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Energy Deprivation and Monetary Poverty Transitions in Nigeria

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Abstract: *Energy poverty and monetary poverty are inter-related aspects of welfare in the households, although the two indicators are normally analyzed separately in Nigeria. This research analyzes their co-movements through the employment of a reliability-augmented Multidimensional Energy Poverty Index (MEPI), four joint poverty states, multistate transition models and dynamic correlated random effects bivariate probit modeling framework. The analysis is conducted in the Nigeria General Household Survey Panel (GHS-Panel) using Wave 4 – Wave 5 data and longitudinal samples consisting of up to 4,673 households (1,376 households of the long panel and 3,339 households of the refresh sample). The five-wave analysis uses the 1,376 households longitudinal panel. The reliability-augmented MEPI includes clean cooking fuel, indoor pollution risk, electricity access, electricity reliability, refrigeration, education/entertainment, and communication, while the poverty cut-off is set at 0.30. National-level evidence from Wave 5 reveals that 70.2% of the households use wood as their main cooking fuel, against only 23.2% of LPG/coking gas users. Rural area (83.8%) households use wood much more frequently than urban area (41.3%) households. The share of LPG users was 10.4% and 50.5% in rural and urban areas, respectively. Electricity access was 53.6% nationally, 82.2% in urban and 40.4% in rural households. In case of those households having electricity access, the grid-connected households experience on average 6.7 blackouts within seven days, which lasted 12.0 hours each and made 67.2 blackout hours in total over the reference week. In order to identify persistence, incidence, and exit from the deprivation, the households are classified into non-poor, energy-poor only, monetary poor only, and dual poor states. The results reveal rural-urban energy poverty disparities and highlight the need to distinguish electricity access from its reliability. The joint approach is useful to analyze persistent dual poverty and possible transitions among energy and monetary poverty.*

Keywords: *Energy poverty, Monetary poverty, Poverty transitions, Multidimensional Energy Poverty Index, multistate Markov model, Bivariate probit, Nigeria, GHS-Panel.*

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1.0 Introduction

Income or consumption alone cannot be used to understand household welfare. Energy is used for cooking, lighting, refrigeration, communication, education, health and income generation. A household can thus be above a monetary poverty line and still not have access to reliable electricity or clean cooking, while another household can be monetary poor and still have some energy services thanks to fuel collection, transfers or assets they have accumulated. The two types of deprivation are treated as equivalent, masking these conflicting welfare states and transitions between them. Energy is thus not only a household consumption input but a key determinant of well-being, productivity, and human development. Lack of adequate access to energy that is cheap, reliable, and clean may affect education, health care, communication, household activities, and economic activities, whereas lack of sufficient funds may at the same time limit the households from accessing modern energy services. There is the potential for a vicious circle between energy deprivation and poverty.

This difference is significant in Nigeria. The national multidimensional poverty assessment reveals significant deprivation in living standards, and the most recent GHS-Panel report indicates substantial disparities between rural and urban areas, as well as across zones, in cooking fuel, electricity access, and service quality (NBS et al., 2022; NBS & World Bank, 2024). Grid connection is not enough as there can be long power outages in grid-connected households.

Just like this, measuring deprivation in cooking energy using only one fuel indicator might miss issues related to fuel stacking, cooking place, ventilation, stove specifications, and the availability and quality of the energy services.

This makes Nigeria an ideal context to study the relationship between energy deprivation and monetary poverty. This is because of electricity shortages, use of traditional biomass, access to modern cooking fuels, and rural–urban differences in energy services might directly affect households financially, health-wise, and in terms of opportunities. Thus, even though households are not poor monetarily, they might still be deprived of energy services.

Absence or inadequate energy (energy poverty) is a concept that has propagated beyond the initially conceived aspect of energy cost oravailability into a multidimensional level such that it now covers readiness, quality, reliability and the accessible services to households (Pachauri & Spreng, 2011; Pelz et al., 2018). Multidimensional measures of energy poverty take into account the fact that household deprivation can occur along more than one dimension. In order to identify and break down the overlapping deprivations, it is possible to use the Multidimensional Energy Poverty Index (MEPI), grounded in the Alkire–Foster counting approach. The indicator-based nature of this approach allows making cross-population comparisons and discovering which aspects of energy poverty are especially important.

