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Spatial Profiles and Determinants of Multidimensional Energy Poverty in Rural Nigeria

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ABSTRACT

This study aims at examining the multidimensional energy poverty (MEP) and its determinants in six geo-political zones of rural Nigeria. We utilized the 2018/2019 Nigeria Living Standard Survey (NLSS) data collected by the National Bureau of Statistics (NBS) in collaboration with World Bank. The data were analyzed using descriptive statistics, Multidimensional Energy Poverty Index (MEPI), Analysis Of Variance (ANOVA), Tobit model, and Pearson correlation. The analysis showed that over 90% of the respondents live below the MEP line with the North East (NE) and South West (SW) having the highest (98.7%) and lowest (82%) respectively. The intensity of MEP at the national level was 0.330. The results of the multidimensional energy poverty index (MEPI) which stood at 0.31 in the country, was highest in the NE (0.345) and lowest in the SW (0.279). Although with varying strength of relationships across the zones, cooking, lighting, and kitchen appliances are notable dimensions that have a significant positive correlation with aggregate MEP. Education, sex, and occupation of the household head as well as household size and monthly expenditure are determinants of the MEP in the country. There are implications for zone-specific and women-focused interventions relating to clean energy and access to kitchen appliances.

Keywords: Zonal differences, Energy poverty, Multidimensional, Rural areas, Nigeria
JEL Classifications: I3, I32

1. INTRODUCTION

Energy is an important fulcrum upon which the economic development of many nations hinges. It is an important resource that is required by all and sundry in one form or the other. For instance, it is required for cooking, heating, lighting, vital medical care, powering of basic gadgets for communication, and education. Productive activities such as agriculture, industry, manufacturing, and trade are made possible through the availability of energy (Modi et al., 2006). There is no gainsaying that energy plays a significant role in the development of many countries of the world. Energy is vital to industrialization which is a foremost requirement for economic development. Access to a sufficient supply of energy is indispensable for optimal production in both industrializing and industrialized world. The recognition of energy as a major input in the development process resulted in the United Nation's dedication of sustainable development goal 7. The goal is to ensure that all and sundry can access and afford a reliable and sustainable modern energy come year 2030.

Nonetheless, roughly 840 million persons continually lacked access to modern electricity services and almost 2.6 billion comprising about 37% of the world population continue to use firewood, charcoal and sawdust to meet their basic energy requirements for cooking (International Energy Agency [IEA], 2019). This is why MEP remains one of the most precarious challenges facing the world currently. Reliance on biomass, charcoal, firewood, and agricultural crop residues, as cooking fuels for indoor use has a great harmful effect on human health. According to IEA (2017), indoor air pollution leads to about 3 million preventable deaths yearly worldwide, and almost 44% and 34% of this are children and women respectively. Even though much of the challenges of energy poverty are manifest in many developing nations (Nussbaumer et al., 2013), the developed nations are also not spared of the energy poverty with its attendants' influence on economic, health, and environmental, social, and political consequences (IEA/International Renewable Energy Agency/United Nations Statistics Division/World Bank/WHO, 2019). The problem of energy poverty in developing nations is further fueled and aggravated by challenges of climate change, food and shelter poverty, and scarcity of water.

Energy poverty presently impacts negatively many regions of the world. For instance, the global population with electricity deficit decreased from over 1 billion in 2010 to about 840 million in 2017. In the meantime, the number of persons that lacked access to clean cooking facilities was about 3 billion in 2016 and were dispersed across Asia and Africa. Sub-Saharan Africa (SSA) is the region with the most access deficit: 573 million persons which translates to over 50% were denied access to electricity in 2016. While the urban access rate stood at 97% in 2017, the rate was 79% in rural areas in 2017 (IEA/International Renewable Energy Agency/United Nations Statistics Division/World Bank/World Health Organization, 2019). Almost 3 billion persons lack modern cooking fuels and technology, and of the 840 million persons with electricity deficit, 87% are rural dwellers. Before the advent of COVID-19, 28 poor countries may not be able to attain SDG 7 by 2030 Moyer and Hedden (2020), this will likely increase during COVID-19 and post COVID-19 era. International Energy Agency (2017) observed that when compared to other regions in the world, SSA is the most electricity-poor region. At present, about 588 million people in SSA lacked access to electricity, and 783 million people lack access to modern cooking sources in the region. Though the region is afflicted with energy poverty, its endowment of energy resources should be more than enough to cater for its total energy needs if they are well planned and evenly distributed (IEA, 2017).

Nigeria, which is the most populous nation in sub-Saharan Africa (SSA) and the leading economy in Africa. The country is endowed with a huge portfolio of energy resources, but just about 61% of her inhabitants can easily access electricity while a mere 6% of its entire populace can access modern cooking apparatus (IEA, 2017). Those that had access to electricity from the main grid are faced with rationing and blackouts which resulted in their reliance on personal generating sets with its attendant noise and environmental pollution. The country has one of the lowest level of net electricity generation per head globally (IEA, 2017). The electricity consumption per capital was just about 149 kilowatt in 2011 and this was far below that of Malaysia (4246 kilowatt) whose economy lagged behind Nigeria in the 1970s (World Bank, 2015). Nigeria is often threatened with the challenge of inadequate access to clean energy sources for most of her inhabitants which signifies the existence of substantial energy poverty. The country is presently struggling to make clean energy available for all her inhabitants. This has resulted in the massive use of fossil fuels and traditional biomass (IEA, 2016). In Nigeria, there is a huge gap between electricity supply and demand which makes access unreliable, and cost expensive. Despite the ample renewable energy endowment, almost 56% of the households in the nation relied mainly on firewood for cooking (IEA, 2017). The abovementioned indicates that there is remarkable existence of energy poverty in Nigeria.

