty in rural Nigeria as confirmed by this study necessitates a deeper understanding of its multidimensionality at the household level. The majority of rural households suffer from moderate energy poverty, with a larger proportion relying primarily on unclean energy sources. Furthermore, energy-poor households are heterogeneous, since some households enter and exit energy poverty while others remain poor. Thus apart from prioritizing government interventions in the geopolitical zones with the highest incidence of energy poverty in rural Nigeria, efforts should be targeted at transiently energy-poor households and predisposing factors which may change over time. For instance, energy policies that target households at various phases based on their energy poverty

status could be developed. Also, enhancing the development of human capital to gain insight into cleaner energy sources and by extension a reduction in energy poverty among rural households in Nigeria could be a step in the right direction. In partnership with corporate entities and non-governmental organisations, policies that will fund initiatives such as household energy support programmes, which are required to transition chronically energy-poor households into energy-non-poor households could be developed. In addition, adequate programmes to raise awareness of the environmental and health risks associated with the use of unclean energy sources, such as firewood could be designed. In addition, rural community markets could aid in the sale of agricultural products and bring households closer to modern energy sources.

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