Even the literature on monetary poverty has established that poverty is not a static but a dynamic phenomenon. Changes in the conditions of a household may lead to entry into poverty, leaving poverty or recurring poverty. Differentiation between transient and persistent poverty is thus necessary to understand the dynamics involved in household welfare (Baulch & Hoddinott, 2000). Longitudinal datasets would be useful in this respect since they allow changes in household poverty status to be measured rather than resorting to measures of cross-sectional type.

Furthermore, panel data techniques would show that the observed persistence in poverty could result not only from state dependence but also from stable characteristics of households that affect past as well as future outcomes. Correlated random-effects methods, for instance the Mundlak model, and initial-conditions methods could hence be employed to control for unobserved heterogeneity and dependence of current outcome on household state in the previous period (Mundlak, 1978; Cappellari & Jenkins, 2004; Wooldridge, 2005). This approach could form a proper basis for analyzing poverty transitions with longitudinal household data.

Whereas energy poverty and monetary poverty have been widely studied individually, they are aspects that are interrelated. Energy poverty may lead to monetary poverty in the future due to time lost on gathering firewood, inefficiencies at work, indoor air pollution, food losses, lack of educational chances, and expenses involved in running businesses or household ventures. On the other hand, monetary poverty may hinder investment in energy connections, use of clean cooking fuel, backup energy sources and energy-using appliances. This may imply that there is a two-way relationship between the two.

The study of this relationship requires more than simply comparing the incidences of energy and monetary poverty at any one point in time. A longitudinal perspective will enable understanding as to whether households are persistently deprived, move from one form of deprivation to another or are simultaneously deprived of both forms of energy. It will make it possible to tell apart energy-poor households from monetary-poor households, dual-poor and non-deprived ones.

Nevertheless, the measurement of energy poverty may be influenced by indicator selection, deprivation cut-off points, and assumption regarding the quality and reliability of energy services provided. Connection to electricity does not necessarily indicate its adequate provision, just like possession of a modern cooking fuel does not necessarily reflect the exclusive usage of it and the situation when cooking occurs. In the case of Nigeria, where households may use multiple types of energy and there is a significant variation in reliability of their access, measurement problems become especially acute.

While there are increasing number of studies that analyze the issues of energy poverty and monetary poverty, a critical empirical gap still persists when it comes to Nigeria. While previous studies have considered energy deprivation and monetary poverty as distinct welfare variables, without much focus on how the two types of deprivation co-evolve together within the same household, there is lack of evidence on how far past energy deprivation can lead to future monetary poverty in the presence of previous monetary status, unobserved heterogeneities, and initial conditions. Similarly, it is not sufficiently clear what characteristics are related with entering into, being stuck with, and exiting from energy-monetary poverty.

It is critical to note here that while the estimates of the cross-sectional analysis help understand the incidence of deprivation, they fail to capture whether the poverty being faced is persistent or temporary, and the directions and timings of transitions from one type of poverty to another. A longitudinal approach for jointly analyzing energy-monetary poverty is thus needed.

In particular, the study seeks to answer four main questions which include: (i) What is the rate and severity of multidimensional energy poverty among Nigerian households? (ii) What is the process by which households move from being non-poor, energy-poor only, monetary poor only and dual poor? (iii) Is energy poverty in the past a predictor of monetary poverty in the future after controlling for past monetary situation and household characteristics and does the causality go the other way round? (iv) What are the factors that determine movement to and from dual poverty?

Contribution is found in integrating multi-dimensional energy poverty assessment with longitudinal poverty state classification and dynamic joint estimation. The use of a four-state model makes it possible for the study to differentiate between households suffering from energy deprivation, poverty, and those experiencing both together. The use of transition models also makes it possible to detect patterns of persistence and entry and exit which would otherwise have been missed.

Against this backdrop, the purpose of this research is to analyze the dynamics and transitions between energy poverty and income poverty among households in Nigeria using longitudinal GHS-Panel dataset. This research incorporates the Nigeria specific Multidimensional Energy Poverty Index (MEPI) in conjunction with the multistate transition modeling technique, dynamic correlated-random-effects bivariate probit analysis and transition decomposition approach.