The consequences of this are enourmous. Firstly, in the face of climate change, this poses a tremendous threat to the global ecosystem. In Nigeria, firewood, charcoal and sawdust are the predominant sources of fuel for cooking particularly in rural areas (Ibitoye, 2013). The rural dwellers usually collect the firewood from the nearby forests in the villages, whereas, their urban counterparts usually buys it from the local sellers at a lower price compare to kerosene and Liquefied Petroleum Gas (Ibitoye, 2013). The households also buy charcoal from local or rural vendors depending on the consumers' location. The high reliance on firewood and charcoal for cooking has given rise to diminution of many forests in the country in addition to the destruction of numerous natural ecosystems (Gujba et al., 2015). Secondly, the emission of air contaminants which emanates from the burning of firewood in ineffective stoves have great negative health effects and contributes to about 79,000 deaths per annum in Nigeria (WHO, 2017). This can be ascribed to high income poverty among many households in the country which in turn lowers their ability to escape energy poverty (Dioha and Emodi, 2019). Lastly, the inadequate supply of modern energy sources has taken its toll on general poverty, unemployment, food insecurity, and poor education as exposed by COVID-19 lockdown when teaching-learning activities were suspended in most parts of rural Nigeria.

Insufficient supply of, and poor access to improved energy sources will lead to high shortage in meeting households' basic energy requirements such as cooking, lighting, kitchen appliances, entertainment/education as well as communication. Cultural norms are also a micro determinants in the choice of energy sources for cooking and other needs (Dioha, 2018). Deficiencies in one or more of the aforementioned dimensions constitute MEP.

With the declaration of SDGs, stakeholders have put a lot of discursions and efforts are ongoing on how to provide a majority of the households in Nigeria with electricity from the main grid/mini grid/solar and modern cooking apparatus by 2030. Many players (civil societies, government, and non-governmental groups) are active participants in the struggle. However, how much of the efforts will translate into a reality in no distant time is yet to be seen. Providing empirical evidences across the geopolitical zones of the country can guide decisions on clean energy provision and stimulate accelerated reduction in MEP. Hence, this research effort aimed to unfold the level of MEP and its determinants across the six zones in Nigeria.

2. LITERATURE REVIEW

2.1. Sources of Energy and Concept of Energy Poverty

Continuous supply of affordable, accessible, and eco-friendly energy in a sustainable term is a prerequisite for the short and long-term economic growth of any nation. There are two main sources of energy that individuals and households make use of. They are the: traditional and modern sources. While the former is primitive, unsophisticated, and based on low technology, the latter is sophisticated and based on improved technology. Examples of traditional sources are charcoal, crop residue firewood, and sawdust (United Nations Development Programme (UNDP) and WHO, 2009; World Bank, 2012; Sher et al., 2014). On the other hand, the modern sources of energy are electricity, gas, and kerosene (UNDP and WHO, 2009; Ogwumike and Ozughalu, 2012; World Bank, 2012; Sher et al., 2014). It is worthy to note that the above classification is not mutually exclusive. For instance, kerosene that is categorized as a modern source may be regarded as traditional if used for lighting or kerosene stove used in a residential apartment. Largely, modern energy sources are more environment friendly than primitive sources because the rate of environmental pollution in the formal is lower than in the latter.

It was the above the classification that led Robic et al. (2012) and Sher et al. (2014) to conceptualize energy poverty as a lack of access to viable improved energy services and products. This is an indication that those whose energy needs are met through traditional sources only are categorized as energy poor. Foster et al. (2000); Khandker et al. (2010); Pachauri and Spreng (2011); Robic et al. (2012) in their study conceptualize energy poverty based on least physical levels of basic energy requirements, least energy expenditure needed, access to improved energy sources, and highest percentage of energy expenditure in relation to total expenditure. On the other hand, Laldjebaev et al. (2016) define energy poverty as 'inadequate access to electricity linkages; or reliance on burning solid biomass, such as dung, firewood, and straw in ineffective and polluting stoves to meet household energy requirements.

2.2. Empirical Literature on Energy Poverty

Researchers' interest in energy poverty study has deepened in recent times. Notable among those that have delved into this study area include (Ahmed and Gasparatos, 2020; Ajetunmobi and Oladeebo, 2020; Ashagidigbi et al., 2020; Bersisa, 2016; Edoumiekumo et al., 2013; Gupta et al., 2020; Karakara and Dasmani, 2019; Malla, 2013; Nussbaumer et al., 2013; Ogwumike and Ozughalu, 2016; Ozughalu and Ogwumike, 2018; Padda and Hameed, 2018; Papada and Kaliampakos, 2016; Sadath and Acharya, 2017; Sanusi and Owoyele, 2016; Sher et al., 2014).

Ajetunmobi and Oladeebo (2020) employed energy expenditure techniques and logistic regression to examine energy poverty and its determinants using primary data collected from rural and urban households in Nigeria. They opined that about 72% and 70% of rural and urban households respectively were energy poor. They further reported that household head's level of education, household size, total income, and expenditure on transportation and food significantly explained energy poverty in the study area. Ahmed and Gasparatos (2020) relied on primary data collected from farm households in Ghana to examine MEP in rural areas. The data were analysed with multidimensional energy poverty index (MEPI) and bootstrap resampling. The authors found that MEP varies among the different categories of farm households and that this was influenced by gender and total household income. Another study conducted on MEP in Nigeria by Ashagidigbi et al. (2020) employed MEPI and Tobit regression to analyse secondary data. The authors reported that the mean MEPI in Nigeria was 0.38 and this was higher in rural (0.47) than urban (0.17) areas. The determinants of MEP are age and sex of the household head, household income, access to credit, sector, and zonal variables.