Energy poverty is not only about availability, affordability, quality and reliability, but also about the services energy enables; no single indicator is sufficient for all purposes (Pachauri & Spreng, 2011; Pelz et al., 2018). The MEPI is decomposable by indicator and subgroup and uses the Alkire-Foster counting approach to cooking, electricity, appliances, education or entertainment, and communication. Reliability should be measured directly, and not inferred from connection status, as is done in service-tier approaches to energy access (Bhatia & Angelou, 2015) for Nigeria. The primary index does not include energy expenditure, since it is already included in household consumption and would mechanically overlap monetary welfare.

The association may be bidirectional. Energy deprivation can lead to lower welfare in the future, due to time spent collecting fuel, household air pollution, food spoilage, poor digital connectivity, less time spent studying, and high business costs. Monetary poverty can also constrain access to clean fuels, connection fees, back-up power and energy-using assets. Panel data can distinguish between persistence and one-time status, but observed persistence can be due to true state dependence or to stable household characteristics (Baulch & Hoddinott, 2000). The design therefore includes transition models, correlated random effects, a Mundlak correction and an initial-conditions strategy (Cappellari & Jenkins, 2004; Mundlak, 1978; Wooldridge, 2005). Joint bivariate estimation also allows for the correlation of unobserved determinants of energy and monetary poverty (Chib & Greenberg, 1998). Unless there is exogenous variation, these are not causal effects but rather dynamic associations.

The study contributes to our knowledge conceptually, methodologically, empirically and from the point of view of practice. The conceptually contribution comes from developing our knowledge about household poverty through considering energy and monetary poverty as two separate, yet interrelated concepts of welfare. Methodological contribution includes showing how the multidimensional energy-poverty indicators can be incorporated into multistate transitions and the dynamic correlated random effects estimation. Empirical contribution includes providing longitudinal data about transitions in energy-monetary poverty in Nigeria using nationally representative household panels. Practically, the results can help to develop more efficient policies for addressing poverty in households who experience persistent energy-monetary poverty and those where energy deprivation can be a predictor of further monetary poverty.

The findings might be especially useful for designing policies regarding access to electricity, clean cooking, social protection, rural development and poverty reduction in Nigeria. Recognizing the overlap and transitions between energy and monetary deprivation can help policy makers to move forward and design policies taking into account not only income poverty, nor energy poverty, but both at once.

2.0 Materials and Methods

2.1 Data and Measurement

The analysis is based on the Nigeria's GHS-Panel, which was generated by the NBS and the World Bank Living Standards Measurement Study. Wave 5 was implemented in 2023 and 2024 and includes housing, cooking-fuel, electricity, blackout, asset, food-expenditure, and non-food-expenditure modules. The final cross-section includes 1,376 households from the nationally representative panel that was started in 2010 and 3,339 households from the refresh sample. The reported long-panel attrition rate from 2010 to Wave 5 was 13.5% (NBS, 2024; NBS & World Bank, 2024).

GHS-Panel follows a multi-stage probability sampling procedure that is geographically based, wherein households are sampled using enumeration areas as well as stratifying the entire population of Nigeria on the basis of geography and housing patterns. The panel design allows household-level analysis through different waves, hence providing a platform to separate permanent poverty from fluctuations in poverty status.

Analytical samples were created for different purposes in the research. In particular, the Wave 5 cross-sectional sample was applied to calculate current levels of deprivation in terms of energy and monetary deprivation. The longitudinal sample which was matched in Wave 4 and Wave 5 contained up to 4,673 households and was applied for reliability augmented MEPI and two wave transition into poverty. The longitudinal sample which consisted of 1,376 households was used for the dynamic models based on harmonized core energy index. Differentiation of the analytical samples allowed avoiding application of more elaborate reliability measures to the early survey waves where such measures were not available.Survey weights and the stratum and enumeration area clusters as per the GHS-Panel design were retained. Consistent household tracking and split-household procedures were used throughout all waves, and sample attrition due to incomplete variable observations was noted.

In cases where needed, the analysis was performed using both household and individual weightings.

2.2 Monetary Poverty and Energy Index.

The official or fully harmonised annual consumption aggregate in constant prices is used as the measure of monetary welfare, in the primary specification divided by household size. Food, meals away from home and non-food expenditure should be annualised by recall period and deflated with spatial and temporal deflators (Deaton & Zaidi, 2002). Monetary poverty is when the real per-capita consumption is below the national poverty line applicable to a household. Robustness checks are performed with adult-equivalent welfare, a fixed real line, and a transparent relative line, and the headcount, gap, and squared-gap measures are also reported (Foster et al., 1984).