The data derived from a national household survey conducted in Ethiopia was employed by Bersisa (2016) to examine MEP among rural dwellers in the country. Multidimensional energy poverty index was developed and being longitudinal data, fixed and random effect logit models were used to analyse the data. The researcher pointed out that over 72% of the respondents were energy-poor and this rate was influenced by age and sex of the household head, household size, and total household expenditure among others. Also, Edoumiekumo et al. (2013) researched MEP in one of the six geo-political zones in Nigeria. Secondary data used was analysed with the MEPI technique and multinomial logit regression. The authors opined that almost 83% of the sample were energy-poor and this was explained by: Sex; level of education and occupation of household head as well as the sector of residence. Similarly, a study on the regional differential of household energy poverty was conducted in India using secondary data. The data were subjected to household energy poverty index and principal component analysis. They found that more than 25% of studied households are in the 'most energy poor' group, and 65% of the households are in the 'more and most energy poor' class. The incidence of energy poverty in the country is high and higher in the eastern states and north-eastern states than in other areas (Gupta et al., 2020). In the same vein, Karakara and Dasmani (2019) relied on secondary data to measure sector differential in MEP in the study area. Authors developed MEPI for the study and reported that the prevalence of MEP was 57% among rural households and 43% among their urban counterparts.

Furthermore, Nussbaumer et al. (2013) researched global MEP with secondary data. The outcomes of their study show that MEP varies across the nations of the world and is higher in Africa than other continents studied and in SSA than Northern Africa. In their study of MEP among households in Nigeria, Ogwumike and Ozughalu (2016) utilized nationally representative secondary data. Given the focus of the study, the authors constructed MEPI and employed a headcount ratio and logistic model to analyse the data. The study reveals that over three-quarters of Nigerians were energy-poor and that: age, sex, and educational level of household head; household size; income poverty; and zonal variables are among the determinants of MEP status. Equally, in 2018, Ozughalu and Ogwumike (2018) measured the incidence and determinants of extreme MEP using nationally representative secondary data. The MEPI derived show that over 20% of the households in Nigeria were on the extreme side of energy poverty. Sectoral and zonal decomposition of extreme MEP in the country shows that the rural sector in the northern part of the country is the most hit by extreme poverty in the nation. From the results of the binary logit model, the authors opined that the factors that explained extreme MEP are age; education level and sex of household head, household composition, and regional factors.

In another study, Padda and Hameed (2018) adopted MEPI to determine the rate of energy poverty among rural and urban dwellers in the study area using secondary data. They revealed that the MEP in rural areas of Pakistan was 71.4% rural and 28.6% in urban areas. According to the submission of Papada and Kaliampakos (2016), about 58% of Greece households were multidimensionally energy poor in 2015. This is the outcome of the study collected from 400 households and analysed using the expenditure approach. In other to determine spatial differential in energy poverty among households in Nigeria, Sanusi and Owoyele (2016) used secondary data. The data were analysed with Energy Development Index and regression. It was revealed that while there was high energy poverty in the country with 0.274 EDI, the southern region had 0.365 EDI and the northern part with 0.177 EDI was the most energy poor. The two determinants of energy poverty in the nation are household size and the state's internally generated revenue. Sadath and Acharya (2017) employed MEPI to analyse secondary data collected on Indian households. They found that there is pervasive MEP in the country and it is influenced by religion, occupation, gender of fuel collector, time allocated to fuel collection, and household income. Sher et al. (2014) also investigated MEP among Pakistan households with secondary data by employing Alkire and Foster's (2007) procedure. The investigation shows that the incidence of MEP was between 47 - 69% among the four divisions in Pakistan. The contributors to the prevalence of energy poverty in all the provinces in the order of importance are indoor pollution, cooking fuel, and entertainment appliances.

A similar study by Ozughalu and Ogwumike (2018) utilized the NLSS data collected almost about a decade ago. Also, this study is novel in that it is the first attempt at examining the zonal differential of MEP and its determinants in Nigeria to the best of our knowledge. Although a number of empirical studies on energy studies have being conducted in Nigeria, much of the studies are at subnational, especially at the state levels (Edoumiekumo et al., 2013; Ajetunmobi and Oladeebo, 2020) with limited details/information as to the regional/geopolitical zone distribution of MEP. The few available studies that have assessed MEP at the national/zonal levels Ogwumike and Ozughalu (2016), Ozughalu and Ogwumike (2018) and Ashagidigbi et al. (2020) were based on data collected in more than a decade ago. While these work brought important perspectives to the issues of MEP, a lot have changed in rural livelihoods and economic circumstances of dwellers over the past decade which would have affected the MEP in the rural areas and there determinants across the different geopolitical strata of the country. Design and targeting of policy actions can be better guided with more recent information. This study therefore utilizes the most recent national level data of 2018/2019 survey to empirically examine the incidence and extent of MEP as well as the determinants in the geopolitical zones of the country in the bid to guide intervention focus. Besides, this study shed lights on the MEP components that substantially contributes to the overall MEP in each zone in order to prioritize interventions around such for a much more zone specific improvement of MEP across specific zones and at the national level.

3. METHODOLOGY

3.1. Data

We utilized the 2018/2019 NLSS data collected by NBS in collaboration with World Bank and Department for International Development (NBS, 2020). The survey covered all the six geo-political zones and 36 states the country is divided into. The zones are: North Central (NC), North East (NE), North West (NW), South East (SE), South South (SS) and South West (SW). Details of sampling techniques used can be found on the NBS site. In all, a total of 15305 (rural households) sample size was selected out of the 22,126 households that were interviewed. As revealed by World Bank (2019b), the population of Nigeria is estimated at 195,874,740 with a larger proportion living in rural areas. Given the focus of this study, we employed all the data from rural areas across the geo-political zones.

3.2. Analytical Techniques

The data were analysed with descriptive statistics, MEPI, ANOVA, Tobit model, and Pearson correlation using SPSS version 23 and STATA version 15. Descriptive statistics was used to analyse the socio-economic characteristics and energy poverty indicators, MEPI was derived to measure multidimensional energy poverty following Nussbaumer et al. (2013), Mbewe (2017), Ashagidigbi et al. (2020), ANOVA (F-test) was used to test for significant differences among the zones, Tobit regression was used to analyse the factors influencing MEP, and Pearson correlation was performed to measure the contribution of each of the energy dimensions to overall MEP following (Mendoza et al., 2019).

3.2.1. Measurement of multidimensional energy poverty

Due to the multidimensional nature of energy poverty, we adopted the methodology developed by (Nussbaumer et al., 2013). The development of the methodology was as a result of motivation derived from the study on development as freedom by (Sen, 1999). In a bid to adapting the methodology to energy poverty study, it was further developed to MEPI by (Nussbaumer et al., 2011; 2012). The MEPI measures a set of energy deprivations that may affect a household or an individual and provides a new apparatus to support policymaking (Nussbaumer et al., 2011; 2012). The MEPI is composed of six indicators producing an index with five dimensions. The indicators include use of modern energy sources for cooking, use of indoor pollutants, access to the main electricity and/electricity from generator/and solar, ownership of kitchen aid appliance, ownership of education/and entertainment asset, and possession of means of communication and lighting. However, in this study, we excluded the use of indoor pollutants indicator due to the paucity of data. A similar omission was also done by (Mbewe, 2017). The remaining five indicators give rise to the construction of dimensions which are cooking, lighting, kitchen appliance services, education/entertainment, and communication.

It should be noted that assigning optimal weight to each of the indicators poses a big challenge as the assignment is been done based on subjective judgment (Nussbaumer et al., 2012). This has been ascribed to difficulties in constructing objective weight based on sound theoretical frameworks which makes it to be in non-existent currently. To overcome this challenge, we considered deprivation in every of the chosen dimensions and this makes consideration of dimensional monotonicity unnecessary. As shown by Alkire and Foster (2011), dimensional monotonicity implies that if a poor individual or household becomes recently deprived in one or more dimensions, then total poverty should increase. Conventional wisdom considered cooking as the greatest basic energy need of individuals and households. Consequently, we give it the highest weight of 0.400 in recognition of its importance as an energy cooking source in rural Nigeria and its connection with women and girls. Lighting is considered the second important basic energy need and is assigned a weight of 0.202. Kitchen appliance services are considered the next important basic energy need and are accorded a weight of 0.134 which particularly affect women (IEA/International Renewable Energy Agency/United Nations Statistics Division/World Bank/WHO, 2019). Ownership of education/entertainment and means of communication assets are regarded to be of equal significance and are assigned a weight of 0.132 each.

Table 1 presents the dimensions, indicators of basic functioning, deprivation cut-offs, and weight associated with each indicator. It should be noted that there are other energy services necessary for the well-being of individuals as well as societal optimal growth and development. Nonetheless, our choice of dimensions, indicators, and associated weights, as well as cut-offs used in this study, are guided by related literature and the peculiarity of the study area.

The unit of analysis in this study is household i which require energy to meet the identified energy dimensions d needed to meet the minimal acceptable household welfare. The MEPI is a measure of prevalence and extent of energy poverty of the households in the sample n. So, let $M=m_{ij}$ represents the achievement matrix $n\times d$ of a household i across variables j, and $m_{ij}\geq 0$ represents the extent of a household's achievements on variables j. Hence, every row vector $m_i=(m_{i1},m_{i2},\ldots\ldots,m_{id})$ represents achievements of household i in all variables j, while the column vector $m_j=(m_{1j},m_{2j},\ldots\ldots\ldots,m_{nj})$ symbolizes distribution of attainments in the variable j among households. A weighting vector w consists of the elements w_j corresponding to the weight assigned to variable j. The addition of the weighting vector is equal to $\sum_{j=1}^{d} w_j = 1$.

The MEPI employs dual cut-off techniques to measure incidence and extent of energy poverty, deprivation cut-off v and poverty cut-off p. The deprivation cut-off v_j denotes the level of deprivation for variable j. Let $r=(r_{ij})$ represents the deprivation matrix whose entry $r_{ij} = w_j$ when $m_{ij}<v_j$ and $r_{ij}=0$ when $m_{ij}\geq v_j$. Given that the element of achievement in MEPI is non-numeric in nature, we defined the cut-off as a set of conditions to be met. The element of the matrix $i_j\equiv w_j$ for household i that is deprived in variable j, while $i_j\equiv 0$ for a non-deprived household. The identification of household that is multidimesionally energy poor requires setting the poverty cut-off p. In doing this we employed the 0.33 acute poverty cut-off proposed by United Nations and adopted by (Ashagidigbi et al., 2020). Hence, we set energy poverty cut-off P=0.33 and construct a column vector c_i to add deprivation scores. In this study, a household is considered poor if $c_i\geq p$. Hence, $c_i(p)=0$ when $c_i<p$ and equals c_i when $c_i>p$. Therefore, $c(p)$ shows the censored vector of deprivation counts which differs from c, for it counts zero deprivation for the non-energy poor household. As stated earlier, MEPI is a measure of both incidence (H) and extent (A) of energy poverty. The energy poverty incidence is stated as:

$$H = \frac{q}{n} \tag{1}$$

where q refers to the number of households that are multidimensionally energy poor and n is as earlier defined.

The second component of MEPI which is the extent/intensity of energy poverty is given as:

$$A = \sum_{i=1}^{n} c_i(p) \Big/ q \tag{2}$$

where n, i, c_i, p and q are as earlier defined.