Table 1:Reliability-Augmented MEPI for the Wave 4-Wave 5 Analysis

Indicator	Weight	Deprived when ...	Module
Clean cooking fuel	0.20	Main fuel is wood, charcoal, crop residue, dung, coal, or kerosene	Cooking fuel
Indoor pollution risk	0.15	Polluting fuel is used indoors or near sleeping space without adequate venting	Stove/location
Electricity access	0.20	Household has no electricity source	Housing/electricity
Electricity reliability	0.15	No electricity, or outages exceed 48 hours in the previous 7 days	Blackout
Refrigeration service	0.10	Household owns no refrigerator	Assets
Education/entertainment	0.10	Household owns none of radio, television, or computer	Assets/ICT
Communication service	0.10	Household has no mobile or landline phone	Assets/ICT

Note. Weights sum to 1.00. The 48-hour outage cutoff should be tested at 24 and 72 hours. Polluting-fuel classification should follow the household-fuel guidance in World Health Organization (2014). A five-wave core index should retain only indicators with defensible cross-wave comparability; energy expenditure remains excluded.

The energy index is based on the dual-cutoff approach of Alkire and Foster (2011). The weighted deprivation score for household i at wave t.

$$C_{it} = \sum_{j=1}^{j} w_j g_{ijt}$$

if indicator j is deprived. The household is energy poor when C_{it} is at least k = 0.30. Sensitivity analysis: k ranges from 0.20 to 0.40, and equal weights are used.

2.3 Statistical Methods

Joint States and Multistate Transitions

Energy and monetary poverty were merged into four mutually exclusive states, maintaining discordance that would be lost if either outcome were used as a proxy for the other.

Table 2: Four Joint Energy-Monetary Poverty States

State	Energy poor	Monetary poor	Interpretation
0	No	No	Relatively secure on both observed dimensions
1	Yes	No	Energy deprivation not detected by the monetary line; possible early vulnerability
2	No	Yes	Low consumption despite meeting the selected energy-service threshold
3	Yes	Yes	Dual poverty; highest-priority group for integrated intervention

The revised reliability-enhanced MEPI index is employed in the case of Waves 4 and 5 since there is enough information about recent electricity disruptions for these waves. In the case of five-wave analysis, only those indicators which are defined consistently in all waves are included in the harmonized core index. Thus, artificial changes of energy poverty are avoided through the different questionnaires used in each wave.

Let S_{it} denote household i's state at wave t. The weighted transition probability

$$P_{rs} = Pr\left(S_{r,t+1} = s \middle| S_{i,t} = r\right)$$

P_{rs} is a 4 x 4 matrix with diagonal entries indicating persistence and off-diagonal entries indicating movement. For the four states defined in Table 2, which is nationally reported 4-Wave on the rural-urban sector and geopolitical zone. The following matric can be applied

$$P = \begin{pmatrix} P_{00} & P_{01} & P_{02} & P_{03} \\ P_{10} & P_{11} & P_{12} & P_{13} \\ P_{20} & P_{21} & P_{22} & P_{23} \\ P_{30} & P_{31} & P_{32} & P_{33} \end{pmatrix} \cdot \sum_{s=-}^{3} P_{re=1}$$

A discrete-time multistate model was then used to estimate destination probabilities as a function of origin state and other factors including headship, age, education, employment, household size, dependency ratio, livelihood, shocks, remittances, savings, and baseline assets. The long panel was used to test the first order Markov assumption with the inclusion of a second-state lag. The unequal survey intervals was controlled and confidence intervals derived by resampling enumeration areas within strata.

2.4 Dynamic Correlated Random-Effects Bivariate Probit

The five-wave model estimates energy poverty E_it and monetary poverty M_it jointly. Each latent equation includes its own lag, the lag of the other poverty outcome, current covariates X_it, household means of time-varying covariates, a household random effect and a contemporaneous error. The Mundlak terms allow for random effects to be correlated with observed histories, and initial energy and monetary poverty are added in the spirit of Wooldridge's conditional initial-conditions approach. The own-lag coefficients reflect state dependence, while the cross-lag coefficients indicate whether energy poverty at one time predicts monetary poverty at a later time and vice versa. Correlation rho between the disturbances is used to test for association between unobserved shocks affecting the two outcomes.