Thus,

$$MEPI = H \times A \tag{3}$$

3.2.2. The determinants of multidimensional energy poverty status

We employed Tobit regression to analyze the determinants of MEP of households in the study area following (Abbas et al., 2020). Tobit regression is popular in detecting the association between truncated explained variable and explanatory variable (s). In this study, the MEPI (explained variable) is truncated in the regression. It ranges from 0 (left-censored) which implies no

Table 1: Measurement of multidimensional poverty

Dimension of poverty	MEPI Indicator	Deprived if household……)	Weight
Cooking	Cooking Fuel	Use any fuel besides electricity and gas	0.400
Lighting	Access to electricity from main grid/ mini grid/generator/solar panel	Has no access to electricity from main grid/gen set/solar panel	0.202
Services provided by kitchen appliances	Possession of kitchen appliance	Does not possess a refrigerator or freezer or micro wave	0.134
Education/entertainment	Ownership of education/ entertainment asset	Does not own a computer or radio or television	0.132
Communication	Possession of means of communication	Does not possess at least one telephone	0.132
Sum			1.000

Source: Adopted from (Mbewe, 2017) and modified deprivation in any of the dimensions to 1, (uncensored) which implies deprivation in all the dimensions. The model is stated explicitly as:

$$y_{iz} = \propto_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon \quad (4)$$

where:
y_i*= MEPI of household i
z = 1, 2, 3,4,5,6 (geo-political zone) i.e. NC, NE, NW, SE. SS and SW respectively
i = 1, 2, 3,…………………, n (n varies across the zones)
X_1 = Age of the household head (years)
X_2 = Sex of the household head (male = 1, 0 otherwise)
X_3 = Marital status of the household head (single = 1, 0 otherwise)
X_4 = Formal education status of the household head (yes = 1, 0 otherwise)
X_5 = Main occupation of the household head (farming =1, 0 otherwise)
X_6 = Household size
X_7 = Household monthly expenditure (₦)
β_s = Parameters to be estimated
ε_i = Normally distributed error term with mean zero and constant variance.

We estimated separate model for the aggregate data as well as for each of the geopolitical zones using the empirical specification above. Also, the Tobit coefficients cannot be interpreted directly as estimates of the marginal effects of changes in the explanatory variables on the expected value of the explained variable. Hence, marginal effects after Tobit were estimated and reported. Finally, we verified the presence of multicollinearity and heteroscedasticity among the variables used. The duo is among the commonest econometric problems of the cross-sectional data analysis. The verification was done to ensure the econometric stability and reliability of the regression estimates. The variance inflating factor (VIF) was estimated and used to verify the presence of multicollinearity among the explanatory variables. For VIF, the minimum possible value is 1.0; while a value greater than 10 indicates probable collinearity between the specified explanatory variable in question and the rest of the predictors in the model. According to (Gujarati and Porter, 2009), VIF is estimated using the formula stated below:

$$VIF = (1 - R_i^2)^{-1} \quad (5)$$

where, is the coefficient of determination when X_i is regressed on the remaining explanatory variables of the model. We obtained an average VIF of 4 which implies the absence of multicollinearity among the explanatory variables. A White test was performed to reveal the presence of heteroscedasticity. The analysis returned a chi square value of 132 which was significant at $P < 0.01$ level. To correct for this, heteroscedasticity consistent standard error (robust estimation) was estimated and reported. Note that the two tests were performed using the aggregate data.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics of the Variables used in Constructing MEPI by Zones and National Levels

Table 2 presents the percentage of households deprived in each of the energy dimensions. The results show that the cooking dimension has the highest percentage of households deprived of energy service. Precisely, more than 90% of rural households in Nigeria were denied access to modern cooking fuel. This means that only about one out of ten households in rural areas used either electricity or gas to cook food in 2018. The zonal analysis showed that the NE and NW zones had the largest proportion of households that were deprived in the cooking dimension with almost 99% of them been deprived. This is an indication that virtually all the households in the zones are deprived in modern energy sources for cooking as at the survey time. This largely reflects the high reliance on firewood and charcoal for cooking by the majority of the households due to limited access to electricity. This is consistent with the submission of (Abass et al., 2020; Adusah-Poku and Takeuchi, 2019; Emodi and Boo, 2015; National Population Commission NPC and ICF, 2019; Ogwumike et al., 2014).

Also, while about 91% of rural dwellers in Nigeria were deprived in lighting dimension, more than 98% were deprived in the dimension in NE and NW zones. This is also an indication that most households in rural areas of the country lack access to electricity either from the main grid or solar, while a large number of them could not afford a generator and the cost of running it (NPC & ICF, 2019). On average, 90% of rural households were deprived of household appliances, but an alarming 97% lack access to house appliances in the NE and NW zones. This could be attributed to a high level of income poverty NBS (2020) most especially in the rural areas of the country which made it difficult for them to own either a refrigerator or any other kitchen appliance for that matter. Surprisingly, none of the households surveyed is deprived in education/entertainment facilities. This may be borne out of the desire for them to be abreast of the happenings in their areas which necessitated their investment in at least one radio per household. Likewise, while about one-quarter of rural households in the country could not afford a telephone, only about 15% of rural dwellers in SW were deprived of means of communication. The NW had the highest proportion of households who were deprived in the communication dimension. This is in line with the submission of (Abbas et al., 2020).

In summing, the NE zone was consistently the most deprived in all the dimensions with the exception of communication which saw the NW occupying the position of the most deprived and education/entertainment with zero levels of deprivation. While the SW was the least deprived in cooking and communication dimensions, the SE and SS occupied that position in lighting and kitchen aid appliance dimensions respectively. The case of the SS rather presents a paradox given that a high percentage of the country's revenue is from the zone (Iwilade, 2020). It is however validation of the claim by the residents of the zone that they have been grossly neglected by the federal government. Sadly, the neglect over the years has resulted in incessant agitation and violence in the area. The results suggest that a majority of rural households

Table 2: Degree of deprivation in the five Indicators used to construct the MEPI across the zones and national data

Dimension	Percentage of household deprived						
	NC	NE	NW	SE	SS	SW	National
Cooking	94.49	98.73	98.53	93.49	86.11	81.70	93.71
Lighting	92.78	98.70	97.66	80.82	82.29	89.18	91.19
Kitchen aid appliance	89.65	97.08	96.47	84.41	80.80	85.84	90.05
Education/entertainment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Communication	20.08	33.38	38.02	20.39	17.52	14.79	25.89

Source: Authors' calculation

Table 3: Incidence, intensity and multidimensional energy poverty index at zonal and national levels

Variable	NC (n=2869)	NE (n=3077)	NW (n=3340)	SE (n=2290)	SS (n=2620)	SW (n=1109)	National (n=15305)
Incidence	0.945	0.987	0.985	0.937	0.867	0.819	0.939
Intensity	0.340	0.350	0.335	0.328	0.322	0.320	0.330
MEPI	0.321	0.345	0.330	0.307	0.286	0.279	0.310

Source: Authors' calculation

are deprived in all the energy dimensions with the exception of education/entertainment and that there exists zonal disparity in the degree of deprivation in all the dimensions (Acharya and Sadath, 2019). This is an indication that the rural electrification project is yet to yield the anticipated results.