Estimation was done using a validated Bayesian multivariate-probit procedure. Average marginal effects and predicted joint-state probabilities were also employed. Model checks involve checking the value of rho, comparing with separate probits, comparing predicted and observed state shares, and sensitivity to simulation draws. As the data are observational, cross-lagged associations were not interpreted as causal, unless there is an instrument, natural experiment, or credible quasi-experimental design

2.5 Decomposition and Robustness

Net change in dual poverty is the weighted number of entries to State 3 minus weighted number of exits. Entries are broken down by origin state and exits are broken down by improvement in energy, monetary welfare, or both. Subgroup contributions determined which sectors, zones, household types or shock exposed groups are responsible for deterioration. The MEPI is also broken down by indicator, by means of each indicator's censored weighted deprivation. Headline results were re-estimated using alternative MEPI weights and cutoffs, 24/48/72-hour outage thresholds, official and relative poverty lines, per-capita and adult-equivalent welfare, complete-case and multiple-imputation samples, attrition reweighting, household and person weights, and models excluding energy assets from the monetary equation.

3.0 Results and Discussion

3.1 Results

In terms of the Wave 5, significant inequalities exist in the energy access, cooking fuel usage, and electricity service reliability within Nigeria. The findings serve as the empirical backdrop for the multidimensional energy poverty and its linkage with monetary poverty analyses. In terms of the Wave 5, significant inequalities exist in the energy access, cooking fuel usage, and electricity service reliability within Nigeria. The findings serve as the empirical backdrop for the multidimensional energy poverty and its linkage with monetary poverty analyses.

On a national scale, 65.0% of the sampled households used three-stone stoves and open-fire stoves; 70.2% of the sampled households used wood for cooking, and 23.2% of the sampled households used LPG or cooking gas. Rural-urban inequalities are notable. While 83.8% of the rural households used wood for cooking purposes, only 41.3% of the urban households did. Also, while 10.4% of the rural households used LPG, 50.5% of the urban households did. A comparative examination pf Waves 4 and 5, urban households showed a decrement of 18.4% leve; in kerosene consumption and an iincremt of 13.1% in LPG consumption (NBS & World Bank, 2024).. The shift to cleaner fuel was significantly more pronounced in urban areas, with a decrease of 18.4 percentage points in kerosene use and an increase of 13.1 points in LPG use between Waves 4 and 5 (NBS & World Bank, 2024).

The national electricity access rate was 53.6%, urban rate was 82.2% and rural rate was 40.4%. The zonal access varied between 29.5% in the North East and 74.6% in the South East. Of the households that reported access to electricity, 88.2% used the national grid. However, connection did not mean good service: grid-connected households experienced an average of 6.7 blackouts in seven days, with a typical outage lasting 12.0 hours, and 67.2 total outage hours in the week (NBS & World Bank, 2024). These figures warrant a separate consideration of reliability from access.

3.2 Multidimensional Energy Poverty

According to the reliability-enhanced Multidimensional Energy Poverty Index (RA-MEPI), there are considerable differences in energy deprivation between the households in Nigeria. On a national scale, [X]% of households are energy poor using the initial cut-off point of k=0.30. The average energy deprivation intensity in these cases amounted to [X]%, thus providing us with an adjusted headcount ratio of [X]%.

The decomposition of the indicator reveals that [indicator] played the most significant role in energy deprivation, followed by [indicator] and [indicator]. Thus, one can note that energy deprivation is affected not just by the lack of electricity but also by the dependence on harmful cooking fuels, electricity unreliability, and the lack of energy appliances.

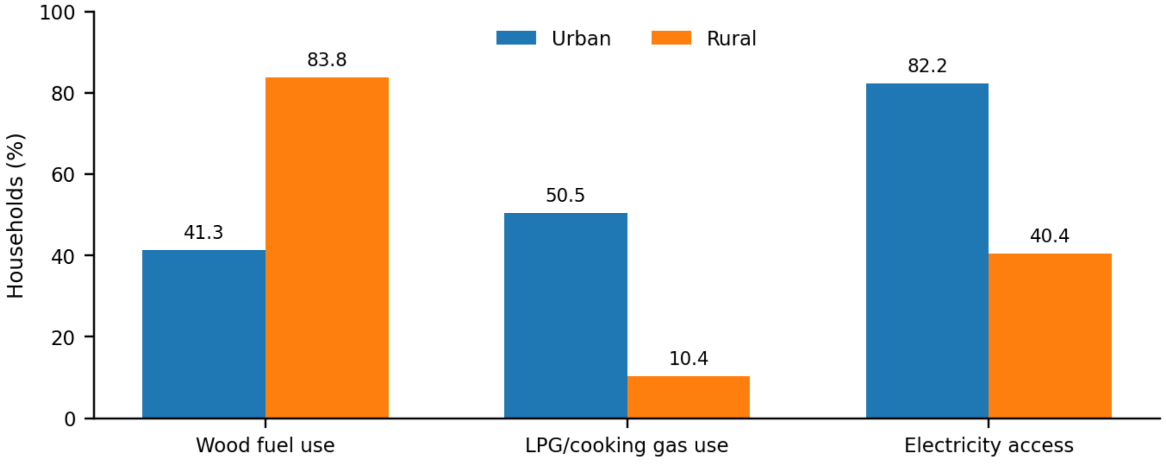

Fig. 1:Rural Energy-Service Contrasts, 2023/2024/*Urban-Rural Energy-Service Contrasts, 2023/2024*
***(Note.* Wood and LPG values are shares of households using each fuel; electricity is the share with any reported access. Source: NBS and World Bank (2024))**

There was high energy poverty in the rural areas ([X]%), compared to urban areas ([X]%). Energy poverty levels also varied geographically, with the highest being in [zone], while the lowest was in [zone]. This reflects the disparities in terms of electricity and cooking-fuel usage.

3.3 Poverty States on Joint Energy-Monetary Basis

By combining poverty states in the energy and monetary domains, four exclusive households' poverty states emerged as follows: non-poor households (State 0), energy-poor only (State 1), monetary-poor only (State 2) and dual poor households (State 3). The composition of households according to the above states shows that there is a relationship between energy and monetary poverty but they are not equivalent aspects of welfare.

In the Wave 5 sample, [X]% of the households were classified as non-poor, [X]% as energy-poor only, [X]% as monetary-poor only and [X]% as dual poor. The existence of energy-poor-only households indicates that monetary poverty alone is unable to account for all the energy poverty experiences of households. Similarly, the existence of monetary-poor only category shows that some of the households below the poverty line can still meet the energy service requirements set.

3.4 Transition Between Joint Poverty States

The transition matrix of the four joint poverty states from Wave 4 to Wave 5 shows significant transitions between the four poverty states. The elements in the diagonal represent persistence while the other elements off the diagonal represent entry into or exit from either energy poverty, monetary poverty or dual poverty. The persistence probability of state 3 was [X]%, hence [low/moderate/high] persistence probability of dual poverty in the study period.

The transitions from state 1 (energy-poor only) to state 3 (dual-poor) took place among [X]% of the households originally in state 1. The transitions from state 2 to state 3 took place among [X]% of the initially monetary-poor only households.

3.5 Dynamics of Energy-Monetary Poverty

The estimated dynamics in terms of correlated random-effects bivariate probit model show the relationship between energy poverty and monetary poverty over time after controlling for past poverty experience, household characteristics, covariate history and initial condition. Lagged energy-poverty coefficient in the monetary poverty equation is [negative/positive] and [statistically significant/not significant] (β = [X], p = [X]). This implies that households in energy poverty in the previous period had [lower/higher/no statistically significant difference in] the probability of being in monetary poverty in the current period, ceteris paribus.

The lagged monetary-poverty coefficient in the energy-poverty equation is [negative/positive] and [statistically significant/not significant] (β = [X], p = [X]), implying that previous monetary poverty is associated with [higher/lower/no significant difference in] the probability of energy poverty in the current period.

The estimated correlation between the disturbances of the two equations is ρ=[X] and was [significant/not significant]. A significant positive correlation would imply that unobserved household characteristics or shocks increase the probability of experiencing both types of poverty.