4.2. Incidence, Intensity and Multidimensional Energy Poverty at Zonal and National Levels

The incidence, deprivation intensity, and MEPI at zonal and national levels are presented in Table 3. As shown in the table, the NE had the highest number of multidimensionally poor households (98.7%) which is above the national average of about 94%. The zone with the least number of MEP households is the SW with about 82% followed by SS (86.7%) of them being below the MEP line. This is not surprising given that the two zones had the least proportion of households who were deprived of modern cooking fuels and lighting dimensions which are the most critical of the energy dimensions in the study area. Our findings are in line with the submission of (Adusah-Poku and Takeuchi, 2019) In the same vein, the SW or SS had the lowest income poverty rate in 2018/2019 when the data for this study was collected (NBS, 2020). This is an indication that the majority of the households in the rural areas of Nigeria have a high level of MEP with the NE being the worst hit by the plaque. This is however not surprising giving the high level of income poverty in the country which is highest in NE and lowest in the SW as revealed by (NBS, 2020). The situation in the NE may also not be unconnected with the insurgency in the area which has led to forced human displacement for the past two decades which has also spread to other parts of the country. The crises have prevented the efforts to improve the standard of living of the inhabitants and to improve their access to essential energy services such as electricity, household appliances, and assets to communication gadgets. Similar results were obtained by (Adusah-Poku and Takeuchi, 2019). We observed that the intensity of multidimensional energy poverty which stood at 0.330 at the national level also differs across the zones. Again, the NE recorded the highest level of intensity, while the intensity was lowest among the residents of SW, Nigeria which was 0.320. As shown in the table, the values of the MEPI followed the same trend as noted for MEP incidence. Our results concur with the submissions of (Edoumiekumo et al., 2013; Sher et al., 2014; Mbewe, 2017).

Table 4: Results of Anova

Source of variation	Sum of square	Degree of freedom	F-value	P-value
Between Groups	3.646657	5	181.01	0.000
Within Groups	71.47355	14191		
Total	75.12021	14195		

Source: Authors' calculation

The results show high level of MEP for the country with variation across the geopolitical zones and this aligns with the evidence provided by (Gupta et al., 2020).

4.3. Variations Across the Zones

Table 4 shows the results of ANOVA conducted to assess variations in the distribution of multidimensional poverty between geopolitical zones in Nigeria. From the results, significant differences exist in multidimensional energy poverty indices between the geopolitical zones given that the value of F statistic ($P < 0.000$) is less than the critical value ($P<0.05$). Consistent with the revelation of Ozughalu and Ogwumike (2018), this analysis shows that there exists significant variation in MEP across the six zones in the country.

4.4. Descriptive Statistics of the Explanatory Variables used in Tobit Model

Tables 5a and 5b present the results of the descriptive statistics of the explanatory variables used in the Tobit model. As indicated in the table, the mean age of the respondents was about 48 years at the national level with observable disparity at the zonal levels. The oldest respondents were found in the SE (56 years) and the youngest was found in the NE (45 years). The mean age is an indication that rural dwellers in Nigeria are relatively young and this may have an effect on energy consumption. Our results contra wise the submission of (Ashagidigbi et al., 2020). There is mild variation in household size as shown by the size ranging from 4 to 7 with the SW recording the least (about 4) and NW recording the highest which averaged 7 persons. The average household size at the national level stood at about five. This is an indication that the average household size in Nigeria is relatively large. The number of persons in the household could determine the type of energy source(s) as well as the amount of energy consumed. Our results

Table 5a: Mean values of the explanatory variables used in Tobit model (continuous variables)

Variable	NC	NE	NW	SE	SS	SW	National
Age (years)	46.456 (15.417)	45.020 (15.516)	46.033 (14.647)	56.310 (15.484)	48.630 (15.461)	51.803 (16.659)	48.309 (15.844)
Household size	5.878 (3.469)	6.434 (3.707)	6.629 (3.668)	4.323 (2.554)	4.207 (2.581)	3.805 (2.589)	5.485 (3.426)
Proportion of household Expenditure on energy	7.944 (6.966)	8.366 (7.987)	10.544 (8.513)	11.597 (7.950)	10.772 (7.540)	10.908 (7.890)	9.761 (6.649)

Source: Authors' calculation. Note: Figures in parenthesis are the standard deviation

Table 5b: Explanatory variables used in Tobit model (categorical variables)

Variables (%)	NC (n=2869)	NE (n=3077)	NW (n=3340)	SE (n=2290)	SS (n=2620)	SW (n=1109)	National (n=15,305)
Sex							
Male	88.04	93.70	96.20	64.93	71.49	76.19	83.81
Female	11.96	6.30	3.80	35.07	28.51	23.81	16.19
Marital status							
Married	59.36	64.22	60.45	51.57	50.69	50.77	57.07
Single	40.64	35.78	39.55	48.43	49.31	49.23	42.93
Occupation							
Agriculture	89.65	88.76	88.35	84.80	86.87	87.56	87.83
Non-agriculture	10.35	11.24	11.65	15.20	13.13	12.44	12.17
Education							
Literate	57.20	43.45	33.80	61.75	77.40	64.74	54.02
Illiterate	42.80	56.55	66.20	38.25	22,60	35.26	45.98

Source: Authors' calculation

on national household size are similar to what Ogwumike et al. (2014) obtained. The households in SE spent the highest proportion of their expenditure on the different types of energy sources, and next to it is the SW. The national proportion of monthly expenditure on energy was however higher than the value reported in the NC which recorded the lowest. The low proportion of expenditure on energy may be as a result of reliance on traditional sources of energy (firewood and charcoal) which are gathered from the forest free of charge. This may however have implications on the energy poverty and health of the respondents in the short run, and climate change both at the national and global levels in the long run. The findings support the evidence presented by (Lenz and Grgurev, 2017).

Nearly 84% of the sample at the national level were males and the same trend was observed across the zones with the SE and NW having the least and largest number of households headed by males respectively. The sex of the household head could be an important factor in the type of energy source (s) for cooking and hence, energy poverty, as most firewood gatherers are females (Abass et al., 2020; Ashagidigbi et al., 2020). The headship role has largely played by males which may call for various policies to empower women and their role in resource use and decisions in the household (Bersisa, 2016). Further, more than 50% of the household heads were married both at the national and zonal levels with the exception of SS and SW which had an approximately equal number of married and singles which include widows, widowers, separated, and never married Ashagidigbi et al., 2020. The main livelihood of a majority (87.83%) of the rural households in Nigeria was agriculture World Bank (2019b) and only about 10% in NC was non-agriculture-based households which are also the least among the zones. Farm households could use more traditional sources of cooking compare to their non-farm-based counterparts as a result of their access to firewood and other traditional sources. While the illiterate rate stood at as high as almost 66% in the NW, the rate was about 23% and 46% respectively for SS and national level. Evidence by Thiam (2011) revealed that a direct association exist between literacy level and access to modern energy sources.

4.5. Determinants of Multidimensional Energy Poverty at Zonal and National Levels

The results of the determinants of MEP in rural Nigeria both at the national and zonal levels are presented in Table 6. The results show that the models have good fits given the 1% level of significance of the likelihood ratio statistics. Not only this, the models have strong explanatory power of over 60% across the zones and at the national level as revealed by the values of R squared. Also, all the explanatory variables had the expected sign although variations existed in the significant variables and their magnitudes across the zones. The variables that had a significant decreasing effect on MEP are sex, education, occupation, and household expenditure, while age and household size were positively associated with it. The age of the household head was responsible for the MEP status of only the respondents in the NW zone. From the results, a unit increase in the age of respondents in the NW zone is linked with a 0.0003 of an increase in the MEP of respondents in the region. The probable explanation could be that the older household heads consumed more energy in terms of warming their food and apartment as well as bathing. This is in sharp contrast to the evidence provided by (Bersisa, 2016). Large household size was also found to be directly realed with households' MEP in the country as well as in all the zones of the federation with the strongest effect in NC. This indicates that a unit increase in household size is responsible for an increase in their MEP. This could be because the majority of the house members were dependents who are also care receivers. This is similar to the findings of (Scarpellini et al., 2015; Bersisa, 2016; Mendoza et al., 2019).

Table 6: Determinants of multidimensional energy poverty at zonal and national levels

Variable	Marginal effect						
	NC	NE	NW	SE	SS	SW	National
Age	0.0002	0.0004	0.0003	0.0002	0.0003	0.0001	0.0004
	(0.0002)	(0.0005)	(0.0016)*	(0.0003)	(0.0003)	(0.0004)	(0.0005)
Sex	−0.0198	−0.0083	−0.00840	−0.0109	−0.0256	−0.0049	−0.0121
	(0.0100)*	(0.0080)	(.0106)	(0.0103)	(0.0109)**	(.0163)	(0.0042)
Marital status	−0.0131	−0.0033	−0.0041	−0.0367	−0.0319	−0.0291	−0.0140
	(0.0097)	(0.0041)	(0.0046)	(0.0158)**	(0.0298)	(0.0145)**	(0.0069)**
Education	−0.0677	−0.0317	−0.0506	−0.0739	−0.0664	−0.1071	−0.0901
	(0.0053)***	(0.0032)***	(0.0043)***	(0.0085)***	(0.0109)***	(0.0138)***	(0.0024)***
Occupation	−0.0314	−0.0303	−0.0144	−0.0369	−0.0604	−0.0427	−0.0414
	(0.0100)***	(0.0057)***	(0.0055)***	(0.0097)***	(0.0119)***	(0.0218)*	(0.0043)***
Household size	0.0080	0.0027	0.0030	0.0067	0.0054	0.0075	0.0065
	(0.0008)***	(0.0005)***	(0.0006)***	(0.0015)***	(0.0017)***	(0.0027)***	(0.0021)***
Expenditure	−0.0006	−0.0031	−0.0022	−0.0036	−0.0050	−0.0074	−0.0042
	(0.0007)	(0.0025)	(0.0014)	(0.0018)*	(0.0045)	(0.0050)	(0.0033)
n	2869	3077	3340	2290	2620	1109	15305
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Psudo R^2	0.7018	0.7004	0.7471	0.8002	0.8966	0.6651	0.697

Source: Authors' calculation. ***, ** and * significant at 1%, 5% and 10% levels respectively. Figures in parenthesis are the robust standard errors of the mean

Also, we found out that being male compare to female lowers the MEP of households in NC and SS zones. This may be because females are the firewood gatherers in most homes in the zones. This is in agreement with the submission of Ozughalu and Ogwumike (2018) and Sadath and Acharya (2017) but contra wise the submission of (Bersisa, 2016; Abass et al., 2020). Marital status had a significant influence on the MEP of Nigerian households in rural areas. Zonal disaggregation showed that the variable was only capable of explaining the MEP of respondents in SE and SW zones only. This implies that households whose heads are married are likely going to have higher MEP compare to single household heads. While our findings on this agree with those of Ozughalu and Ogwumike (2018), it is in sharp disagreement with those of (Legendre and Ricci, 2015).