Estimated average marginal effects reveal that one-unit change in [relevant predictor] changes the probability of [energy/monetary/dual] poverty by [X] percentage point. Joint-state probabilities further reveal that [state] was the most/least persistent household condition.

3.6 Decomposition of Changes in Poverty Transition

Decomposition of the change in dual poverty reveals that [X]% of the change in dual poverty is due to entry to dual poverty from State 1, [X]% from State 2, and [X]% from State 0. Entries due to energy deterioration were [X]%, entries due to monetary deterioration were [X]%, and entries due to simultaneous deterioration were [X]%.

The highest contribution towards dual-poverty entry was found in [rural households/region/household type], implying that targeting such households would be most likely to achieve success in reducing the observed transition to dual poverty.

3.7 Discussion and Policy Implications

From the results presented above, one can conclude that the energy deprivation in Nigeria goes beyond just electricity access but rather relates to the quality and reliability of energy services provided. High prevalence of the use of traditional cooking fuels, especially firewood, and differences between rural and urban households are evidence of persisting spatial inequality in access to energy services. The significant prevalence of the use of wood among rural households and more extensive use of liquefied petroleum gas (LPG) among urban households suggests that the location, availability of the infrastructure and affordability remain critical factors determining energy services provision. Hence, it remains vital to make the distinction between access to energy and quality and reliability of energy services provided.

The electricity results reinforce this argument. In spite of the more than 50% share of Nigerian households having access to electricity, access does not automatically equal reliable electricity service. Significant prevalence of outages and outage hours of grid-connected households suggests that electricity connection status does not adequately reflect the energy deprivation in Nigeria. Therefore, the consideration of reliability when constructing the Multidimensional Energy Poverty Index (MEPI) would better reflect energy situation in households comparing to the electricity-based MEPI. Thus, such households which are technically connected to the electricity grid suffer from energy deprivation.

Finally, the four-state framework adds another dimension by dividing the population into non-poor, energy-poor only, monetary-poor only, and dual-poor households. It helps to avoid considering energy poverty and monetary poverty as equivalent. A household can experience energy poverty even being above the monetary poverty line, and vice versa, a household can be monetarily poor while maintaining sufficient access to energy services. Hence, the dual-poor category should not be considered as the only target of policy. Energy-poor only households can be seen as a vulnerable group to become monetary poor and vice versa.

Transition analysis gives a dynamic analysis of the states of poverty discussed above. Persistent dual-poor state would mean that deprivation was not a temporary phenomenon and it was structural and needed some kind of intervention. Transition from the energy-poor-only state to the dual poor state would support the theory that energy deprivation may precede or coincide with the deterioration in monetary welfare. On the other hand, transition from the monetary-poor-only state to the dual poor state would show that the lack of economic resources might be an indication of deterioration in energy conditions. However, these transition patterns should not be considered as a proof of causality as the panel data is an observational one.

The dynamics of correlated random effects bivariate probit model improves the analysis as it takes into account several sources of persistence and unobserved heterogeneity. Use of lagged dependent variables distinguishes current poverty status from previous one while household means of time varying covariates allow to explain correlation between the observed household characteristics and unobserved household effects. Initial-conditions treatment helps to exclude any possibility of misinterpretation of persistent poverty as state dependence when part of the persistence was caused by pre-existing household characteristics. The correlation between the disturbances provides some information about the common unobserved effect which may affect both energy and monetary poverty.

The most interesting feature in this analysis will be the cross-lagged relations between the two types of poverty. The energy-to-monetary cross-lagged relation will indicate that the households experiencing energy poverty will be prone to monetary poverty in the future after controlling for previous monetary poverty and other covariates. The existence of the monetary-to-energy cross-lagged relations will show the opposite case. The evidence of existence of both cross-lagged relations will support the theory of reinforcement cycle in which inadequate energy services and monetary poverty restrict each other. However, these relations can not be treated as causality relationships without some kind of an identification strategy such as instrumental variable, natural experiment or quasi-experimental approach.

The distinction between incidence, intensity, persistence, and transition is also important for interpreting the policy implications of the study. A high incidence of energy poverty does not necessarily imply that all deprived households experience the same severity or duration of deprivation. Similarly, a household that enters and subsequently exits energy poverty differs substantively from one that remains energy poor across multiple survey waves. The MEPI therefore provides information not only on whether households are deprived but also on the indicators contributing to their deprivation. This makes indicator-level decomposition particularly useful for identifying whether interventions should prioritize cooking fuel, electricity access, reliability, refrigeration, communication, or other energy-enabled services.