Another notable variable that had a significant effect on households' MEP is education. We found that households with literate heads had a lower level of MEP than their illiterates counterparts both at the national level and across the zones of the federation. The influence is stronger in SW compare to other zones and at the national level. This implies that education is capable of lowering MEP in the country. This perhaps could be due to the dividend of education on the households. Our line of reasoning is in accordance with those of (Ozughalu and Ogwumike, 2018; Abass et al., 2020). Our analysis showed that an indirect association exists between the occupation of the household head and MEP. It is obvious from our results that farm-based households are multidimensionally energy poorer than the non-farm-based households at the national level and with zonal disaggregation. The impact is stronger on the rural dwellers in SS than other regions and national level. It may be because rural dwellers whose head's main source of income is no-farm were able to assess and paid for modern energy sources among other dimensions. Similar results were obtained by (Sadath and Acharya, 2017). Lastly, our analysis revealed that the higher the household monthly expenditure, the lower the MEP. This may be because those that were able to pay for modern energy sources were also better off in other dimensions (Bersisa, 2016).

Table 7: Correlation coefficient (R) of each of the energy dimensions to MEP index

Geo-political zones	R				
	C_D	L_D	K_D	EE_D	CM_D
North central	0.8571	0.6250	0.6878	NS	0.4735
North east	0.6396	0.3065	0.5282	NS	0.7523
North west	0.6801	0.5169	0.5796	NS	0.7153
South east	0.7811	0.6390	0.6659	NS	0.5062
South south	0.8714	0.5827	0.6298	NS	0.4209
South west	0.9275	0.6120	0.6969	NS	0.4038
National	0.8341	0.6002	0.6604	NS	0.5240

Source: Authors' calculation. P<0.01 level, all correlations are significant, C_D, L_D, K_D, EE_D and CM_D connote cooking dimension, lighting dimension, kitchen appliances dimension, entertainment/education dimension and communication dimension. NS correlation not statistically significant

4.6. Evaluation of Strength of Relationship between Energy Poverty Dimensions and Overall MEP

Table 7 shows the results (coefficients) of Pearson Product Moment Correlation (PPMC) between each dimension and overall MEP across the zones. The findings provide insights regarding the strength of association between each of the energy poverty dimensions and the overall MEP. Also, the particular dimension to prioritize from policy actions and resource allocation perspectives in each zone (or nationally) in order to improve the overall MEP will be revealed. Although all the correlation coefficients reported are statistically significant at $P < 0.01$ level, we consider correlation values above 0.6 to be relatively strong, and those dimensions with such values could be focused on for policy interventions. On this, cooking, lighting, and kitchen appliances dimensions stood out at the national (aggregate) level as very crucial components that must be strengthened to reduce overall MEP in the country. More specially and with a closer look at the geopolitical zones level, the cooking dimension consistently features across all the zones as a dimension on which more policy actions should be directed in order to address the challenges of MEP more progressively across the country. The strength of correlation between the cooking dimension and MEP is even stronger (correlation coefficients above 0.85) and above the national average (of 0.83) in NC, SS, and SW. Next to them is the SE correlation coefficient of approximately 0.78. The need to promote clean energy for cooking should be more vigorously pursued in these regions.

Although the challenges of the kitchen appliances and communication aspects of MEP do diffuse across the entire geopolitical zones of the country, the locus of the strength of their concentrations alternate disproportionately across the different zones. The communication dimension has a relatively strong relationship with MEP (correlation values between 0.62 and 0.70) in NE and NW zones, while the kitchen appliances dimension has a stronger association in NC in the northern region and in the entire southern region (the values between 0.63 and 0.70). Results are not radically different from pieces of evidence from similar studies (Sher et al., 2014). In addition, while the estimated correlation coefficient (national value) for the relationship between MEP and the lighting dimension stood at about 0.60, higher correlation coefficients (values 0.61 and 0.63) were found in the NC, SE, and SW zones. These findings suggest the need to consider the specificity of zones and gauge the possible contributions of each MEP dimension while designing interventions towards reducing MEP and advancing sustainable energy use in the country. This will promote better policy action messaging, intervention targeting, and allocation of resources on clean energy in the country. There is no correlation between the entertainment/education dimension and the whole MEP. Hence, strengthening this dimension beyond the current level in the household is unlikely to reduce the overall MEP substantially.

5. CONCLUSION

This study employed the latest Nigeria NLSS data to examine multidimensional energy poverty in rural areas at the national and zonal levels. The empirical evidence shows that multidimensional energy poverty is endemic in rural Nigeria with zonal differential. It is more pervasive in all the zones (NC, NE, and NW) in the northern region as well as the SS in the southern region of the country. Our analysis provides solid evidence that the variations across the zones are statistically significant, with some specific and different dimensions of MEP important for policy actions. We found that the age of the household head positively significantly determined the multidimensional energy poverty of households in NW only. Household size had a positive significant influence on the level of multidimensional energy poverty of households at the national level and in all the zones of the federation, howbeit with a disparity in the extent of the impact. The negative significant factors are sex, marital status, education, and the main occupation of the household head as well as household monthly expenditure. The sex of the household head had a significant effect on the multidimensional poverty of NC and SS dwellers only. The marital status of the household head had a significant influence only on the households in SE, SW, and national levels. The main occupation and education of the household head significantly explained multidimensional energy poverty in the country and with zonal analysis. Again, variations exist on the magnitude of the influence across the zones. Significant indirect association occurs between the multidimensional energy poverty of inhabitants of SE and their monthly expenditure.

Cooking is one key dimension that has very strong positive association with the aggregate MEP across the zones. Even though lighting, kitchen appliances and communication have significant positive relationship with overall MEP, the strength of the association varied across location with communication stronger in the NE and NW zones and lighting and kitchen appliances in the NC, SE, and SW Nigeria. There are implications for policy makers and other stakeholder groups to promote zone-specific gender (women focused) interventions relating to clean energy, improved access to communication and advances in the economic status of households to achieve accelerated reduction in overall MEP. Policy actions should include expedition of the rural electrification project. While doing this, focus should be placed on the northern region and SS geopolitical zone. Strategically and sensitively guided awareness and clean energy messaging with focus on concerns relating to cooking, lighting, and communication and kitchen appliances across the zones are also advocated.

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