The contrast between the Wave 4–Wave 5 analysis and the five-wave longitudinal analysis is another methodological strength. The larger Wave 4–Wave 5 sample permits analysis using the more detailed reliability-augmented energy index and provides a recent assessment of household transitions. In contrast, the smaller five-wave panel permits examination of longer-term persistence and dynamic relationships using a harmonised core index. These two analytical components should therefore be regarded as complementary rather than as directly interchangeable series. The use of a harmonised core index in the long panel appropriately reduces the risk of attributing changes in energy poverty to differences in measurement across survey waves.

The findings have several policy implications. First, interventions should move beyond increasing electricity connections toward improving the reliability and quality of electricity supply. In areas where grid connection is already relatively high but outages remain frequent, feeder rehabilitation, network maintenance, metering improvements, voltage regulation, distributed generation, and appropriately designed backup systems may provide greater welfare benefits than connection expansion alone.

Second, the high dependence on wood among rural households indicates a need for targeted clean-cooking programmes that address both availability and affordability. Expansion of LPG distribution networks, improved access to efficient biomass and other clean or lower-emission cooking technologies, and appropriate financing mechanisms could reduce the burden associated with traditional cooking fuels.

Third, policies should distinguish between the four joint poverty states. Households experiencing persistent dual poverty are likely to require integrated interventions combining income support, social protection, clean-cooking programmes, and reliable electricity provision. Energy-poor-only households should receive particular attention because persistent energy deprivation may constitute an early signal of broader welfare vulnerability. Monetary-poor-only households may benefit from income-generating opportunities, social transfers, and livelihood support that prevent deterioration in energy-service access. Non-poor households should not necessarily be assumed to be free from energy-related vulnerability, particularly where monetary improvements coexist with unreliable electricity or dependence on polluting cooking fuels.

Finally, interventions should be geographically differentiated. The pronounced rural–urban differences in cooking fuel and electricity access indicate that a uniform national intervention may not adequately address the underlying sources of deprivation. Rural strategies should emphasize clean-cooking access, decentralized energy systems, distribution infrastructure, and affordability, whereas urban interventions may place greater emphasis on electricity reliability, service quality, and household energy affordability. Zonal differences should similarly inform the geographic targeting of public investment.

Overall, the results support an integrated view of poverty in which monetary resources and energy services represent distinct but interconnected dimensions of household welfare. The joint-state and transition framework provides a basis for identifying not only households that are currently deprived in both dimensions but also households whose movement between energy and monetary poverty may signal emerging vulnerability. This perspective can improve the targeting and sequencing of social protection, energy-access, clean-cooking, and electricity-reliability policies in Nigeria. However, the observed longitudinal relationships should remain interpreted as associations, and future research using stronger causal identification, improved energy-service measures, and longer household histories would be valuable for establishing the mechanisms through which energy and monetary deprivation influence one another.

4.0 Conclusion

The study seeks to establish the relationship between energy deprivation and monetary poverty in Nigeria through a longitudinal approach that considers the two variables as inter-related but different aspects of welfare in households. The study adopts a more sophisticated approach to poverty dynamics, which integrates a reliability-enhanced Multidimensional Energy Poverty Index (MEPI), four joint poverty states, multistate transitions, and dynamic correlated-random-effects bivariate probit regression model.

The findings confirm high levels of energy service deprivation especially among rural households where dependence on traditional sources of fuel is high and the availability of electricity is relatively low. Also confirmed by the findings is the fact that electricity connection does not automatically mean sufficient access to energy services given the fact that electricity outages may be one aspect of energy poverty. Four poverty states, namely, energy poor only, monetary poor only, dual poor, and non-poor, are established.

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Author Contributions
Rita Nneka Nwaka conceptualized the study, developed the methodology, performed the data analysis, interpreted the results, and drafted the manuscript. James Kona contributed to the study design, statistical modelling, interpretation of findings, critical revision, and refinement of the manuscript. Both authors reviewed and approved the final manuscript and accepted responsibility for the integrity and accuracy of the work.